CTD profile data, including beam attenuation from R/V Thomas G. Thompson TT039, TT043, TT045, TT049, TT050, TT053, TT054 cruises in the Arabian Sea (U.S. JGOFS Arabian Sea project)

Website: https://www.bco-dmo.org/dataset/2516
Version: final
Version Date: 2002-06-06

Project
» U.S. JGOFS Arabian Sea (Arabian Sea)

Program
» U.S. Joint Global Ocean Flux Study (U.S. JGOFS)

Contributors	Affiliation	Role
Morrison, John M.	North Carolina State University - Marine, Earth and Atmospheric Sciences (NCSU MEAS)	Principal Investigator
Codispoti, Louis A.	Old Dominion University (ODU)	Co-Principal Investigator
Chandler, Cynthia L.	Woods Hole Oceanographic Institution (WHOI BCO-DMO)	BCO-DMO Data Manager

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Dataset Description

CTD profile data averaged at two decibar intervals, including beam attenuation

Methods & Sampling

See Platform deployments for cruise specific documentation

Data Processing Description

Beam Attenuation Coefficient, Light Scattering, Fluorescence protocols

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Texas A&M University

Data Reduction Scheme

The primary purpose for measuring the beam attenuation in JGOFS programs is to determine the concentration and distribution of particulate matter (PM) or particulate organic carbon (POC) in the water with continuous profiling rather than with limited discrete samples. Towards this end, a 25 cm Sea Tech Transmissometer was interfaced with the University of Washington's SeaBird CTD for all Arabian Sea cruises. Transmissometer data were analyzed for the five process cruises (TN043, TN045, TN049, TN050 and TN054) that occupied a standard set of stations. Data from the raw CTD files were binned at 2 db intervals through SeaBird's SEASOFT program, which has a spike removal subroutine which we have tested and found to remove transmissometer data spikes properly. The data were corrected for factory and field air calibrations. Beam transmission was converted to beam attenuation coefficients using c=-(1/r)*ln(%Tr/100) where c=beam attenuation coefficient (m^-1), r=beam path length (m), and Tr=% beam transmission.

The Arabian Sea data set presented some challenges because 1-4 different transmissometers were used on any given cruise, complicating the data calibration. It is impractical to do a proper bench or air calibration prior for each CTD cast since the deck of the ship is not always a clean environment and atmospheric conditions can change rapidly and affect the air readings. One calibration method is to compare the beam attenuation at depth where the particle concentration is relatively invariant. The primary concern is ensuring that the optical windows are uniformly clean, which is best determined by comparing adjacent profiles. Unfortunately, many of the CTD casts extended only to 150 m or less, which was usually shallower than the particle minimum. Furthermore, the stations covered a wide geographic area, so it is more likely that the particle minimum at depth could vary. The primary method for comparing the beam attenuation signal to particulate matter (PM) concentration or particulate organic carbon (POC) concentration is to filter water samples and determine the dry weight using stable filters (0.4 um pore size Poretics filters in this case), or the amount of organic carbon on a glass fiber filter (0.7 um nominal pore size). The beam c data for those bottle depths (chosen as the cp value of the 2 db bin within which the sample depth fell) are then regressed against PM or POC using a Model II regression to determine the intercept where the concentration of particles in the water equals zero. Theoretically this value should be 0.364 since the transmissometers are set at the factory to read 0.364 in particle-free water. PM was filtered on four of the five cruises where beam c was analyzed. POC was measured on the one cruise for which no PM measurements were made (TN049) as well as most of the other cruises.

In order to determine the attenuation specific to particulate matter, the attenuation due to water must be subtracted from the beam c values (cp = c - cw). Practically, cw is determined as the minimum attenuation measured during each cruise. It must be noted that this minimum attenuation value is the "cleanest" water observed and is not particle free. Thus, the regressions of the cp data versus particle concentrations must be adjusted.

A prediction of the PM concentration can be obtained from the resulting equations for each cruise:

```
TN043 ->    PM = 602 * cp      (r^2 = 0.86)
TN045 ->    PM = 483 * cp      (r^2 = 0.87)
TN050 ->    PM = 687 * cp      (r^2 = 0.92)
TN054 ->    PM = 615 * cp      (r^2 = 0.86)
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PM is in ug/Kg, and cp is attenuation per meter.

Note that these are Model II regressions so the equations are the same if PM is regressed versus cp or vice versa. For comparison, the relationships between particle concentration and attenuation in surface waters of previous JGOFS programs were:

PM = 1022*cp North Atlantic Bloom Exp.
PM = 451*cp EqPac Spring Time Series
PM = 647*cp EqPac Fall Time Series

Chlorophyll

Chlorophyll-a fluorescence distribution in the Arabian Sea was determined, in-situ, with a SeaTech Fluorometer. The fluorometer was interfaced with the Sea-Bird CTD, and the data were acquired in the same format as the transmissometer data. The Fluorometer is a standard irradiation/emission system. When chlorophyll a is excited by blue light (425 nm), it will fluoresce at a peak wavelength of 685 nm (red light). The emission detector is filtered to a peak response in order to make the measurement insensitive to the excitation source. The amount of fluoresced light detected is converted to a voltage range of 0 to 5 volts. A signal gain of 10x was used, setting sensitivity to 3mg chl-a m^-3. The fluorometer is set to sample with a three second time constant to smooth the data. A baffle has been placed in front of the emission detector in an attempt to make it insensitive to ambient light (SeaTech Fluorometer Manual). The SEASOFT software converts the measured voltage into a relative chlorophyll-a value using the equation:

[volts * signal gain/5] + offset = mg chl-a m^-3

These relative values were calibrated using discreet chlorophyll samples (taken by various JGOFS scientists and analyzed onboard the ship using a Turner Fluorometer). There is a good (r^2 = 0.90) linear correlation between fluorometer-determined chlorophyll-a fluorescence, and the chlorophyll-a concentrations determined using a Turner fluorometer. Regressions were made for each cruise individually, but the correlations (based on the standard deviation of the slope and intercept) were improved when data from cruises TN049, TN050, and TN054 were combined. Prior to TN049, chlorophyll samples were taken from the Trace-Metal rosette, which contained no CTD or fluorometer for accurate depth or fluorescence measurements. We attempted a comparison between standard CTD/fluorometer profiles made close in time to the Trace-Metal casts on which chlorophyll measurements were made, but the lack of accurate depths or water density for the discreet samples plus the temporal variability between casts introduced too much scatter for a useful correlation. There were too few chlorophyll a measurements made on the standard CTD casts during TN043 and TN045 to independently calibrate the fluorometer. This added to the appeal of a general calibration for the fluorescence signal for all cruises, though we recognize that data for two cruises were not included. We emphasize for future work that it is necessary to have a fluorometer and CTD on the rosette at the time chlorophyll samples are being taken in order to accurately calibrate the fluorescence signal. Furthermore continuous profiles from a fluorometer provide higher resolution than discreet samples alone.

Slightly different slopes and intercepts were observed in the fluorescence/chlorophyll correlations for samples above and below the chlorophyll maximum. Therefore the depth of the chlorophyll maximum was determined by visual inspection of each profile (to avoid confusion with individual spikes) and the samples were divided into two categories, separated at a depth 10 m beneath the maximum fluorescence value. The assumption (substantiated by inspection of the data) is that chlorophyll-containing particles within the subsurface chlorophyll maximum are more similar to those above the maximum than below. A model II linear regression on each group of data indicated a very slight difference in slopes between the two groups, but a substantial offset in the intercepts. This results in a difference in the concentration of predicted chlorophyll based on the fluorescence above and below the chlorophyll maximum. Similar differences in chlorophyll fluorescence above and below the chlorophyll maximum were noticed by Pak et al.(1988). Equations are provided here for both regions in the Arabian Sea.

Above the depth of the chlorophyll maximum:
Chl a = 0.357*Fl + 0.078 (r^2 = 0.86)

Below the depth of the chlorophyll maximum:
Chl a = 0.389*Fl - 0.05 (r^2 = 0.93)

LSS - SeaTech Light Scattering Sensor

Light scattering due to particles was monitored using a SeaTech Light Scattering Sensor (LSS). The LSS projects light from two 880 nm (infrared) LEDs into a sampling volume that varies depending upon the concentration of particulate matter, but that is roughly the shape of a stretched balloon. Back-scattered light from the particulate matter is measured by a detector. The range on the LSS was set to 0 - 33 mg/l. The amount of light detected is scaled to a 0-5 volt output, but in the Arabian Sea most values were less than 0.5 volts. The LSS output depends upon the nature of the particulate matter and will vary with changes in particle size distribution, shape, index of refraction, organic/inorganic content etc. Therefore the LSS requires site-specific calibration. The LSS was interfaced with the SeaBird CTD and the data were handled in the same format as the transmissometer and fluorometer data.

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Parameters

Parameter	Description	Units
event	a unique number assigned to each sampling operation consisting of month MM, day DD, hour HH and minute mm	
sta	station number	
sta_std	Arabian Sea standard station identifier	
cast	CTD cast number	
date	date (YYYYMMDD) decoded as follows YYYY = year, MM = month, DD = day Date converted to UTC(GMT).	
time	time of day in UTC(GMT)	decimal hours
lat	latitude of cast, negative = south	decimal degrees
lon	longitude of cast, negative = west	decimal degrees
depth	sample depth reported as meters	meters
press	sample depth reported as pressure	decibars
temp	temperature, IPTS-68	degrees C
cond	conductivity	milliSiemens/centimeter
sal	salinity, PSS-78	dimensionless
potemp	potential temperature, IPTS-68	degrees C
sigma_t	sigma-t	kilogram/meter^3
sigma_0	sigma theta (potental density)	kilogram/meter^3
beam_cp	beam attenuation due to particles	1/meter
light_bs	backscattered light from a Light Scattering Sensor	volts
fluor	relative fluorescence, corrected by Seabird software to chlorophyll-a	milligram/meter^3

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Instruments

Dataset-specific Instrument Name	CTD Seabird 911
Generic Instrument Name	CTD Sea-Bird 911
Dataset-specific Description	CTD measurements taken by a SBE9 and SBE 11 (SeaBird) CTD package.
Generic Instrument Description	The Sea-Bird SBE 911 is a type of CTD instrument package. The SBE 911 includes the SBE 9 Underwater Unit and the SBE 11 Deck Unit (for real-time readout using conductive wire) for deployment from a vessel. The combination of the SBE 9 and SBE 11 is called a SBE 911. The SBE 9 uses Sea-Bird's standard modular temperature and conductivity sensors (SBE 3 and SBE 4). The SBE 9 CTD can be configured with auxiliary sensors to measure other parameters including dissolved oxygen, pH, turbidity, fluorescence, light (PAR), light transmission, etc.). More information from Sea-Bird Electronics.

Dataset-specific Instrument Name	SeaTech Fluorometer
Generic Instrument Name	Sea Tech Fluorometer
Dataset-specific Description	Chlorophyll-a fluorescence distribution in the Arabian Sea was determined, in-situ, with a SeaTech Fluorometer. The fluorometer was interfaced with the Sea-Bird CTD, and the data were acquired in the same format as the transmissometer data. The Fluorometer is a standard irradiation/emission system. When chlorophyll a is excited by blue light (425 nm), it will fluoresce at a peak wavelength of 685 nm (red light). The emission detector is filtered to a peak response in order to make the measurement insensitive to the excitation source. The amount of fluoresced light detected is converted to a voltage range of 0 to 5 volts. A signal gain of 10x was used, setting sensitivity to 3mg chl-a m^-3. The fluorometer is set to sample with a three second time constant to smooth the data. A baffle has been placed in front of the emission detector in an attempt to make it insensitive to ambient light(SeaTech Fluorometer Manual).
Generic Instrument Description	The Sea Tech chlorophyll-a fluorometer has internally selectable settings to adjust for different ranges of chlorophyll concentration, and is designed to measure chlorophyll-a fluorescence in situ. The instrument is stable with time and temperature and uses specially selected optical filters enabling accurate measurements of chlorophyll a. It can be deployed in moored or profiling mode. This instrument designation is used when specific make and model are not known. The Sea Tech Fluorometer was manufactured by Sea Tech, Inc. (Corvalis, OR, USA).

Dataset-specific Instrument Name	SeaTech Transmissometer
Generic Instrument Name	Sea Tech Transmissometer
Dataset-specific Description	A 25 cm Sea Tech Transmissometer was interfaced with the University of Washington's SeaBird CTD for all Arabian Sea cruises.
Generic Instrument Description	The Sea Tech Transmissometer can be deployed in either moored or profiling mode to estimate the concentration of suspended or particulate matter in seawater. The transmissometer measures the beam attenuation coefficient in the red spectral band (660 nm) of the laser lightsource over the instrument's path-length (e.g. 20 or 25 cm). This instrument designation is used when specific make and model are not known. The Sea Tech Transmissometer was manufactured by Sea Tech, Inc. (Corvalis, OR, USA).

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Deployments

TT043

Website	https://www.bco-dmo.org/deployment/57704
Platform	R/V Thomas G. Thompson
Report	http://osprey.bcodmo.org/datasetDeployment.cfm?ddid=2580&did=353&flag=view
Start Date	1995-01-08
End Date	1995-02-05
	Purpose: Process Cruise #1 (Late NE Monsoon) **Methods & Sampling** PI: John Morrison of: North Carolina State University PI on Optics: Wilford Gardner, Mary Jo Richardson dataset: CTD profile data averaged at two decibar intervals, including beam attenuation dates: January 08, 1995 to February 01, 1995 location: N: 22.4830 S: 9.9826 W: 57.2999 E: 68.7500 project/cruise: Arabian Sea/TTN-043 - Process Cruise 1 (Late NE Monsoon) ship: Thomas Thompson John M. Morrison -- 15 December 1995 TN043: U.S. JGOFS Arabian Sea Process Study -- Process Cruise #1: This "readme" file pertains to the CTD data taken during RV T.G. Thompson cruise TN043. This cruise was the first JGOFS Arabian Sea Process Leg and took place between 8 January and 5 February 1995. Dr. M. Roman of the University of Maryland's Horn Point Laboratory was the chief scientist. A number of CTD casts were made in test mode. The data from these casts were deemed unrecoverable (noisy data due to winch problems) and are listed as follows: event 01220023 station 17 cast 11 event 01290934 station 27 cast 05 event 01312228 station 29 cast 03 Digital dissolved oxygen, transmissometer and fluoruometer data were also collected on the CTD, but are not reported here as we have not calibrated this data. The raw data files may be requested from: DR.JOHN M. MORRISON NORTH CAROLINA STATE UNIVERSITY DEPARTMENT OF MARINE, EARTH AND ATMOSPHERIC SCIENCES JORDAN HALL RM. 1125 BOX 8208 RALEIGH, NC 27695-8208 EMAIL: John_Morrison@NCSU.EDU PHONE: 919-515-7449 CTD Calibration: On this cruise, two different CTD configurations were used. The processing and calibration information for each of the configurations are given below: configuration 1 ------------------------------ John M. Morrison 15 December 1995 Setup, processing and calibation information for the initial setup of the CTD for cruise TN043. It was used for the following casts: cruise 043 station 001 cast 01 cruise 043 station 002 cast 01 cruise 043 station 003 cast 01 cruise 043 station 003 cast 03 cruise 043 station 004 cast 01 cruise 043 station 004 cast 04 cruise 043 station 005 cast 01 cruise 043 station 006 cast 01 cruise 043 station 006 cast 03 cruise 043 station 007 cast 01 cruise 043 station 007 cast 05 Sea-Bird Processing Information: (Example from ctd cast 04300201) * Sea-Bird SBE 9 Raw Data File: * FileName = G:ï¿½4300201.DAT * Software Version 4.205 *

Temperature SN = 1605 * Conductivity SN = 1371 * Number of Bytes Per Scan = 37 * Number of Voltage Words = 4 * System UpLoad Time = Jan 09 1995 02:08:20 * NMEA Latitude = 22 28.96 N * NMEA Longitude = 061 11.08 E * NMEA UpLoad Time = not available * Store Lat/Lon Data = Add to Header and Append to Every Scan * Ship: R/V Thomas G. Thompson * Cruise: JGOFS Arabian Sea Expedition # nquan = 15 # nvalues = 508 # units = metric # name 0 = t068: temperature, pri, IPTS-68 [deg C] # name 1 = c0mS/cm: conductivity, primary [mS/cm] # name 2 = pr: pressure [db] # name 3 = t168: temperature, sec, IPTS-68 [deg C] # name 4 = c1mS/cm: conductivity, secondary [mS/cm] # name 5 = oxML/L: oxygen [ml/l] # name 6 = xmiss: transmissometer # name 7 = flS: fluorometer, sea tech # name 8 = depS: depth, salt water [m] # name 9 = potemp068: potential temperature, pri, IPTS-68 [deg C] # name 10 = sigma-t00: density, sigma-t [kg/m^3], T0, C0 # name 11 = sigma-i00: density, sigma-theta [kg/m^3], T0, C0 # name 12 = sal00: salinity, PSS-78 [PSU], T0, C0 # name 13 = sal11: salinity, PSS-78 [PSU], T1, C1 # name 14 = flag: 0.000e+00 # span 0 = 16.4013, 24.5890 # span 1 = 45.821327, 54.931889 # span 2 = 1.000, 256.000 # span 3 = 16.4010, 24.5959 # span 4 = 45.815933, 54.939217 # span 5 = -0.28523, 10.73771 # span 6 = 28.99, 91.08 # span 7 = 0.000e+00, 0.000e+00 # span 8 = 0.994, 254.240 # span 9 = 16.3613, 24.5776 # span 10 = 24.6830, 26.6361 # span 11 = 24.6838, 26.6459 # span 12 = 36.1022, 36.7169 # span 13 = 36.0998, 36.7173 # span 14 = 0.000e+00, 0.000e+00 # interval = decibars: 1 # start_time = Jan 09 1995 02:08:20 # bad_flag = -9.990e-29 # serial_numbers = t0:1605, c0:1371, pr:34901, t1:1316, c1:1084, ox:352, upoly0:AC3, upoly1:AC3, stLs60D # datcnv_date = Jan 09 1995 03:40:04, 4.205 # datcnv_in = 04300201.DAT CTD_24.CON 1605 1371 34901 # datcnv_skipover = 0 # wildedit_date = Jan 09 1995 03:42:01, 4.205 # wildedit_in = 04300201.CNV # wildedit_pass1_nstd = 2.0 # wildedit_pass2_nstd = 20.0 # wildedit_npoint = 100 # wildedit_vars = t068 c0mS/cm pr t168 c1mS/cm oxML/L xmiss flS # wildedit_excl_bad_scans = yes # celltm_date = Jan 09 1995 03:42:45, 4.205 # celltm_in = TEMP.CNV # celltm_alpha = 0.0300, 0.0000 # celltm_tau = 9.0000, 0.0000 # filter_date = Jan 09 1995 03:43:22, 4.205 # filter_in = 04300201.CNV # filter_low_pass_tc_A = 0.150 # filter_low_pass_tc_B = 0.100 # filter_low_pass_A_vars = pr # filter_low_pass_B_vars = # loopedit_date = Jan 09 1995 03:44:38, 4.205 # loopedit_in = TEMP.CNV # loopedit_minVelocity = 0.000 # loopedit_excl_bad_scans = yes # binavg_date = Jan 09 1995 03:45:30, 4.205 # binavg_in = 04300201.CNV # binavg_bintype = Pressure Bins # binavg_binsize = 1.00 # binavg_excl_bad_scans = yes # binavg_downcast_only = no # binavg_skipover = 0 # binavg_surface_bin = yes, min = 0.500, max = 0.500, value = 0.000 # derive_date = Jan 09 1995 03:46:09, 4.205 # derive_in = TEMP.CNV CTD_24.CON # file_type = ascii *END* Calibration: Calibration for Conductivity and Salinity: MINIMUM DEPTH USED = 500.000 Conductivity STDEV= 0.00259877 MEAN= 0.00169401 Salinity STDEV= 0.00266719 MEAN= 0.00180285 If full range was used for the Conductivity and Salinity Calibration, the mean remains the same, but the STDEV becomes larger as would be expected in the high-gradient, and variable surface layers. Therefore, a correction of -.002 was applied to the shipboard Conductivities and Salinities. The reported Conductivities and Salinities are good to +/- .003. configuration 2 ---------------------------------- John M. Morrison 15 December 1995 Setup, processing and calibation information for the second setup of the CTD for cruise TN043. It was used for the following casts: cruise 043 station 007 cast 11 cruise 043 station 007 cast 13 cruise 043 station 007 cast 14 cruise 043 station 008 cast 01 cruise 043 station 008 cast 03 cruise 043 station 009 cast 01 cruise 043 station 009 cast 03 cruise 043 station 010 cast 01 cruise 043 station 010 cast 03 cruise 043 station 011 cast 01 cruise 043 station 011 cast 04 cruise 043 station 012 cast 01 cruise 043 station 012 cast 03 cruise 043 station 013 cast 01 cruise 043 station 013 cast 07 cruise 043 station 013 cast 09 cruise 043 station 013 cast 10 cruise 043 station 013 cast 11 cruise 043 station 014 cast 01 cruise 043 station 014 cast 03 cruise 043 station 015 cast 01 cruise 043 station 015 cast 03 cruise 043 station 016 cast 01 cruise 043 station 016 cast 03 cruise 043 station 017 cast 01 cruise 043 station 017 cast 05 cruise 043 station 017 cast 09 cruise 043 station 017 cast 10 cruise 043 station 017 cast 11 cruise 043 station 018 cast 01 cruise 043 station 018 cast 03 cruise 043 station 019 cast 02 cruise 043 station 019 cast 03 cruise 043 station 020 cast 01 cruise 043 station 020 cast 02 cruise 043 station 021 cast 01 cruise 043 station 021 cast 05 cruise 043 station 021 cast 08 cruise 043 station 021 cast 10 cruise 043 station 021 cast 12 cruise 043 station 021 cast 13 cruise 043 station 022 cast 01 cruise 043 station 023 cast 01 cruise 043 station 024 cast 01 cruise 043 station 024 cast 03 cruise 043 station 025 cast 01 cruise 043 station 025 cast 03 cruise 043 station 026 cast 01 cruise 043 station 026 cast 05 cruise 043 station 026 cast 08 cruise 043 station 026 cast 10 cruise 043 station 026 cast 12 cruise 043 station 027 cast 01 cruise 043 station 027 cast 02 cruise 043 station 027 cast 05 cruise 043 station 028 cast 01 cruise 043 station 028 cast 05 cruise 043 station 028 cast 09 cruise 043 station 028 cast 10

Description	cruise 043 station 028 cast 11 cruise 043 station 029 cast 01 cruise 043 station 029 cast 02 cruise 043 station 029 cast 03 cruise 043 station 030 cast 01 Sea-Bird Processing Information: (Example from ctd cast 04300713) * Sea-Bird SBE 9 Raw Data File: * FileName = G:ï¿½4300713.DAT * Software Version 4.205 * Temperature SN = 1605 * Conductivity SN = 1371 * Number of Bytes Per Scan = 37 * Number of Voltage Words = 4 * System UpLoad Time = Jan 13 1995 09:20:09 * NMEA Latitude = 19 9.98 N * NMEA Longitude = 067 9.97 E * NMEA UpLoad Time = not available * Store Lat/Lon Data = Add to Header and Append to Every Scan * Ship: R/V Thomas G. Thompson * Cruise: JGOFS Arabian Sea Expedition # nquan = 15 # nvalues = 5061 # units = metric # name 0 = t068: temperature, pri, IPTS-68 [deg C] # name 1 = c0mS/cm: conductivity, primary [mS/cm] # name 2 = pr: pressure [db] # name 3 = t168: temperature, sec, IPTS-68 [deg C] # name 4 = c1mS/cm: conductivity, secondary [mS/cm] # name 5 = oxML/L: oxygen [ml/l] # name 6 = xmiss: transmissometer # name 7 = flS: fluorometer, sea tech # name 8 = depS: depth, salt water [m] # name 9 = potemp068: potential temperature, pri, IPTS-68 [deg C] # name 10 = sigma-t00: density, sigma-t [kg/m^3], T0, C0 # name 11 = sigma-i00: density, sigma-theta [kg/m^3], T0, C0 # name 12 = sal00: salinity, PSS-78 [PSU], T0, C0 # name 13 = sal11: salinity, PSS-78 [PSU], T1, C1 # name 14 = flag: 0.000e+00 # span 0 = 2.1813, 24.9021 # span 1 = 31.823267, 55.041656 # span 2 = 1.000, 2532.000 # span 3 = 2.1820, 24.9060 # span 4 = 31.821650, 55.043922 # span 5 = -1.72205, 3.64451 # span 6 = 89.83, 93.30 # span 7 = 2.202e-01, 1.966e+00 # span 8 = 0.994, 2501.573 # span 9 = 1.9943, 24.9015 # span 10 = 24.5439, 27.7705 # span 11 = 24.5441, 27.7856 # span 12 = 34.7668, 36.5490 # span 13 = 34.7638, 36.5478 # span 14 = 0.000e+00, 0.000e+00 # interval = decibars: 1 # start_time = Jan 13 1995 09:20:09 # bad_flag = -9.990e-29 # serial_numbers = t0:1605, c0:1371, pr:57657, t1:1316, c1:1084, ox:132, stLs6000:239, xmiss:173D, flS:D # datcnv_date = Jan 13 1995 11:19:52, 4.205 # datcnv_in = 04300713.DAT CTD_24.CON 1605 1371 57657 # datcnv_skipover = 0 # wildedit_date = Jan 13 1995 11:27:22, 4.205 # wildedit_in = 04300713.CNV # wildedit_pass1_nstd = 2.0 # wildedit_pass2_nstd = 20.0 # wildedit_npoint = 100 # wildedit_vars = t068 c0mS/cm pr t168 c1mS/cm oxML/L xmiss flS # wildedit_excl_bad_scans = yes # celltm_date = Jan 13 1995 11:30:04, 4.205 # celltm_in = TEMP.CNV # celltm_alpha = 0.0300, 0.0000 # celltm_tau = 9.0000, 0.0000 # filter_date = Jan 13 1995 11:32:20, 4.205 # filter_in = 04300713.CNV # filter_low_pass_tc_A = 0.150 # filter_low_pass_tc_B = 0.100 # filter_low_pass_A_vars = pr # filter_low_pass_B_vars = # loopedit_date = Jan 13 1995 11:37:05, 4.205 # loopedit_in = TEMP.CNV # loopedit_minVelocity = 0.000 # loopedit_excl_bad_scans = yes # binavg_date = Jan 13 1995 11:40:25, 4.205 # binavg_in = 04300713.CNV # binavg_bintype = Pressure Bins # binavg_binsize = 1.00 # binavg_excl_bad_scans = yes # binavg_downcast_only = no # binavg_skipover = 0 # binavg_surface_bin = yes, min = 0.500, max = 0.500, value = 0.000 # derive_date = Jan 13 1995 11:42:59, 4.205 # derive_in = TEMP.CNV CTD_24.CON # file_type = ascii *END* Calibration: Calibration for Conductivity and Salinity: MINIMUM DEPTH USED = 500.000 Conductivity STDEV= 0.00258307 MEAN= -0.00156166 Salinity STDEV= 0.00273680 MEAN= -0.00164091 If full range was used for the Conductivity and Salinity Calibration, the mean remains the same, but the STDEV becomes larger as would be expected in the high-gradient, and variable surface layers. Therefore, a correction of +.002 was applied to the shipboard Conductivities and Salinities. The reported Conductivities and Salinities are good to +/- .003. **Processing Description** Beam Attenuation Coefficient, Light Scattering, Fluorescence protocols Wilford Gardner, Jan Gundersen, Mary Jo Richardson. Texas A&M University Data Reduction Scheme The primary purpose for measuring the beam attenuation in JGOFS programs is to determine the concentration and distribution of particulate matter (PM) or particulate organic carbon (POC) in the water with continuous profiling rather than with limited discrete samples. Towards this end, a 25 cm Sea Tech Transmissometer was interfaced with the University of Washington's SeaBird CTD for all Arabian Sea cruises. Transmissometer data were analyzed for the five process cruises (TN043, TN045, TN049, TN050 and TN054) that occupied a standard set of stations. Data from the raw CTD files were binned at 2 db intervals through SeaBird's SEASOFT program, which has a spike removal subroutine which we have tested and found to remove transmissometer data spikes properly. The data were corrected for factory and field air calibrations. Beam transmission was converted to beam attenuation coefficients using c=-(1/r)*ln(%Tr/100) where c=beam attenuation coefficient (m^-1), r=beam path length (m), and Tr=% beam transmission. The Arabian Sea data set presented some challenges because 1-4 different transmissometers were used on any given cruise, complicating the data calibration. It is impractical to do a proper bench or air calibration prior for each CTD cast since the deck of the ship is not always a clean environment and atmospheric conditions can change rapidly and

affect the air readings. One calibration method is to compare the beam attenuation at depth where the particle concentration is relatively invariant. The primary concern is ensuring that the optical windows are uniformly clean, which is best determined by comparing adjacent profiles. Unfortunately, many of the CTD casts extended only to 150 m or less, which was usually shallower than the particle minimum. Furthermore, the stations covered a wide geographic area, so it is more likely that the particle minimum at depth could vary. The primary method for comparing the beam attenuation signal to particulate matter (PM) concentration or particulate organic carbon (POC) concentration is to filter water samples and determine the dry weight using stable filters (0.4 um pore size Poretics filters in this case), or the amount of organic carbon on a glass fiber filter (0.7 um nominal pore size). The beam c data for those bottle depths (chosen as the cp value of the 2 db bin within which the sample depth fell) are then regressed against PM or POC using a Model II regression to determine the intercept where the concentration of particles in the water equals zero. Theoretically this value should be 0.364 since the transmissometers are set at the factory to read 0.364 in particle-free water. PM was filtered on four of the five cruises where beam c was analyzed. POC was measured on the one cruise for which no PM measurements were made (TN049) as well as most of the other cruises. In order to determine the attenuation specific to particulate matter, the attenuation due to water must be subtracted from the beam c values (cp = c - cw). Practically, cw is determined as the minimum attenuation measured during each cruise. It must be noted that this minimum attenuation value is the "cleanest" water observed and is not particle free. Thus, the regressions of the cp data versus particle concentrations must be adjusted. A prediction of the PM concentration can be obtained from the resulting equations for each cruise: TN043 -> PM = 602 * cp (r^2 = 0.86) TN045 -> PM = 483 * cp (r^2 = 0.87) TN050 -> PM = 687 * cp (r^2 = 0.92) TN054 -> PM = 615 * cp (r^2 = 0.86) PM is in ug/Kg, and cp is attenuation per meter. Note that these are Model II regressions so the equations are the same if PM is regressed versus cp or vice versa. For comparison, the relationships between particle concentration and attenuation in surface waters of previous JGOFS programs were: PM = 1022*cp North Atlantic Bloom Exp. PM = 451*cp EqPac Spring Time Series PM = 647*cp EqPac Fall Time Series Chlorophyll Chlorophyll-a fluorescence distribution in the Arabian Sea was determined, in-situ, with a SeaTech Fluorometer. The fluorometer was interfaced with the Sea-Bird CTD, and the data were acquired in the same format as the transmissometer data. The Fluorometer is a standard irradiation/emission system. When chlorophyll a is excited by blue light (425 nm), it will fluoresce at a peak wavelength of 685 nm (red light). The emission detector is filtered to a peak response in order to make the measurement insensitive to the excitation source. The amount of fluoresced light detected is converted to a voltage range of 0 to 5 volts. A signal gain of 10x was used, setting sensitivity to 3mg chl-a m^-3. The fluorometer is set to sample with a three second time constant to smooth the data. A baffle has been placed in front of the emission detector in an attempt to make it insensitive to ambient light (SeaTech Fluorometer Manual). The SEASOFT software converts the measured voltage into a relative chlorophyll-a value using the equation: [volts * signal gain/5] + offset = mg chl-a m^-3 These relative values were calibrated using discreet chlorophyll samples (taken by various JGOFS scientists and analyzed onboard the ship using a Turner Fluorometer). There is a good (r^2 = 0.90) linear correlation between fluorometer-determined chlorophyll-a fluorescence, and the chlorophyll-a concentrations determined using a Turner fluorometer. Regressions were made for each cruise individually, but the correlations (based on the standard deviation of the slope and intercept) were improved when data from cruises TN049, TN050, and TN054 were combined. Prior to TN049, chlorophyll samples were taken from the Trace-Metal rosette, which contained no CTD or fluorometer for accurate depth or fluorescence measurements. We attempted a comparison between standard CTD/fluorometer profiles made close in time to the Trace-Metal casts on which chlorophyll measurements were made, but the lack of accurate depths or water density for the discreet samples plus the temporal variability between casts introduced too much scatter for a useful correlation. There were too few chlorophyll a measurements made on the standard CTD casts during TN043 and TN045 to independently calibrate the fluorometer. This added to the appeal of a general calibration for the fluorescence signal for all cruises, though we recognize that data for two cruises were not included. We emphasize for future work that it is necessary to have a fluorometer and CTD on the rosette at the time chlorophyll samples are being taken in order to accurately calibrate the fluorescence signal. Furthermore continuous profiles from a fluorometer provide higher resolution than discreet samples alone. Slightly different slopes and intercepts were observed in the fluorescence/chlorophyll correlations for samples above and below the chlorophyll maximum. Therefore the depth of the chlorophyll maximum was determined by visual inspection of each profile (to avoid confusion with individual spikes) and the samples were divided into two categories, separated at a depth 10 m beneath the

	maximum fluorescence value. The assumption (substantiated by inspection of the data) is that chlorophyll-containing particles within the subsurface chlorophyll maximum are more similar to those above the maximum than below. A model II linear regression on each group of data indicated a very slight difference in slopes between the two groups, but a substantial offset in the intercepts. This results in a difference in the concentration of predicted chlorophyll based on the fluorescence above and below the chlorophyll maximum. Similar differences in chlorophyll fluorescence above and below the chlorophyll maximum were noticed by Pak et al. (1988). Equations are provided here for both regions in the Arabian Sea. Above the depth of the chlorophyll maximum: Chl a = 0.357*Fl + 0.078 (r^2 = 0.86) Below the depth of the chlorophyll maximum: Chl a = 0.389*Fl - 0.05 (r^2 = 0.93) LSS - SeaTech Light Scattering Sensor Light scattering due to particles was monitored using a SeaTech Light Scattering Sensor (LSS). The LSS projects light from two 880 nm (infrared) LEDs into a sampling volume that varies depending upon the concentration of particulate matter, but that is roughly the shape of a stretched balloon. Back-scattered light from the particulate matter is measured by a detector. The range on the LSS was set to 0 - 33 mg/l. The amount of light detected is scaled to a 0-5 volt output, but in the Arabian Sea most values were less than 0.5 volts. The LSS output depends upon the nature of the particulate matter and will vary with changes in particle size distribution, shape, index of refraction, organic/inorganic content etc. Therefore the LSS requires site-specific calibration. The LSS was interfaced with the SeaBird CTD and the data were handled in the same format as the transmissometer and fluorometer data.

TT045

Website	https://www.bco-dmo.org/deployment/57706
Platform	R/V Thomas G. Thompson
Start Date	1995-03-14
End Date	1995-04-10
	Methods & Sampling PI: John Morrison of: North Carolina State University PI on Optics: Wilford Gardner, Mary Jo Richardson dataset: CTD profile data at two decibar intervals, including beam attenuation dates: March 14, 1995 to April 08, 1995 location: N: 22.4858 S: 9.9993 W: 57.3007 E: 68.7532 project/cruise: Arabian Sea/TTN-045 - Process Cruise 2 (Spring Intermonsoon) ship: Thomas Thompson John M. Morrison -- 20 December 1995 TN045: JGOFS Arabian Sea Process Study -- Process Cruise #2: This "readme" file pertains to the CTD data taken during RV T.G. Thompson cruise TN045. This cruise was the second JGOFS Arabian Sea Process Leg and took place during March-April 1995. Dr. John Marra of the Lamont Doherty Earth Observatory was the chief scientist. Digital dissolved oxygen, transmissometer and fluoruometer data were also collected on the CTD, but are not reported here as we have not calibrated this data. The raw data files may be requested from: DR.JOHN M. MORRISON NORTH CAROLINA STATE UNIVERSITY DEPARTMENT OF MARINE, EARTH AND ATMOSPHERIC SCIENCES JORDAN HALL RM. 1125 BOX 8208 RALEIGH, NC 27695-8208 EMAIL: John_Morrison@NCSU.EDU PHONE: 919-515-7449 CTD Calibration: On this cruise, one CTD configuration was used. The processing and calibration information for this configuration is given below: This the setup, processing and calibation information for the setup of all the CTD casts for cruise TN045. Sea-Bird Processing Information: Example from /jgofs/tn045/ctd/0400101.cnv * Sea-Bird SBE 9 Raw Data File: * FileName = G: **Processing Description** Beam Attenuation Coefficient, Light Scattering, Fluorescence protocols Wilford Gardner, Jan Gundersen, Mary Jo Richardson. Texas A&M University Data Reduction Scheme The primary purpose for measuring the beam attenuation in JGOFS programs is to determine the concentration and distribution of particulate matter (PM) or particulate organic carbon (POC) in the water with continuous profiling rather than with limited discrete samples. Towards this end, a 25 cm Sea Tech Transmissometer was interfaced with the University of Washington's SeaBird CTD for all Arabian Sea cruises. Transmissometer data were analyzed for the five process cruises (TN043, TN045, TN049, TN050 and TN054) that occupied a standard set of stations. Data from the raw CTD files were binned at 2 db intervals through SeaBird's SEASOFT program, which has a spike removal subroutine which we have tested and found to remove transmissometer data spikes properly. The data were corrected for factory and field air

Description	calibrations. Beam transmission was converted to beam attenuation coefficients using c=-(1/r)*ln(%Tr/100) where c=beam attenuation coefficient (m^-1), r=beam path length (m), and Tr=% beam transmission. The Arabian Sea data set presented some challenges because 1-4 different transmissometers were used on any given cruise, complicating the data calibration. It is impractical to do a proper bench or air calibration prior for each CTD cast since the deck of the ship is not always a clean environment and atmospheric conditions can change rapidly and affect the air readings. One calibration method is to compare the beam attenuation at depth where the particle concentration is relatively invariant. The primary concern is ensuring that the optical windows are uniformly clean, which is best determined by comparing adjacent profiles. Unfortunately, many of the CTD casts extended only to 150 m or less, which was usually shallower than the particle minimum. Furthermore, the stations covered a wide geographic area, so it is more likely that the particle minimum at depth could vary. The primary method for comparing the beam attenuation signal to particulate matter (PM) concentration or particulate organic carbon (POC) concentration is to filter water samples and determine the dry weight using stable filters (0.4 um pore size Poretics filters in this case), or the amount of organic carbon on a glass fiber filter (0.7 um nominal pore size). The beam c data for those bottle depths (chosen as the cp value of the 2 db bin within which the sample depth fell) are then regressed against PM or POC using a Model II regression to determine the intercept where the concentration of particles in the water equals zero. Theoretically this value should be 0.364 since the transmissometers are set at the factory to read 0.364 in particle-free water. PM was filtered on four of the five cruises where beam c was analyzed. POC was measured on the one cruise for which no PM measurements were made (TN049) as well as most of the other cruises. In order to determine the attenuation specific to particulate matter, the attenuation due to water must be subtracted from the beam c values (cp = c - cw). Practically, cw is determined as the minimum attenuation measured during each cruise. It must be noted that this minimum attenuation value is the "cleanest" water observed and is not particle free. Thus, the regressions of the cp data versus particle concentrations must be adjusted. A prediction of the PM concentration can be obtained from the resulting equations for each cruise: TN043 -> PM = 602 * cp (r^2 = 0.86) TN045 -> PM = 483 * cp (r^2 = 0.87) TN050 -> PM = 687 * cp (r^2 = 0.92) TN054 -> PM = 615 * cp (r^2 = 0.86) PM is in ug/Kg, and cp is attenuation per meter. Note that these are Model II regressions so the equations are the same if PM is regressed versus cp or vice versa. For comparison, the relationships between particle concentration and attenuation in surface waters of previous JGOFS programs were: PM = 1022*cp North Atlantic Bloom Exp. PM = 451*cp EqPac Spring Time Series PM = 647*cp EqPac Fall Time Series Chlorophyll Chlorophyll-a fluorescence distribution in the Arabian Sea was determined, in-situ, with a SeaTech Fluorometer. The fluorometer was interfaced with the Sea-Bird CTD, and the data were acquired in the same format as the transmissometer data. The Fluorometer is a standard irradiation/emission system. When chlorophyll a is excited by blue light (425 nm), it will fluoresce at a peak wavelength of 685 nm (red light). The emission detector is filtered to a peak response in order to make the measurement insensitive to the excitation source. The amount of fluoresced light detected is converted to a voltage range of 0 to 5 volts. A signal gain of 10x was used, setting sensitivity to 3mg chl-a m^-3. The fluorometer is set to sample with a three second time constant to smooth the data. A baffle has been placed in front of the emission detector in an attempt to make it insensitive to ambient light (SeaTech Fluorometer Manual). The SEASOFT software converts the measured voltage into a relative chlorophyll-a value using the equation: [volts * signal gain/5] + offset = mg chl-a m^-3 These relative values were calibrated using discreet chlorophyll samples (taken by various JGOFS scientists and analyzed onboard the ship using a Turner Fluorometer). There is a good (r^2 = 0.90) linear correlation between fluorometer-determined chlorophyll-a fluorescence, and the chlorophyll-a concentrations determined using a Turner fluorometer. Regressions were made for each cruise individually, but the correlations (based on the standard deviation of the slope and intercept) were improved when data from cruises TN049, TN050, and TN054 were combined. Prior to TN049, chlorophyll samples were taken from the Trace-Metal rosette, which contained no CTD or fluorometer for accurate depth or fluorescence measurements. We attempted a comparison between standard CTD/fluorometer profiles made close in time to the Trace-Metal casts on which chlorophyll measurements were made, but the lack of accurate depths or water density for the discreet samples plus the temporal variability between casts introduced too much scatter for a useful correlation. There were too few chlorophyll a measurements made on the standard CTD casts during TN043 and TN045 to independently calibrate the fluorometer. This added to the appeal of a general calibration for the fluorescence signal for all cruises, though we recognize that data for two cruises were not included. We emphasize for future work that it is necessary to have a fluorometer and CTD on the rosette at the time chlorophyll samples are being taken in order to

	accurately calibrate the fluorescence signal. Furthermore continuous profiles from a fluorometer provide higher resolution than discreet samples alone. Slightly different slopes and intercepts were observed in the fluorescence/chlorophyll correlations for samples above and below the chlorophyll maximum. Therefore the depth of the chlorophyll maximum was determined by visual inspection of each profile (to avoid confusion with individual spikes) and the samples were divided into two categories, separated at a depth 10 m beneath the maximum fluorescence value. The assumption (substantiated by inspection of the data) is that chlorophyll-containing particles within the subsurface chlorophyll maximum are more similar to those above the maximum than below. A model II linear regression on each group of data indicated a very slight difference in slopes between the two groups, but a substantial offset in the intercepts. This results in a difference in the concentration of predicted chlorophyll based on the fluorescence above and below the chlorophyll maximum. Similar differences in chlorophyll fluorescence above and below the chlorophyll maximum were noticed by Pak et al. (1988). Equations are provided here for both regions in the Arabian Sea. Above the depth of the chlorophyll maximum: Chl a = 0.357*Fl + 0.078 (r^2 = 0.86) Below the depth of the chlorophyll maximum: Chl a = 0.389*Fl - 0.05 (r^2 = 0.93) LSS - SeaTech Light Scattering Sensor Light scattering due to particles was monitored using a SeaTech Light Scattering Sensor (LSS). The LSS projects light from two 880 nm (infrared) LEDs into a sampling volume that varies depending upon the concentration of particulate matter, but that is roughly the shape of a stretched balloon. Back-scattered light from the particulate matter is measured by a detector. The range on the LSS was set to 0 - 33 mg/l. The amount of light detected is scaled to a 0-5 volt output, but in the Arabian Sea most values were less than 0.5 volts. The LSS output depends upon the nature of the particulate matter and will vary with changes in particle size distribution, shape, index of refraction, organic/inorganic content etc. Therefore the LSS requires site-specific calibration. The LSS was interfaced with the SeaBird CTD and the data were handled in the same format as the transmissometer and fluorometer data.

TT049

Website	https://www.bco-dmo.org/deployment/57710
Platform	R/V Thomas G. Thompson
Start Date	1995-07-17
End Date	1995-08-15
	Methods & Sampling PI: John Morrison of: North Carolina State University PI on Optics: Wilford Gardner, Mary Jo Richardson dataset: CTD profile data averaged at two decibar intervals, including beam attenuation dates: July 18, 1995 to August 13, 1995 location: N: 22.5268 S: 9.911 W: 57.2997 E: 68.7507 project/cruise: Arabian Sea/TTN-049 - Process Cruise 4 (Middle SW Monsoon) ship: Thomas Thompson John M. Morrison -- 23 April 1996 TN049: JGOFS Arabian Sea Process Study -- Process Cruise #4: This "readme" file pertains to the CTD data taken during RV T.G. Thompson cruise TN049. This cruise was the fourth JGOFS Arabian Sea Process Leg and took place during July - August 1995. Dr. Richard Barber of Duke University Marine Laboratory (rbarber@mail.duke.edu) was the chief scientist. CTD Calibration: On this cruise, one CTD configurations was used. The processing and calibration information for this configuration is given in as follows: Processing and calibation information for the initial setup of the CTD for cruise TN049. See special section for station 04903101. Sea-Bird Processing Information: Example from 04900101.cnv * Sea-Bird SBE 9 Raw Data File: * FileName = G: **Processing Description** Beam Attenuation Coefficient, Light Scattering, Fluorescence protocols Wilford Gardner, Jan Gundersen, Mary Jo Richardson. Texas A&M University Data Reduction Scheme The primary purpose for measuring the beam attenuation in JGOFS programs is to determine the concentration and distribution of particulate matter (PM) or particulate organic carbon (POC) in the water with continuous profiling rather than with limited discrete samples. Towards this end, a 25 cm Sea Tech Transmissometer was interfaced with the University of Washington's SeaBird CTD for all Arabian Sea cruises. Transmissometer data were analyzed for the five process cruises (TN043, TN045, TN049, TN050 and TN054) that occupied a standard set of stations. Data from the raw CTD files were binned at 2 db intervals through SeaBird's SEASOFT program, which has a spike removal subroutine which we have tested and found to remove

Description	transmissometer data spikes properly. The data were corrected for factory and field air calibrations. Beam transmission was converted to beam attenuation coefficients using c=-(1/r)*ln(%Tr/100) where c=beam attenuation coefficient (m^-1), r=beam path length (m), and Tr=% beam transmission. The Arabian Sea data set presented some challenges because 1-4 different transmissometers were used on any given cruise, complicating the data calibration. It is impractical to do a proper bench or air calibration prior for each CTD cast since the deck of the ship is not always a clean environment and atmospheric conditions can change rapidly and affect the air readings. One calibration method is to compare the beam attenuation at depth where the particle concentration is relatively invariant. The primary concern is ensuring that the optical windows are uniformly clean, which is best determined by comparing adjacent profiles. Unfortunately, many of the CTD casts extended only to 150 m or less, which was usually shallower than the particle minimum. Furthermore, the stations covered a wide geographic area, so it is more likely that the particle minimum at depth could vary. The primary method for comparing the beam attenuation signal to particulate matter (PM) concentration or particulate organic carbon (POC) concentration is to filter water samples and determine the dry weight using stable filters (0.4 um pore size Poretics filters in this case), or the amount of organic carbon on a glass fiber filter (0.7 um nominal pore size). The beam c data for those bottle depths (chosen as the cp value of the 2 db bin within which the sample depth fell) are then regressed against PM or POC using a Model II regression to determine the intercept where the concentration of particles in the water equals zero. Theoretically this value should be 0.364 since the transmissometers are set at the factory to read 0.364 in particle-free water. PM was filtered on four of the five cruises where beam c was analyzed. POC was measured on the one cruise for which no PM measurements were made (TN049) as well as most of the other cruises. In order to determine the attenuation specific to particulate matter, the attenuation due to water must be subtracted from the beam c values (cp = c - cw). Practically, cw is determined as the minimum attenuation measured during each cruise. It must be noted that this minimum attenuation value is the "cleanest" water observed and is not particle free. Thus, the regressions of the cp data versus particle concentrations must be adjusted. A prediction of the PM concentration can be obtained from the resulting equations for each cruise: TN043 -> PM = 602 * cp (r^2 = 0.86) TN045 -> PM = 483 * cp (r^2 = 0.87) TN050 -> PM = 687 * cp (r^2 = 0.92) TN054 -> PM = 615 * cp (r^2 = 0.86) PM is in ug/Kg, and cp is attenuation per meter. Note that these are Model II regressions so the equations are the same if PM is regressed versus cp or vice versa. For comparison, the relationships between particle concentration and attenuation in surface waters of previous JGOFS programs were: PM = 1022*cp North Atlantic Bloom Exp. PM = 451*cp EqPac Spring Time Series PM = 647*cp EqPac Fall Time Series Chlorophyll Chlorophyll-a fluorescence distribution in the Arabian Sea was determined, in-situ, with a SeaTech Fluorometer. The fluorometer was interfaced with the Sea-Bird CTD, and the data were acquired in the same format as the transmissometer data. The Fluorometer is a standard irradiation/emission system. When chlorophyll a is excited by blue light (425 nm), it will fluoresce at a peak wavelength of 685 nm (red light). The emission detector is filtered to a peak response in order to make the measurement insensitive to the excitation source. The amount of fluoresced light detected is converted to a voltage range of 0 to 5 volts. A signal gain of 10x was used, setting sensitivity to 3mg chl-a m^-3. The fluorometer is set to sample with a three second time constant to smooth the data. A baffle has been placed in front of the emission detector in an attempt to make it insensitive to ambient light (SeaTech Fluorometer Manual). The SEASOFT software converts the measured voltage into a relative chlorophyll-a value using the equation: [volts * signal gain/5] + offset = mg chl-a m^-3 These relative values were calibrated using discreet chlorophyll samples (taken by various JGOFS scientists and analyzed onboard the ship using a Turner Fluorometer). There is a good (r^2 = 0.90) linear correlation between fluorometer-determined chlorophyll-a fluorescence, and the chlorophyll-a concentrations determined using a Turner fluorometer. Regressions were made for each cruise individually, but the correlations (based on the standard deviation of the slope and intercept) were improved when data from cruises TN049, TN050, and TN054 were combined. Prior to TN049, chlorophyll samples were taken from the Trace-Metal rosette, which contained no CTD or fluorometer for accurate depth or fluorescence measurements. We attempted a comparison between standard CTD/fluorometer profiles made close in time to the Trace-Metal casts on which chlorophyll measurements were made, but the lack of accurate depths or water density for the discreet samples plus the temporal variability between casts introduced too much scatter for a useful correlation. There were too few chlorophyll a measurements made on the standard CTD casts during TN043 and TN045 to independently calibrate the fluorometer. This added to the appeal of a general calibration for the fluorescence signal for all cruises, though we recognize that data for two cruises were not included. We emphasize for future work that it is necessary to have a

	fluorometer and CTD on the rosette at the time chlorophyll samples are being taken in order to accurately calibrate the fluorescence signal. Furthermore continuous profiles from a fluorometer provide higher resolution than discreet samples alone. Slightly different slopes and intercepts were observed in the fluorescence/chlorophyll correlations for samples above and below the chlorophyll maximum. Therefore the depth of the chlorophyll maximum was determined by visual inspection of each profile (to avoid confusion with individual spikes) and the samples were divided into two categories, separated at a depth 10 m beneath the maximum fluorescence value. The assumption (substantiated by inspection of the data) is that chlorophyll-containing particles within the subsurface chlorophyll maximum are more similar to those above the maximum than below. A model II linear regression on each group of data indicated a very slight difference in slopes between the two groups, but a substantial offset in the intercepts. This results in a difference in the concentration of predicted chlorophyll based on the fluorescence above and below the chlorophyll maximum. Similar differences in chlorophyll fluorescence above and below the chlorophyll maximum were noticed by Pak et al. (1988). Equations are provided here for both regions in the Arabian Sea. Above the depth of the chlorophyll maximum: Chl a = 0.357*Fl + 0.078 (r^2 = 0.86) Below the depth of the chlorophyll maximum: Chl a = 0.389*Fl - 0.05 (r^2 = 0.93) LSS - SeaTech Light Scattering Sensor Light scattering due to particles was monitored using a SeaTech Light Scattering Sensor (LSS). The LSS projects light from two 880 nm (infrared) LEDs into a sampling volume that varies depending upon the concentration of particulate matter, but that is roughly the shape of a stretched balloon. Back-scattered light from the particulate matter is measured by a detector. The range on the LSS was set to 0 - 33 mg/l. The amount of light detected is scaled to a 0-5 volt output, but in the Arabian Sea most values were less than 0.5 volts. The LSS output depends upon the nature of the particulate matter and will vary with changes in particle size distribution, shape, index of refraction, organic/inorganic content etc. Therefore the LSS requires site-specific calibration. The LSS was interfaced with the SeaBird CTD and the data were handled in the same format as the transmissometer and fluorometer data.

TT050

Website	https://www.bco-dmo.org/deployment/57711
Platform	R/V Thomas G. Thompson
Start Date	1995-08-18
End Date	1995-09-15
Description	**Methods & Sampling** PI: John Morrison of: North Carolina State University PI on Optics: Wilford Gardner, Mary Jo Richardson dataset: CTD profile data averaged at two decibar intervals, including beam attenuation dates: August 18, 1995 to September 13, 1995 location: N: 22.4998 S: 9.9125 W: 57.3004 E: 68.7527 project/cruise: Arabian Sea/TTN-050 - Process Cruise 5 (Late SW Monsoon) ship: Thomas Thompson John M. Morrison -- 8 July 1996 TN050: JGOFS Arabian Sea Process Study -- Process Cruise #5 This "readme" file pertains to the CTD data taken during RV T.G. Thompson cruise TN050. This cruise was the fifth JGOFS Arabian Sea Process Leg and took place during August - September 1995. Prof. Sharon L. Smith of the University of Miami (ssmith@rsmas.miami.edu) was the chief scientist. Digital dissolved oxygen, transmissometer and fluoruometer data were also collected on the CTD, but are not reported here as we have not calibrated this data. CTD Calibration: On this cruise, one CTD configurations was used. The processing and calibration information for this configuration is given as follows: John M. Morrison 28 May 1996 This is the setup, processing and calibation information for the CTD for cruise TN050. Both the primary and secondary set of CTD sensors were calibrated for this cruise. The calibrated data from the primary set of sensors are used for the final data files, except for 4 stations where the primary CTD sensors malfunctioned. This malfunction appeared to be to a failure of the pump or something being trapped in the conductivity cell of the primary sensor. In addition, in both the primary and secondary sensors, there was a trend in the differences between the CTD and bottle salinities in the upper 500 meters of the data. Therefore, the upper 500 meters were calibrated separately from the data below 500 meters. Finally, a filter of +/-0.01 was applied to the differences between CTD and Bottle salinities to remove large differences associated with the salinity gradient region of the water column and not associated with the calibration of the CTD sensors. Both calibrations are given below, as well as a listing of stations for which each calibration was used. ____ Sea-Bird Processing Information: Example from 05000101.cnv * Sea-Bird SBE 9 Raw Data File: * FileName = G:

TT053

Website	https://www.bco-dmo.org/deployment/57714
Platform	R/V Thomas G. Thompson
Start Date	1995-10-29
End Date	1995-11-26
Description	**Methods & Sampling** PI: John Morrison of: North Carolina State University dataset: CTD profile data averaged at two decibar intervals dates: October 29, 1995 to November 25, 1995 location: N: 24.3329 S: 10.0823 W: 56.4858 E: 67.1784 project/cruise: Arabian Sea/TTN-053 - Process Cruise 6 (bio-optics) ship: Thomas Thompson John M. Morrison -- 18 July 1996 TN053: JGOFS Arabian Sea Process Study -- Process Cruise #6: This "readme" file pertains to the CTD data taken during RV T.G. Thompson cruise TN053. This cruise was the sixth JGOFS Arabian Sea Process Leg and took place during October - November 1995. Barney Balch of the Bigelow Laboratory for Ocean Sciences (balch@phyto.bigelow.org) was the chief scientist. Digital dissolved oxygen, transmissometer and fluorometer data were also collected on the CTD, but are not reported here as we have not calibrated this data. The raw data files may be requested from: DR.JOHN M. MORRISON NORTH CAROLINA STATE UNIVERSITY DEPARTMENT OF MARINE, EARTH AND ATMOSPHERIC SCIENCES JORDAN HALL RM. 1125 BOX 8208 RALEIGH, NC 27695-8208 EMAIL: John_Morrison@NCSU.EDU PHONE: 919-515-7449 FAX: 919-515-7802 CTD Calibration: On this cruise, one CTD configurations was used. The processing and calibration information for this configuration is given as follows: This the setup, processing and calibation information for the CTD for cruise TN053. Sea-Bird Processing Information: Example from 05300101.cnv Sea-Bird SBE 9 Raw Data File: * FileName = G:

TT054

Website	https://www.bco-dmo.org/deployment/57715
Platform	R/V Thomas G. Thompson
Start Date	1995-11-30
End Date	1995-12-28
	Methods & Sampling PI: John Morrison of: North Carolina State University PI on Optics: Wilford Gardner, Mary Jo Richardson dataset: CTD profile data averaged at two decibar intervals, including beam attenuation dates: November 30, 1995 to December 26, 1995 location: N: 22.5171 S: 9.9673 W: 57.2992 E: 68.7849 project/cruise: Arabian Sea/TTN-054 - Process Cruise 7 (Early NE Monsoon) ship: Thomas Thompson John M. Morrison -- 18 July 1996 TN054: JGOFS Arabian Sea Process Study -- Process Cruise #7: This "readme" file pertains to the CTD data taken during RV T.G. Thompson cruise TN054. This cruise was the seventh JGOFS Arabian Sea Process Leg and took place during November - December 1995. Wilford Gardner of Texas A&M University (wgardner@astra.tamu.edu) was the chief scientist. Dissolved oxygen, ransmissometer and fluorometer data were also collected on the CTD, but are not reported here as we have not calibrated this data. The raw data files may be requested from: DR.JOHN M. MORRISON NORTH CAROLINA STATE UNIVERSITY DEPARTMENT OF MARINE, EARTH AND ATMOSPHERIC SCIENCES JORDAN HALL RM. 1125 BOX 8208 RALEIGH, NC 27695-8208 CTD Calibration: On this cruise, one CTD configurations was used. The processing and calibration information for this configuration are given below: John M. Morrison -- 25 June 1996 This the setup, processing and calibation information for the CTD for cruise TN054. Sea-Bird Processing Information: Example from 05400101.cnv * Sea-Bird SBE 9 Raw Data File: * FileName = G: **Processing Description** Beam Attenuation Coefficient, Light Scattering, Fluorescence protocols Wilford Gardner, Jan Gundersen, Mary Jo Richardson. Texas A&M University Data Reduction Scheme The primary purpose for measuring the beam attenuation in JGOFS programs is to determine the concentration and distribution of particulate matter (PM) or particulate organic carbon (POC) in the water with continuous profiling rather than with limited discrete samples. Towards this end, a 25 cm Sea Tech Transmissometer was interfaced with the University of Washington's SeaBird CTD for all Arabian Sea cruises. Transmissometer data were analyzed for the five

Description	process cruises (TN043, TN045, TN049, TN050 and TN054) that occupied a standard set of stations. Data from the raw CTD files were binned at 2 db intervals through SeaBird's SEASOFT program, which has a spike removal subroutine which we have tested and found to remove transmissometer data spikes properly. The data were corrected for factory and field air calibrations. Beam transmission was converted to beam attenuation coefficients using c=-(1/r)*ln(%Tr/100) where c=beam attenuation coefficient (m^-1), r=beam path length (m), and Tr=% beam transmission. The Arabian Sea data set presented some challenges because 1-4 different transmissometers were used on any given cruise, complicating the data calibration. It is impractical to do a proper bench or air calibration prior for each CTD cast since the deck of the ship is not always a clean environment and atmospheric conditions can change rapidly and affect the air readings. One calibration method is to compare the beam attenuation at depth where the particle concentration is relatively invariant. The primary concern is ensuring that the optical windows are uniformly clean, which is best determined by comparing adjacent profiles. Unfortunately, many of the CTD casts extended only to 150 m or less, which was usually shallower than the particle minimum. Furthermore, the stations covered a wide geographic area, so it is more likely that the particle minimum at depth could vary. The primary method for comparing the beam attenuation signal to particulate matter (PM) concentration or particulate organic carbon (POC) concentration is to filter water samples and determine the dry weight using stable filters (0.4 um pore size Poretics filters in this case), or the amount of organic carbon on a glass fiber filter (0.7 um nominal pore size). The beam c data for those bottle depths (chosen as the cp value of the 2 db bin within which the sample depth fell) are then regressed against PM or POC using a Model II regression to determine the intercept where the concentration of particles in the water equals zero. Theoretically this value should be 0.364 since the transmissometers are set at the factory to read 0.364 in particle-free water. PM was filtered on four of the five cruises where beam c was analyzed. POC was measured on the one cruise for which no PM measurements were made (TN049) as well as most of the other cruises. In order to determine the attenuation specific to particulate matter, the attenuation due to water must be subtracted from the beam c values (cp = c - cw). Practically, cw is determined as the minimum attenuation measured during each cruise. It must be noted that this minimum attenuation value is the "cleanest" water observed and is not particle free. Thus, the regressions of the cp data versus particle concentrations must be adjusted. A prediction of the PM concentration can be obtained from the resulting equations for each cruise: TN043 -> PM = 602 * cp (r^2 = 0.86) TN045 -> PM = 483 * cp (r^2 = 0.87) TN050 -> PM = 687 * cp (r^2 = 0.92) TN054 -> PM = 615 * cp (r^2 = 0.86) PM is in ug/Kg, and cp is attenuation per meter. Note that these are Model II regressions so the equations are the same if PM is regressed versus cp or vice versa. For comparison, the relationships between particle concentration and attenuation in surface waters of previous JGOFS programs were: PM = 1022*cp North Atlantic Bloom Exp. PM = 451*cp EqPac Spring Time Series PM = 647*cp EqPac Fall Time Series Chlorophyll Chlorophyll-a fluorescence distribution in the Arabian Sea was determined, in-situ, with a SeaTech Fluorometer. The fluorometer was interfaced with the Sea-Bird CTD, and the data were acquired in the same format as the transmissometer data. The Fluorometer is a standard irradiation/emission system. When chlorophyll a is excited by blue light (425 nm), it will fluoresce at a peak wavelength of 685 nm (red light). The emission detector is filtered to a peak response in order to make the measurement insensitive to the excitation source. The amount of fluoresced light detected is converted to a voltage range of 0 to 5 volts. A signal gain of 10x was used, setting sensitivity to 3mg chl-a m^-3. The fluorometer is set to sample with a three second time constant to smooth the data. A baffle has been placed in front of the emission detector in an attempt to make it insensitive to ambient light (SeaTech Fluorometer Manual). The SEASOFT software converts the measured voltage into a relative chlorophyll-a value using the equation: [volts * signal gain/5] + offset = mg chl-a m^-3 These relative values were calibrated using discreet chlorophyll samples (taken by various JGOFS scientists and analyzed onboard the ship using a Turner Fluorometer). There is a good (r^2 = 0.90) linear correlation between fluorometer-determined chlorophyll-a fluorescence, and the chlorophyll-a concentrations determined using a Turner fluorometer. Regressions were made for each cruise individually, but the correlations (based on the standard deviation of the slope and intercept) were improved when data from cruises TN049, TN050, and TN054 were combined. Prior to TN049, chlorophyll samples were taken from the Trace-Metal rosette, which contained no CTD or fluorometer for accurate depth or fluorescence measurements. We attempted a comparison between standard CTD/fluorometer profiles made close in time to the Trace-Metal casts on which chlorophyll measurements were made, but the lack of accurate depths or water density for the discreet samples plus the temporal variability between casts introduced too much scatter for a useful correlation. There were too few chlorophyll a measurements made on the standard CTD casts during TN043 and

	TN045 to independently calibrate the fluorometer. This added to the appeal of a general calibration for the fluorescence signal for all cruises, though we recognize that data for two cruises were not included. We emphasize for future work that it is necessary to have a fluorometer and CTD on the rosette at the time chlorophyll samples are being taken in order to accurately calibrate the fluorescence signal. Furthermore continuous profiles from a fluorometer provide higher resolution than discreet samples alone. Slightly different slopes and intercepts were observed in the fluorescence/chlorophyll correlations for samples above and below the chlorophyll maximum. Therefore the depth of the chlorophyll maximum was determined by visual inspection of each profile (to avoid confusion with individual spikes) and the samples were divided into two categories, separated at a depth 10 m beneath the maximum fluorescence value. The assumption (substantiated by inspection of the data) is that chlorophyll-containing particles within the subsurface chlorophyll maximum are more similar to those above the maximum than below. A model II linear regression on each group of data indicated a very slight difference in slopes between the two groups, but a substantial offset in the intercepts. This results in a difference in the concentration of predicted chlorophyll based on the fluorescence above and below the chlorophyll maximum. Similar differences in chlorophyll fluorescence above and below the chlorophyll maximum were noticed by Pak et al. (1988). Equations are provided here for both regions in the Arabian Sea. Above the depth of the chlorophyll maximum: Chl a = 0.357*Fl + 0.078 (r^2 = 0.86) Below the depth of the chlorophyll maximum: Chl a = 0.389*Fl - 0.05 (r^2 = 0.93) LSS - SeaTech Light Scattering Sensor Light scattering due to particles was monitored using a SeaTech Light Scattering Sensor (LSS). The LSS projects light from two 880 nm (infrared) LEDs into a sampling volume that varies depending upon the concentration of particulate matter, but that is roughly the shape of a stretched balloon. Back-scattered light from the particulate matter is measured by a detector. The range on the LSS was set to 0 - 33 mg/l. The amount of light detected is scaled to a 0-5 volt output, but in the Arabian Sea most values were less than 0.5 volts. The LSS output depends upon the nature of the particulate matter and will vary with changes in particle size distribution, shape, index of refraction, organic/inorganic content etc. Therefore the LSS requires site-specific calibration. The LSS was interfaced with the SeaBird CTD and the data were handled in the same format as the transmissometer and fluorometer data.

TT039

Website	https://www.bco-dmo.org/deployment/57700
Platform	R/V Thomas G. Thompson
Report	http://usjgofs.whoi.edu/arabian-docs/smith-update.html
Start Date	1994-09-18
End Date	1994-10-07
Description	Intercalibration and Training Cruise **Methods & Sampling** PI: John Morrison dataset: CTD profile data at one decibar intervals project/cruise: Arabian Sea/TTN039 - Intercalibration Cruise ship: Thomas Thompson John M. Morrison 15 August 1995 TN039 -- JGOFS Arabian Sea Process Training and Calibration Cruise: General Comments: This "readme" file pertains to the CTD data collected during RV T.G. Thompson cruise TN039. This cruise took advantage of the sampling and training opportunities provided by the Thompson's transit leg from Singapore to Oman. The purposes of this cruise included: 1) testing equipment and methods that would be used on the subsequent JGOFS Arabian Sea process cruises, 2) finalizing the hydrographic and data-processing protocols that would be used on subsequent JGOFS Arabian Sea process cruises, 3) training participants from Pakistan and Oman, 4) collecting as much data as possible to extend the temporal and spatial coverage of the time-series observations included in the JGOFS Arabian Sea process study. The stations from which the data was deemed unrecoverable are listed as follows: stations deleted cruise tn039 sta 4 cast 1 cruise tn039 sta 6 cast 1 cruise tn039 sta 6 cast 2 stations truncated Deleted data below 1000 db, sta 21 cast 2 Deleted data below 3000 db, sta 21 cast 3 Digital dissolved oxygen, transmissometer and fluoruometer data were also collected on the CTD, but are not reported here as we have not calibrated this data. The raw data files may be requested from: DR.JOHN M. MORRISON NORTH CAROLINA STATE UNIVERSITY DEPARTMENT OF MARINE, EARTH AND ATMOSPHERIC SCIENCES JORDAN HALL RM. 1125 BOX 8208 RALEIGH, NC 27695-8208 EMAIL: John_Morrison@NCSU.EDU PHONE: 919-515-7449 CTD Calibration: On this cruise, three different CTD configurations were used. The processing and calibration information for each of the configurations are given below: Setup, processing and calibration information for the Primary setup for cruise TN039 Setup, processing and calibration information for the Secondary (a) setup for cruise TN039 Setup, processing and calibration information for the Secondary (b) setup for cruise TN039

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Project Information

U.S. JGOFS Arabian Sea (Arabian Sea)

Website: http://usjgofs.whoi.edu/research/arabian.html

Coverage: Arabian Sea

The U.S. Arabian Sea Expedition which began in September 1994 and ended in January 1996, had three major components: a U.S. JGOFS Process Study, supported by the National Science Foundation (NSF); Forced Upper Ocean Dynamics, an Office of Naval Research (ONR) initiative; and shipboard and aircraft measurements supported by the National Aeronautics and Space Administration (NASA). The Expedition consisted of 17 cruises aboard the R/V Thomas Thompson, year-long moored deployments of five instrumented surface buoys and five sediment-trap arrays, aircraft overflights and satellite observations. Of the seventeen ship cruises, six were allocated to repeat process survey cruises, four to SeaSoar mapping cruises, six to mooring and benthic work, and a single calibration cruise which was essentially conducted in transit to the Arabian Sea.

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Program Information

U.S. Joint Global Ocean Flux Study (U.S. JGOFS)

Website: http://usjgofs.whoi.edu/

Coverage: Global

The United States Joint Global Ocean Flux Study was a national component of international JGOFS and an integral part of global climate change research.

The U.S. launched the Joint Global Ocean Flux Study (JGOFS) in the late 1980s to study the ocean carbon cycle. An ambitious goal was set to understand the controls on the concentrations and fluxes of carbon and associated nutrients in the ocean. A new field of ocean biogeochemistry emerged with an emphasis on quality measurements of carbon system parameters and interdisciplinary field studies of the biological, chemical and physical process which control the ocean carbon cycle. As we studied ocean biogeochemistry, we learned that our simple views of carbon uptake and transport were severely limited, and a new "wave" of ocean science was born. U.S. JGOFS has been supported primarily by the U.S. National Science Foundation in collaboration with the National Oceanic and Atmospheric Administration, the National Aeronautics and Space Administration, the Department of Energy and the Office of Naval Research. U.S. JGOFS, ended in 2005 with the conclusion of the Synthesis and Modeling Project (SMP).

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Funding

Funding Source	Award
National Science Foundation (NSF)	unknown Arabian Sea NSF

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