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Acoustic Doppler Current Profiling from the

JGOFS Arabian Sea Cruises

Aboard the RV T.G. THOMPSON

TN043, January 8, 1995 - February 4, 1995

TN044, February 8, 1995 - February 25, 1995

TN045, March 14, 1995 - April 10, 1995

TN046, April 14, 1995 - April 29, 1995

by

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1. Introduction

Acoustic Doppler current profiler (ADCP) data from the R/V T.G. THOMPSON is part of the core data for the U.S. JGOFS Arabian Sea project along with hydrographic and nutrient data. Seventeen cruises on the THOMPSON are scheduled to take place between September 1994 and January 1996, Table 1. (The cruises on the THOMPSON are numbered consecutively from the ship's commissioning with the first JGOFS cruise designated TN039.) This is the second in a series of data reports covering the ADCP data from the Arabian Sea JGOFS cruises TN043 through TN046. The first data report presented results from cruises TN039 through TN042 (Flagg and Shi, 1995).

All but the first cruise have been or will be staged from Muscat, Oman. Seven of the cruises, referred to as process cruises, follow the standard cruise track, Figure 1, making hydrographic, chemical and biological measurements. The remainder of the cruises which are for the deployment and retrieval of moored equipment and towing of a SeaSoar take place generally within the region defined by a set track. Each cruise is scheduled for a duration of between two weeks and one month.

ADCP data are being collected on all the JGOFS Arabian Sea cruises using an autonomous data acquisition system developed for ship-of-opportunity cruises. This system, referred to as the AutoADCP, makes it possible to collect the ADCP data without the constant monitoring usually necessary and assures constant data coverage and uniform data quality. The AutoADCP system is an extension of RD Instrument's DAS version 2.48 using enhancements made possible with "user-exit" programs. Because of the AutoADCP system, the JGOFS cruises do not have a person on board dedicated to the ADCP. Rather, the ship's technicians provide general monitoring for hardware and/or software problems and retrieve the data at the end of the cruises. Because of this arrangement the technicians on the THOMPSON have an important and critical role in the success of the JGOFS ADCP data set. The ADCP configurations used for the data collection are the result of experience, consultation with other JGOFS investigators, and testing during the calibration and training cruise, TN039.

This data report presents ADCP results from the second group of four JGOFS cruises, TN043 through TN046, concentrating on the data collection and processing methods. The ADCP data itself reside in a CODAS data base at Brookhaven National Laboratory and is generally available to JGOFS investigators through contact with the authors. The CODAS data base and associated ADCP processing software were developed over a number of years by Eric Firing and his group at the University of Hawaii. The CODAS software is shareware available for PC's or Unix computers and is the single most widely used ADCP processing program for ship mounted units.

Figure 1: Arabian Sea standard cruise track with the station locations repeating for the process cruises, and an array of current meter moorings: The o, +, and * indicate, respectively, long, intermediate and hydro stations. The symbol o designates sediment trap moorings. The smaller circles centered about 15.5°N, 61.5°E represent the locations of the five long-term moorings.

2. ADCP Installation on the R/V THOMPSON

2.1 ADCP Hardware

The ADCP used on the R/V T.G. THOMPSON is a 153.6 kHz ADCP, model VM-150, manufactured by RD Instruments of San Diego, CA. The ADCP was sent to RD Instruments for a complete overhaul and calibration in June/July 1994 just prior to the commencement of the JGOFS program. The four-beam concave ADCP transducer, serial number 127, is mounted in a faired transducer pod that protrudes below the hull of the THOMPSON by about two feet such that the depth of the transducer is nominally 5.9 meters (19 feet). The transducer pod eliminates, or at least reduces, the impact of bubble-sweep-down on the ADCP. The transducer is exposed directly to the sea. Experience with this installation during the relatively calm conditions of the first eight cruises indicates that this is an excellent installation producing high quality data at all ship speeds. The impact of high waves on ADCP performance is unknown at present although the ability to produce high quality data is now being tested severely during the JGOFS monsoon cruises. The ADCP deck unit is installed in the THOMPSON's computer lab in a computer rack above a sub-bottom depth sounder. The temperature of the deck unit with the depth sounder operating was measured to be 30° Celsius on TN039. While the computer lab of the THOMPSON is air-conditioned, there are occasional large variations in temperature that may be alter the deck unit's operating environment. The ADCP deck unit is plugged into the ship's uninterruptable power supply where the AC voltage measured at the outlet on TN039 was 117 volts.

On the R/V T.G. THOMPSON, the AutoADCP programs have been installed on two PC computers, both of which are connected by a Pathworks network to virtual disks on a DEC 5000-200 Unix workstation. In September 1994, one of the THOMPSON's PCs (a Delphi 286) was set up to collect the data, while a PC supplied by Brookhaven (a Dell 310) was used for real-time presentation of the results. The AutoADCP programs were installed on both computers so that the data collection could be switched to the Brookhaven PC if the primary PC suffered a failure.

Standard ADCP data is displayed on the THOMPSON's Delphi 286. The presentation consists of 5-minute ensemble averaged profiles of U (zonal) and V (meridional) velocity, AGC (backscatter intensity) and percentage of good pings. In addition to the data gathering performed by the AutoADCP system, another set of programs was written in MATLAB to present ADCP data in real-time. These programs run on the second computer, the Dell 386, and make use of the networked virtual disk that is common with the AutoADCP system to access the most recent pingdata files. The real-time displays include vertical sections of U (zonal) velocity, V (meridional) velocity and range corrected backscatter intensity. The usual setup displays the last 12 hours of ADCP data, updating the display at 15 minute intervals.

2.2 AutoADCP Data Acquisition System

ADCP data is being collected on the R/V T.G. THOMPSON throughout the Arabian Sea JGOFS project. To insure that the best possible data is obtained and to minimize interference with other program components, a modification to RD Instrument's data acquisition system for narrow-band ADCPs, DAS 2.48, is used, enabling autonomous operation. This capability was developed previously in a collaboration among Brookhaven National Laboratory, the University of Rhode Island and RD Instruments. The program expands upon the standard DAS's capabilities making it possible to automatically start and stop the collection of the data and to change the configuration of the DAS depending upon the ship's location. The AutoADCP system is also designed to make back-up copies of the pingdata files and provides a means of restarting the system if for any reason the DAS locked-up.

The major component of the system is a "user-exit" program named FLAG.EXE. This program is called up at the end of each ADCP ensemble, determines the ship's position, and compares it with pre-defined regions, Figure 2. When the ship leaves one region for another, the DAS's configuration file is updated, the computer reboots, and starts pinging using the new configuration. Provision has also been made for a watchdog timer and automatic backup of pingdata files each time a file is filled. The utility of the AutoADCP DAS is that ensemble interval, number of bins, bin and pulse size, bottom tracking, and other configuration parameters can be controlled without an on-board operator monitoring the DAS's performance. This makes for a more consistent and robust data set.

In order for the ADCP's data acquisition system to collect the data it is necessary to define the desired system configuration in the file START.CNF. The AutoADCP system determines the appropriate region by comparing the ship's position with the regions defined in the POSITION.DAT file. If necessary, a configuration for the new region is copied into the START.CNF file and the PC is rebooted. Most of the data in the program was obtained using the configuration for the northern Arabian Sea. The ARABSEA.CNF file is shown in Table 2.

In addition, the system includes the WOCE standard enhancements to the DAS with another "user-exit" program, UE4.EXE, which was developed by Eric Firing's group at the University of Hawaii. This program is designed to improve upon some features of RD Instruments' DAS software. The most important element is that UE4 records the position of the ship at either end of the ensemble rather than as the average position during the ensemble. This allows for a more precise computation of the ship's velocity during an ensemble. The UE4 program has been expanded recently so that it now works with Ashtech's GPS attitude sensor that uses phase differential GPS to determine the ship's heading. The Ashtech heading data is not only more accurate than the ship's gyro compass, but also immune to the latitudinal speed and turning errors that degrade gyros. However, because the Ashtech heading data can have gaps, the primary heading information for the ADCP retains the gyro compass. The recorded Ashtech heading data is used on a post-cruise basis to adjust the compass heading as needed.

Figure 2: The ADCP regions of the Arabian Sea, Bay of Bengal, and western portion of the Indonesian Archipelago, which dictate control over the operation of the ADCP with configuration file. The configuration regions include possible ports of call and the continental shelves as well as the open ocean of the Arabian Sea and Bay of Bengal.

The Ashtech receiver was available for cruise TN044. The unit died on TN045 and has only recently been reinstalled on the THOMPSON for cruise TN049.

A third user-exit program, AGCAVE.EXE, modifies the way the DAS collects acoustic backscattered intensity data. Without the addition of this program, the DAS records the intensity (which used to be called amplitude) data as a single profile composed of the average of all four beams. This degrades the intensity data because without calibration, the individual beams produce slightly different profiles. To address this problem and to allow for post-cruise calibration of the intensity data, AGCAVE was developed. The program forms ensemble averaged profiles for each beam and stores the results separately in the pingdata data file location reserved for "last AGC".

These are the main programs in the Autonomous ADCP DAS system so that it only requires an occasional check to insure that the hardware is still functioning. At the end of each cruise the pingdata files have been copied to a SyQuest removable hard disk and sent to Brookhaven National Laboratory for processing.

2.3 Navigation

Navigation information for the THOMPSON was provided by a GPS satellite navigation system. The intent was to use a P-code GPS receiver for the JGOFS cruises. However, permission to use the more accurate system was delayed and the P-code receiver was not used during the first four cruises of the program (Flagg and Shi, 1995). Finally the receiver was made operational in January, 1995 in preparation for cruise TN043 and has been working successfully for cruises TN043 through middle of cruise TN046 (Appendix B). The improvement in the navigation quality due to the P-code receiver is significant and quite obvious during the processing of the ADCP data (see below).

The use of the P-code data was controlled by the UE4 configuration file where the P-code data stream was set as the primary navigation source. The position data from the Ashtech receiver, when it was available, was used as a back up. The UE4 user-exit program reads the navigation data contained in the NEMA "GGA" message at the end of the ensemble and records the result in the "user buffer" area. With the P-code receiver in the system, the laptop computer used to reformat of the "GGA" message during the earlier cruises was no longer used. The UE4 program also maintained the PC clock to within 2 seconds of the GPS time provided in the GGA message.

Relative accuracy of ensemble end-point positions during the first four cruises using the C/A GPS code receiver had an rms value of about 33 meters for both latitude and longitude. Starting with cruise TN043 the THOMPSON was able to use a P-code GPS receiver. This has made a large difference in navigational accuracy. The change in navigational quality is most visible in the initial estimates of the reference layer velocities where there has been a factor of four to five reduction in the short-term variance suggesting a similar reduction in rms short-term position accuracy. During the ADCP data processing the navigation fixes are smoothed (Appendix B) to lessen the effects of the

quasi-random navigation errors. With the P-code GPS receiver the required smoothing to produce high quality results is significantly less.

2.4 Compass

The primary heading data for the ADCP was provided by the THOMPSON's gyro compass. Both the latitude and speed corrections for the compass were daily/regularly updated by bridge personnel depending upon the ship's activities (Bill Martin, personal communication). When the ship stops on station, the gyro is apparently set to zero. On cruise TN044 the compass was augmented with an Ashtech GPS attitude sensor which provided a data stream that could be used during post processing to reduce errors inherent to gyro compasses. The Ashtech operated only for a day on TN045.

3. Data Processing and Analysis

The binary pingdata files from each cruise were processed on a Silicon Graphics Indy workstation using the ship-board ADCP processing programs developed by the ADCP group at the University of Hawaii. These programs consisted of two parts, a set of processing programs and a data base system called CODAS (Common Oceanographic Data Access System) written in C, and a series of MATLAB analysis routines for post-processing and plotting the ADCP velocity and backscatter data. The CODAS routines were augmented to handle the backscatter intensity data in keeping with the methods developed by Flagg and Smith (1985) and Flagg, et al. (1994).

3.1 Velocity

The binary pingdata files were first scanned to produce listings of the headers and ADCP configurations for each of the pingdata files and to extract the GPS navigation data contained in the user-buffer area. Using the header listings as a guide to the appropriate ADCP profiles, the ADCP data in the pingdata files were loaded into a separate CODAS data base for each cruise. The editing of the data started with a determination of parameters to flag complete ADCP profiles or portions of profiles. The basic editing parameter was the percent good determined by the ADCP and recorded along with the velocity data. The minimum percent good was set to 30 percent. There were four other editing parameters that were also used: The first was a bottom search criterion that is the difference between the minimum backscatter intensity and a subsequent maximum. Most of the JGOFS Arabian cruise time has been spent in waters considerably deeper than the ADCP's range so this parameter was often ignored. In shallower water bottom tracking was used which also determined the bottom depth and that data was used to edit the ADCP profiles for bottom interference. The second flagging parameter was the error velocity, the difference between the vertical velocity calculated by the transducer pairs. The third parameter was the variance of the vertical velocity over the entire profile. The last editing parameter was the second difference (ie. $\propto \partial^2 / \partial z^2$) in the vertical and horizontal velocity components. Collectively, these parameters flag interference from the bottom, from instrumentation

suspended from the ship, from large aggregations of fish or scatterers and other, possibly anomalous, behavior.

Each velocity and backscatter profile were examined visually and in light of the flagging parameters. On the whole, the ADCP data from these cruises was very clean. The vertical diel migration of euphausiids and mictofids often caused high vertical velocity variances and false bottom indications. Generally, profiles that showed this vertical migration were kept in the data set. One of the more notable features of this data set was the dramatic effect that diel migration had on the range of the ADCP. During daylight hours when the plankton were at depth the ADCP easily reached 350 to 400 meters but during the night when the plankton were in the upper layer the range often decreased to 200 to 250 meters. On cruise TN039, increasing the ADCP's acoustic output power at night by increasing pulse length (to 32 m) did not effect the range to any noticeable degree. Apparently, there were simply no scatterers left behind in the mad rush out of the low-oxygen layer and up into the food (and predator) containing layers.

Calibration of the ADPC's orientation and velocity scaling was accomplished using data collected on a 29 hour run up the Malacca Straits during the calibration and training cruise, TN039, when bottom tracking was enabled. During this time the ship had an average speed of about 13 knots (6.75 m/s) and an average heading of 308°. A least square fit between the ship's track determined from the bottom track velocities and that determined from the GPS positions indicated that the transducer had a rotation offset of 1.53° and an amplitude scale factor of 1.000. Subsequently, the ADCP calibration was checked on another bottom track run along the continental shelf south of Oman during cruise TN039 and using water tracking on cruise TN041. From the three hour run along the Oman shelf where the ship was steaming at 4.4 knots on a heading of 261°, the rotation correction was 1.29° while the scale factor was 1.006. The water tracking calibration from TN041 used about 85 right-angle turns produced during several rectilinear patterns made while the ship was making SeaBeam bottom surveys. The water track calibration resulted in a scale factor of 0.999 and rotation correction of 1.39°. While all the calibration runs yielded similar values, we have used the coefficients from the bottom track run up the Malacca Straits since that section covered a long distance under nearly ideal conditions.

During the second cruise in this series, TN044, Frank Bahr changed the heading offset in the ADCP configuration files from 45° to 43.5° to account for the miss-alignment and improve the real-time output. Thus, the ADCP data from TN043 were rotated 1.53° in the data base while no extra rotation was done for cruises TN045 and TN046.

Cruise TN044 made use of the Ashtech attitude data recorded by the UE4 user-exit program. For each ensemble the UE4 program determines, among other things, the ensemble average difference between the ship's compass and the Ashtech heading based upon approximately one second sampling, recording the result in the user buffer portion of the pingdata files. During processing of the ADCP data, a file is created with the angular differences which are used to rotate the velocity vectors for each ensemble. The mean offset during TN044 between the Ashtech and the ship's compass was -3.17°, ranging from

a minimum offset of -1.8° to a maximum of -4.4° . This procedure corrects for the various compass errors but leaves the ADCP angular data relative to new reference frame. It was therefore necessary to determine the angular offset of the Ashtech antennae relative to ADCP using the bottom tracking. Bottom track data from a 7.5 hour run near the end of cruise TN044 along the Omani shelf covering a distance of about 100km, resulted in an angular offset of 3.314° . The data from the cruise were then rotated by this amount. Note that this correction and the mean difference between the compass and the Ashtech are nearly equal and of opposite sign.

Once the ADCP profiles were edited and the velocities scaled and rotated, the navigation data, extracted from the user-buffer, were combined with reference layer velocities to produce smoothed versions of the ship's track and absolute reference layer velocities. In deep water the reference layer spanned bins 5 to 20 (46 to 166 meters) while in the shallower waters of the Oman shelf the reference layer was defined as bins 3 to 8 (30 to 70 meters). The smoothing of the reference layer velocity was done using a Blackman window convolution filter (Bahr, Firing and Songnian, 1989) with a width of one hour. This filter has a half-power point at about 20 minutes corresponding to a distance of about 8 km at 13 knots. The smoothed reference layer velocity was then added to the ship's velocity relative to the reference layer to produce a smoothed version of the total ship's velocity. The displacements calculated from the smoothed ship's velocity were then fit to the position data to yield a smoothed cruise track. The smoothed reference layer velocities and positions were then loaded into the data base. At this point in the processing the velocity data in the CODAS data base was ready to be extracted for plotting and analysis.

3.2 Acoustic Backscatter Intensity

Backscatter intensity data, in terms of digital counts from each of the ADCP's four transducers, were loaded into the CODAS data base directly from the pingdata files along with the velocity data. In addition, two blank variables, CALIB_AMP and ZOOP_BIOMASS, were also loaded into the data base to make room for parameters will be calculated later. Calibrating the intensities from each of the beams and combining them to produce a single calibrated intensity profile for each ensemble is the first step in processing backscatter intensity. The calibration procedure is based upon the method outlined in RD Instruments' technical bulletin ADCP-90-04 issued in December 1994 that attempts to determine the absolute value of the volume reverberation, S_v , from each depth bin. The calibration equation for S_v for each beam is:

$$S_v = 10 \log_{10} \left(\frac{4.47 \times 10^{-20} K_2 K_s (T_x + 273) (10^{K_r (E - E_r)/10} - 1) R^2}{c L K_1 10^{-2\alpha R/10}} \right), \quad (1)$$

where the K's are calibration coefficients, c is the speed of sound at the transducer, m/s, L is the pulse length, m, T_x is the transducer temperature, $^\circ\text{C}$, α is the sound absorption coefficient, dB/m, R is the slant range, m, E_r is the intensity reference level, and E is the echo intensity level. Both E and E_r are given in terms of counts. Two of the constants, K_1

and K_2 , are determined by RD Instruments during instrument checkout. K_1 is the power sent to the transducer and is given by:

$$K_1 = K_{1c} \left(\frac{1.397 V_s - 4.27}{37.14} \right)^2, \quad (2)$$

where V_s is the measured rms AC voltage supplied to the deck unit, 117 v, and the values of K_{1c} supplied by RD Instruments for the THOMPSON for beams 1 to 4 are:

Beam	K_{1c} Watts
1	5.424
2	5.647
3	6.609
4	6.172

The system noise factors, K_2 , also supplied by RD Instruments for the THOMPSON for beams 1 to 4 are:

Beam	K_2
1	2.158
2	2.244
3	1.854
4	2.183

The conversion factor, K_c , from ADCP counts to measured intensity in dB is given by:

$$K_c = 127.3 / (T_e + 273), \quad (3)$$

where T_e is the temperature of the deck unit on the THOMPSON which was 30°C when measured. The reference thermal transducer noise, E_r , for the beams is given by:

$$E_r = E_{rc} + (292 + 0.133 T_e)(1 - a) + (27.3 + 0.1 T_x)(1 - b), \quad (4)$$

$$a = \frac{T_e + 273}{T_{ec} + 273}, \quad b = \frac{T_x + 273}{T_{xc} + 273}, \quad (5)$$

where E_{rc} is the measured reference thermal noise and T_{ec} and T_{xc} are the deck unit and transducer temperatures at the time when E_{rc} was measured. For the THOMPSON data the values of E_{rc} for each beam were taken to be the minimum backscatter counts values recorded during the entire first cruise, minus one count to avoid numerical problems with calculating logarithms. T_{ec} was taken to be 30°C while the values of E_{rc} and T_{xc} for the THOMPSON were:

Beam	E _{rc} counts	T _{xc} °C
1	12	28.4
2	15	28.1
3	17	28.7
4	16	27.2

The absorption coefficient is given by Urick (1982) as:

$$\alpha = \left(1.86 \times 10^{-2} S f_i \left(\frac{f_i^2}{f_i^2 + f^2} \right) + 2.68 \times 10^{-2} \left(\frac{f_i^2}{f_i} \right) \right) \left(\frac{1 - 6.54 \times 10^{-4} P}{914.4} \right), \quad (6)$$

where P is the pressure in atmospheres, f is the frequency of the ADCP which is 153.6 kHz for the ADCP on the THOMPSON and

$$f_i = 21.9 \times 10^6 \left(\frac{1520}{(T_x + 273)} \right). \quad (7)$$

The absorption coefficient for each bin is the average value between the transducer and the bin because the pressure term has a noticeable effect and needs to be included. The transducer temperature is clearly not the correct value except near the transducer itself but at this point we have not attempted to refine this value further by using CTD cast results.

This procedure brings the four acoustic beams into close, but not perfect agreement. Typically over the normal range of variability, the beams might differ by one to two dB. As a result, we have taken an ad-hoc approach to insure that over the length of a section or cruise all the beams will yield the same average backscatter profile. This secondary correction is done using the linear transformation:

$$S_{vc} = a_0 + a_1 S_v, \quad (8)$$

where the scaling and offset factors for each beam relative to the mean profile are determined by least squares.

In the past this has been a straight forward procedure but in the Arabian Sea there was enough biological patchiness that when the ship was on station a single beam occasionally indicated substantially larger concentrations of scatterers than the others. Under these circumstances, scatter plots of a single beam's return versus the average of all four beams showed enough scatter to adversely influence the least square calculations. To distinguish those profiles with large inter-beam variations, we calculated the rms difference of each profile relative to the mean from all four beams. An examination of the time dependence of the rms difference showed that high values were exclusively associated with period when the ship was on station. The reverse was not necessarily the case. From this behavior we surmise that the distribution of plankton and/or fish can be patchy on the scale of one to two hundred meters, the distance the beam spread at a range of one to two hundred meters. Thus, when the ship is still the anomalous scatterers can

remain within a beam for a significant portion of an ensemble and increase the recorded backscatter intensity. Figure 3 shows a plot of backscatter intensity differences between beam 1 profiles and beam averaged profiles when the rms intensity differences were greater than 1.5 dB. (This plot was generated before the secondary corrections were applied which leads to a positive mean offset.) The figure shows that the large beam discrepancies are confined to the ADCP's mid-range, between bins 12 and 32. These bins correspond to depths between 114 and 274 meters spanning the thermocline in the Arabian Sea and the depths over which the oxygen concentrations decrease to very small values. It would appear that there are individual large fish, schools of smaller fish, or plankton patches that tend to congregate in and just above the thermocline perhaps waiting to feed on the upward migrating meso-planktonic euphausiids and mictophids.

Having determined a plausible explanation for the anomalous intensity values, we were able to edit the profiles and include only those whose rms intensity differences were less than or equal to 1 dB. The secondary correction factors, determined using an edited set of profiles from the calibration and training cruise, TN039, were:

Beam	a_0 , dB	a_1
1	-1.6387	0.9991
2	-0.2789	0.9983
3	0.9646	0.9954
4	-0.0794	0.9926

During the processing, the ensemble averaged backscatter profiles are combined to form a single profile for each ensemble. For those ensembles where the rms intensity differences relative to the mean are greater than 1 dB, indicating contamination from anomalous scatterer densities, the averaged profiles are set to nulls. A comparison of the a single beam's backscatter results relative to the average from all the beams after secondary correction has been applied, is shown in Figure 4.

Figure 3: Plot of the difference between the partially calibrated backscatter intensities from Beam #1 and the mean intensities from all four beams when the rms difference was greater than 1.5 dB. The data was taken from cruise TN039. The occurrence of these relatively large differences is restricted to periods when the ship is on station. It appears to reflect inhomogeneities in the small-scale distribution of fish and/or plankton. The bin length is 8 meters and the first bin is centered at a depth of approximately 22 meters.

Figure 4: Scatter plot of the alibrated backscatter intensity from Beam #1 versus the average calibrated intensity from all four beams from profiles where the rms differences between the individual beams and the beam-averaged profiles were less than or equal to 1.0 dB.

4. Data Collection

4.1 TN043

This cruise was the first of the JGOFS process cruises and was intended to cover the early part of the northeast monsoon. The ship left Muscat on January 8, 1995, proceeded clockwise around the standard JGOFS cruise track, and returned to Muscat on February 4, 1995, Figure 5. Mike Roman was the chief scientist and Mike Realander was the ship's technician responsible for monitoring the ADCP system. Mike Realander installed the connection between the new P-code GPS receiver and the ADCP's data acquisition system on this cruise, removing the laptop PC that had been acting as an interface with the ship's standard GPS system. The ADCP worked successfully throughout the cruise using the P-code GPS receiver for navigation.

4.2 TN044

This cruise was the second of the ONR/NRL SeaSoar cruises. The THOMPSON left Muscat on February 8, 1995 and returned earlier than planned on February 25, 1995 because of problems with one of the Z-drives, Figure 6. Ken Brink was the chief scientist and Bill Martin was the ship's technician responsible for monitoring the ADCP system. The Ashtech GPS attitude unit was installed for the first time on the THOMPSON for this cruise although it took considerable effort on Bill Martin's and Frank Bahr's parts to accomplish this. There was a delay in getting the Ashtech on-line so that the ADCP data with enhanced directional data started February 12, 1995. Bill Martin and Frank Bahr also modified the UE4 configuration file so that the Ashtech data would be properly processed and recorded. In addition, Frank Bahr changed the heading offset in the configuration files to correspond to the offset we had determined earlier from bottom track and water track calibration runs.

4.3 TN045

The start of this cruise was delayed because of the problem with the THOMPSON's propulsion system. At the end of TN044 the THOMPSON transited to a shipyard in Abu Dubai passing through the Straits of Hormus. We managed to get the ADCP turned on for at least part of this repair cruise and that data is included with the TN045 data set. Cruise TN045 itself, the second of the JGOFS process cruises, departed Muscat on March 14, 1995, proceeded clockwise around the JGOFS standard cruise track and returned to Muscat on April 10, 1995, Figure 7. John Marra was the chief scientist for this inter-monsoonal cruise while Mike Grogan was the ship's technician responsible for monitoring the ADCP system. The Ashtech unit died after the first day on this cruise and so we reverted to the earlier method for dealing with the heading data.

Figure 5: Cruise map of the northeast monsoon JGOFS process cruise, TN043. The RV T.G. Thompson left Muscat on January 8, 1995 and returned on February 4, 1995. Numbers along the track represent sections and stations for vector and contour plottings which are shown in Appendix C. The corresponding positions and the start and end of times are tabulated in Appendix A.

Figure 6: Cruise map of the second ONR/NRL SeaSoar cruise, TN044. The RV T.G. Thompson left Muscat on February 8, 1995 and returned on February 25, 1995. Below is the same as Figure 5.

Figure 7: Cruise map of the second ONR/NRL SeaSoar cruise, TN045. Included in this cruise is the deviation to Abu Dubai for repairs between February 28 and April 13, 1995. The RV T.G. Thompson left Muscat for the process cruise itself on March 14 and returned on April 10, 1995. Below is the same as Figure 5.

4.4 TN046

The purpose of cruise TN046 was to recover and redeploy the current meter and surface meteorological array centered at 15° 30'N, 61° 31'E, Figure 8. On the return leg from the mooring site the ship ran northwest toward the coast and then alongshore to the northeast. The THOMPSON left Muscat on April 14 and returned on April 29, 1995 with Bob Weller as chief scientist and Bill Martin as the ship's technician responsible for monitoring the ADCP. The ADCP worked well throughout middle of the cruise using the P-code GPS receiver but without the Ashtech.

Figure 8: Cruise map of the second ONR/NRL SeaSoar cruise, TN046. The RV T.G. Thompson left Muscat on April 14 and returned on April 29, 1995. Below is the same as Figure 5.

5. Profile Quality

In processing the ADCP data, a set of diagnostic products are routinely produced. Typically, the cruise is broken into sections along the track or subsections of special interest. The diagnostic products include separate underway and on station profiles of averages and standard deviations of horizontal velocity shear (first differences), vertical velocity, error velocity, backscatter intensity, and percent good, based upon the ensemble data. In general, analysis of these results show the same acceptable behavior for all the cruises examined so far. Cruise TN044 where both the P-code GPS receiver and Ashtech attitude sensor are available is of special interest because that data set should be of the highest quality possible with current technology. The quality parameters for that cruise, however, do not indicate significant differences, at least in terms of vertical shears and the suite of diagnostic variables, relative to the other cruises.

Illustrating the results of the data quality analyses are plots from TN044 during the period when the THOMPSON took hydrographic stations and steamed along the main JGOFS transect. Along this transect 833 ensembles were extracted while the ship was on-station ($< 1.5 \text{ m s}^{-1}$) and 401 ensembles while the ship was underway ($> 5.0 \text{ m s}^{-1}$). The weather was calm during the cruise so the results reflect the data processing, geometry of the ADCP's transducers and flow regime generated by the ship itself. (The effect of the heavy weather during the monsoon periods will be assessed from later cruises.) This section is characterized by vigorous currents, up to 0.4 m s^{-1} , whose direction varies from southwest to northeast. Both velocity components usually have a shear zone between 100 and 200 m depth although in some places coherent structures extend to 400 m. As on all the other cruises, this transect is characterized by large diel plankton migrations which reduced the ADCP's range from almost 400 meters during the day to 200 to 250 meters during the night.

The first difference vertical shear diagnostics of Figures 9a,b are intended to illustrate those portions of the profile affected by misalignments of the tracking filters possible near the surface, in regions of high shear and in regions of low return signal. However there is relatively small vertical shear in the horizontal velocity components, distributed between 100 and 300 m, it does not seem to cause any filter tracking problems. Despite fluctuations in the ADCP's range due to the diel scatterer migration it does not appear to be any tracking filter induced; notwithstanding noise bias is evident in the deeper bins. Near the surface there is significant shear in the upper couple of bins which is particularly noticeable in the zonal underway data. It would appear that at least some of this is due to flow distortions caused by the ship itself while underway. Other than near the surface, there is very little difference between the mean profiles generated when the ship was underway and those when the ship stopped. The shear standard deviation profiles for both components indicate increase in variability below 200 to 300 m, which coincides with the maximum ranges of night profiles. The percent good criteria used in accepting velocity results ($\geq 30 \%$) eliminates those portions of the profiles which at the extreme range generate this high shear standard deviations. Overall, looking at data from this section and others, it seems that the choice of blanking interval of

Figure 9: Diagnostic profiles of ensemble averaged a) zonal vertical shear, b) meridional vertical shear, c) vertical velocity, d) error velocity, e) backscatter intensity, f) percent good for underway and on-station ADCP data taken along the main JGOFS transect on cruise TN044 (see Figure 6).

95-10-24 15:44

c) W component, ADCP TN044
(Solid: On Station; Dash: Underway)

d) ERROR VELOCITY, ADCP TN044
(Solid: On Station; Dash: Underway)

95-10-24 14:11

e) AMPLITUDE, ADCP TN044
(Solid: On Station; Dash: Underway)

SPECTRAL WIDTH, ADCP TN044
(Solid: On Station; Dash: Underway)

f) PERCENT GOOD, ADCP TN044
(Solid: On Station; Dash: Underway)

95-10-24 14:11

4 meters and filter tracking direct command, B009001, are adequate for the THOMPSON's ADCP.

The vertical, W , and error, E , velocities are expected to be fairly small, and significant deviations would indicate misalignment of the transducers either relative to the vertical or between themselves. The profiles of average underway and on station vertical velocities, Figure 9c, show that below about 75 m they are relatively small, but that there is an increase of about -1.2 cm s^{-1} when the ship was underway. (Due to an error in plotting similar velocity plots in the first Arabian Sea ADCP data report, the vertical velocities are plotted relative to the mean between bins 5 and 20.) An 1 cm s^{-1} average vertical velocity could be caused by a 0.1° angular offset from the vertical which indicates that the THOMPSON runs on a remarkably even keel. The vertical velocity while the ship was underway is large negative in the upper 50 meters, and decreases nearly exponentially with depth. When the ship was on-station the vertical velocity is generally small and negative near the surface. This behavior of the vertical velocity is a common aspect of ship-mounted ADCPs. Although the cause has not been definitely determined, probably it is a result of the flow field about the ship's hull. The standard deviation of the vertical velocity shows significant depth dependence and differences between on station and underway time periods. The reason is unclear although it may reflect day-night differences in the periods covered by the underway and on station data subsets in the presence of diel migration.

The profiles of the error velocity and its standard deviation, Figure 9d, are small and generally constant with depth. The error velocity is the difference between vertical velocity estimates from orthogonal pairs of beams. On the THOMPSON the ADCP is oriented so that the axes defined by the beam pairs are aligned about 45° from the fore and aft ship axis. When the ship is on station the error velocity is nearly zero while it is about 1 cm s^{-1} when the ship is underway.

The average backscatter intensity (aka amplitude) profiles, in terms of digital counts, for both underway and on-station conditions, Figure 9e, shows the usual large decrease with depth. These averaged profiles are not filtered using a percent good criterion and include all ensembles selected for this section. Without range correction, the backscatter intensity profiles accentuate the upper water column. The standard deviation profiles indicate maximum variability between 100 and 300 m reflecting the planktonic diel migration under which a large proportion of the plankton rises from their daytime depths around 300 meters to the upper 100 meters during the night.

The percent good profiles, Figure 9f, indicates that highly reliable data covered the upper two hundred meters, but below that, the range was subject to the effects of diel migration. During the night the effective range of the ADCP in the northern Arabian Sea during these cruises was generally not more than 250 meters. We experimented with doubling the pulse lengths to 32 meters during cruise TN039 to see if we could increase the range during the night without achieving any measurable effect.

6. Acknowledgments

We would like to express our appreciation for the assistance of George White, Mike Realander, Bill Martin, Mike Grogran and the THOMPSON's crew in the initial set up the ADCP system and in the continuing data collection. We also got significant help from Eric Firing and Frank Bahr at early stages in the program, especially Frank Bahr who has checked on the AutoADCP system and helped the Ashtech receiver available during his cruises. Eric Firing and Julie Renada were also very helpful during the installation of the CODAS processing system on our Unix computer.

References

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Table 1. Cruise schedule for the U.S. JGOFS Arabian Sea Project. The bold-faced entries are the cruises covered by this data report.

Cruise ID	Start Date	End Date	Chief Sci.	Purpose
TN039	09/20/94	10/07/94	L. Codispoti	Calibration & Training
TN040	10/11/94	10/25/94	C. Erikson	Mooring Deployment
TN041	10/28/94	11/21/94	S. Honjo	Sediment Traps & Coring
TN042	11/28/94	12/17/94	D. Young	SeaSoar Survey #1
TN043	01/08/95	02/04/95	M. Roman	Process Cruise #1
TN044	02/08/95	02/25/95	K. Brink	SeaSoar Survey #2
TN045	03/14/95	04/10/95	J. Marra	Process Cruise #2
TN046	04/14/95	04/29/95	R. Weller	Mooring Turn-Around
TN047	05/03/95	05/21/95	J. Dymond	Process Cruise #3
TN048	06/21/95	07/13/95	K. Brink	SeaSoar Survey #3
TN049	07/17/95	08/15/95	R. Barber	Process Cruise #4
TN050	08/17/95	09/15/95	S. Smith	Process Cruise #5
TN051	09/18/95	10/11/95	R. Arnone	SeaSoar Survey #4
TN052	10/14/95	10/25/95	D. Rudnick	Mooring Retrieval
TN053	10/28/95	11/26/95	B. Balch	Process Cruise #6
TN054	11/29/95	12/27/95	W. Gardner	Process Cruise #7
TN055	12/31/95	01/19/96	W. Prell	Sed. Trap Retrieval

Table 2. The listing of the Arabian Sea regional ADCP configuration used for the deep water portion of the U.S. JGOFS Arabian Sea project cruises after the heading offset had been revised to reflect the bottom track calibrations on TN044.

AD,SI,HUNDREDTHS	300.00 Sampling interval
AD,NB,WHOLE	50 Number of Depth Bins
AD,BL,WHOLE	3 Bin Length
AD,PL,WHOLE	16 Pulse Length
AD,BK,TENTHS	4.0 Blank Beyond Transmit
AD,PE,WHOLE	1 Pings Per Ensemble
AD,PC,HUNDREDTHS	1.00 Pulse Cycle Time
AD,PG,WHOLE	25 Percent Pings Good Threshold
XX,OD2,WHOLE	5 [SYSTEM DEFAULT, OD2]
XX,TE,HUNDREDTHS	0.00 [SYSTEM DEFAULT, TE]
AD,US,BOOLE	YES Use Direct Commands on StartUp
DP,TR,BOOLE	NO Toggle roll compensation
DP,TP,BOOLE	NO Toggle Pitch compensation
DP,TH,BOOLE	YES Toggle Heading compensation
DP,VS,BOOLE	YES Calculate Sound Velocity from TEMP/Salinity
DP,UR,BOOLE	YES Use Reference Layer
DP,FR,WHOLE	5 First Bin for reference Layer
DP,LR,WHOLE	20 Last Bin for reference Layer
DP,BT,BOOLE	NO Use Bottom Track
DP,B3,BOOLE	NO Use 3 Beam Solutions
DP,EV,BOOLE	YES Use Error Velocity as Percent Good Criterion
DP,ME,TENTHS	250.0 Max. Error Velocity for Valid Data (cm/sec)
DR,RD,BOOLE	YES Recording on disk
DR,RX,BOOLE	YES Record N/S (FORE/AFT) Vel.
DR,RY,BOOLE	YES Record E/W (FORT/STBD) Vel.
DR,RZ,BOOLE	YES Record vertical vel.
DR,RE,BOOLE	YES Record error Good
DR,RB,BOOLE	NO Bytes of user prog. buffer
DR,RP,BOOLE	YES Record Percent good
DR,RA,BOOLE	YES Record average AGC/Bin
DR,RN,BOOLE	YES Record Ancillary data
DR,AP,BOOLE	YES Auto-ping on start-up
XX,LDR,TRI	3 [SYSTEM DEFAULT, LDR]
XX,RB2,WHOLE	192 [SYSTEM DEFAULT, RB2]
DR,RC,BOOLE	NO Record CTD data
XX,FB,WHOLE	1 [SYSTEM DEFAULT, FB]
XX,PU,BOOLE	NO [SYSTEM DEFAULT, PU]
GC,TG,TRI	1 DISPLAY (NO/GRAPH/TAB)
GC,ZV,WHOLE	4 ZERO VELOCITY REFERENCE (S/B/M/L)
GC,VL,WHOLE	-200 LOWEST VELOCITY ON GRAPH
CG,VH,WHOLE	200 HIGHEST VELOCITY ON GRAPH
GC,DL,WHOLE	0 LOWEST DEPTHS ON GRAPH

GC,DH,WHOLE	200 HIGHEST DEPTHS ON GRAPH
GC,SW,BOOLE	YES SET DEPTHS WINDOW TO INCLUDE ALL
BINS	
GC,MP,WHOLE	25 MINIMUM PERCENT GOOD TO PLOT
SG,PNS,BOOLE	YES PLOT NORTH/SOUTH VEL.
SG,PEW,BOOLE	YES PLOT EAST/WEST VEL.
SG,PVT,BOOLE	NO PLOT VERTICAL VEL.
SG,PEV,BOOLE	NO PLOT ERROR VEL.
SG,PPE,BOOLE	NO PLOT PERCENT ERROR
SG,PMD,BOOLE	NO PLOT MAG AND DIR
SG,PSW,BOOLE	NO PLOT AVERAGE SP. W.
SG,PAV,BOOLE	YES PLOT AVERAGE AGC.
SG,PPG,BOOLE	YES PLOT PERCENT GOOD
SG,PD1,BOOLE	NO PLOT DOPPLER 1
SG,PD2,BOOLE	NO PLOT DOPPLER 2
SG,PD3,BOOLE	NO PLOT DOPPLER 3
SG,PD4,BOOLE	NO PLOT DOPPLER 4
SG,PW1,BOOLE	NO PLOT SP. W. 1
SG,PW2,BOOLE	NO PLOT SP. W. 2
SG,PW3,BOOLE	NO PLOT SP. W. 3
SG,PW4,BOOLE	NO PLOT SP. W. 4
SG,PA1,BOOLE	NO PLOT AGC 1
SG,PA2,BOOLE	NO PLOT AGC 2
SG,PA3,BOOLE	NO PLOT AGC 3
SG,PA4,BOOLE	NO PLOT AGC 4
SG,PP3,BOOLE	NO PLOT 3-BEAM SOLUTION
SS,OD,WHOLE	0 OffSet for Depth
SS,OH,TENTHS	43.5 OffSet for Heading
SS,OP,TENTHS	0.0 OffSet for Pitch
SS,ZR,TENTHS	0.0 OffSet for Roll
SS,OT,HUNDREDTHS	45.00 OffSet FOR temp
SS,ST,HUNDREDTHS	50.00 Scale for Temp
SS,SL,HUNDREDTHS	36.00 Salinity (PPT)
SS,UD,BOOLE	YES Toggle UP/DOWN
SS,CV,BOOLE	NO Toggle concave/Convex transducerhead
SS,MA,TENTHS	30.0 Mounting angle for transducers.
SS,SS,HUNDREDTHS	1500.00 Speed of Sound (m/sec)
XX,GP,BOOLE	YES [SYSTEM DEFAULT, GP]
XX,DD,TENTHS	1.0 [SYSTEM DEFAULT, DD]
XX,PT,BOOLE	NO [SYSTEM DEFAULT, PT]
XX,TU,TRI	2 [SYSTEM DEFAULT, TU]
TB,FP,WHOLE	1 FIRST BINS TO PRINT
TB,LP,WHOLE	64 LAST BIN TO PRINT
TB,SK,WHOLE	6 SKIP INTERVAL BETWEEN BINS
TB,DT,BOOLE	YES DIAGNOSTIC TAB MODE
DU,TD,BOOLE	NO TOGGLE USE OF DUMMY DATA

XX,PN,WHOLE	0 [SYSTEM DEFAULT, PN]
DR,SD,WHOLE	4 Second recording drive
DR,PD,WHOLE	3 First recording drive (1=A:,2=B: ...)
DP,PX,BOOLE	NO Profiler does XYZE transform
SS,LC,TENTHS	5.0 Limit of Knots change
SS,NW,TENTHS	0.5 Weight of new knots of value
GC,GM,TRI	2 GRAPHICS CONTROL 0=LO RES, 1=HI RES,
2=ENHANCED	
AD,PS,BOOLE	NO YES=SERIAL/NO=PARALLEL Profiler Link
XX,LNN,BOOLE	YES [SYSTEM DEFAULT, LNN]
XX,BM,BOOLE	YES [SYSTEM DEFAULT, BM]
XX,RSD,BOOLE	NO RECORD STANDARD DEVIATION OF
VELOCITIES PER BIN	
XX,DRV,WHOLE	0 [SYSTEM DEFAULT, DRV]
XX,PBD,WHOLE	3 [SYSTEM DEFAULT, PBD]
TB,RS,BOOLE	NO SHOW RHPT STATISTIC
UX,EE,BOOLE	YES ENABLE EXIT TO EXTERNAL PROGRAM
SS,VSC,TRI	0 Velocity scale adjustment
AD,DM,BOOLE	NO USE DMA
TB,SC,BOOLE	NO SHOW CTD DATA
AD,CW,BOOLE	YES Collect spectral width
DR,RW,BOOLE	YES Record average SP.W./Bin
DR,RRD,BOOLE	NO Record last raw dopplers
DR,RRR,BOOLE	YES Record last raw AGC
DR,RRW,BOOLE	NO Record last SP.W.
DR,R3,BOOLE	NO Record average 3-Beam solutions
DR,RBS,BOOLE	YES Record beam statistic
XX,STD,BOOLE	NO [SYSTEM DEFAULT, STD]
LR,HB,HUNDREDTHS	0.00 Heading Bias
SL,1,ARRAY5	0 1 8 NONE 19200 PROFILER
SL,2,ARRAY5	0 1 8 NONE 1200 LORAN RECEIVER
SL,3,ARRAY5	0 1 8 NONE 1200 REMOTE DISPLAY
SL,4,ARRAY5	0 1 8 NONE 1200 ENSEMBLE OUTPUT
SL,5,ARRAY5	0 1 8 NONE 1200 AUX 1
SL,6,ARRAY5	0 1 8 NONE 1200 AUX 2
DU,1,ARRAY6	100.00 100.00 60.00 0.00 0.00 YES D1
DU,2,ARRAY6	-100.00 -100.00 60.00 0.00 0.00 YES D2
DU,3,ARRAY6	200.00 200.00 60.00 0.00 0.00 YES D3
DU,4,ARRAY6	-200.00 -200.00 60.00 0.00 0.00 YES D4
DU,5,ARRAY6	200.00 19.00 60.00 0.00 0.00 YES AGC
DU,6,ARRAY6	0.00 0.00 60.00 0.00 0.00 NO SP. W.
DU,7,ARRAY6	0.00 0.00 60.00 0.00 0.00 NO ROLL
DU,8,ARRAY6	0.00 0.00 60.00 0.00 0.00 NO PITCH
DU,9,ARRAY6	0.00 0.00 60.00 0.00 0.00 NO HEADING
DU,10,ARRAY6	0.00 0.00 60.00 0.00 0.00 NO
TEMPERATURE	

DC,1,SPECIAL "FH00001" MACRO 1
DC,2,SPECIAL "CF64" MACRO 2
DC,3,SPECIAL "E0004020099" MACRO 3
DC,4,SPECIAL "B009001" MACRO 4
CI,1,SPECIAL "Arabian Sea" CRUISE ID GOES HERE
LR,1,SPECIAL " " LORAN FILE NAME GOES HERE

Appendix A. List of Sections

Each cruise is divided into sections and stations to form either nearly linear transects or coverage over some localized area. In the following, we list the start date, stop date, and the beginning and end positions of each of the sections (the sections and stations are illustrated in each cruise track, Section 4). The current vectors plots, zonal and meridonal velocity contour plots, and backscatter intensity contour plots shown in the following sections are all based upon the listed section segments.

Section List for TN043

Sect #	Start Date	Time	Year- Day	Lat °N	Long °E	End Date	Time	Year- Day	Lat °N	Long °E
1	95/01/08	04:31:34	7.189	23.648	58.625	95/01/08	14:22:21	7.599	22.422	59.985
2	95/01/08	14:22:21	7.599	22.403	59.984	95/01/09	04:47:05	8.199	22.484	61.184
3	95/01/09	04:47:05	8.199	22.484	61.183	95/01/11	21:21:36	10.890	19.167	67.166
4	95/01/11	21:21:36	10.890	19.166	67.166	95/01/13	15:07:12	12.630	19.170	67.165
5	95/01/13	15:07:12	12.630	19.167	67.166	95/01/15	11:57:04	14.498	15.491	68.764
6	95/01/15	11:57:04	14.490	15.493	68.764	95/01/16	05:57:04	15.248	14.907	66.873
7	95/01/16	05:57:04	15.240	14.904	66.873	95/01/17	07:55:12	16.330	10.005	64.904
8	95/01/17	07:55:12	16.330	10.005	64.904	95/01/18	21:07:12	17.880	10.001	64.898
9	95/01/18	21:07:12	17.880	10.001	64.898	95/01/20	10:48:00	19.450	14.444	65.000
10	95/01/20	10:48:00	19.450	14.449	65.000	95/01/22	00:57:36	21.040	14.541	64.970
11	95/01/22	00:57:36	21.040	14.541	64.970	95/01/23	12:14:24	22.510	15.990	62.043
12	95/01/23	12:14:24	22.510	15.990	62.043	95/01/25	12:14:24	24.510	15.997	61.987
13	95/01/25	12:14:24	24.510	15.997	61.987	95/01/25	18:25:14	24.768	15.563	61.497
14	95/01/25	18:25:14	24.760	15.563	61.497	95/01/26	04:45:16	25.198	16.416	61.232
15	95/01/26	04:45:16	25.190	16.416	61.232	95/01/26	18:57:36	25.790	17.200	59.767
16	95/01/26	18:57:36	25.790	17.200	59.767	95/01/28	09:07:12	27.380	17.202	59.767
17	95/01/28	09:07:12	27.380	17.202	59.767	95/01/28	14:24:00	27.600	17.675	58.868
18	95/01/28	14:24:00	27.600	17.675	58.868	95/01/29	10:19:12	28.430	17.791	58.980
19	95/01/29	10:19:12	28.430	17.791	58.980	95/01/29	15:36:00	28.650	18.097	58.035
20	95/01/29	15:36:00	28.650	18.097	58.035	95/01/31	09:21:36	30.390	18.079	57.996
21	95/01/31	09:21:36	30.390	18.079	57.996	95/01/31	23:59:57	31.000	18.453	57.299
22	95/01/31	23:59:57	31.000	18.453	57.299	95/02/01	14:20:43	31.598	18.999	59.005
23	95/02/01	14:20:43	31.590	18.999	59.005	95/02/03	04:47:34	33.200	22.233	60.126
24	95/02/03	04:47:34	33.200	22.233	60.126	95/02/04	17:50:00	34.743	23.231	59.146

Section List for TN044

Sect #	Start Date	Time	Year- Day	Lat °N	Long °E	End Date	Time	Year- Day	Lat °N	Long °E
1	95/02/08	04:40:31	38.195	23.650	58.615	95/02/10	12:59:40	40.541	18.132	58.011
1a	95/02/08	04:40:31	38.195	23.650	58.615	95/02/09	01:19:12	39.055	22.456	60.209
1b	95/02/09	01:23:31	39.058	22.444	60.287	95/02/09	22:09:07	39.923	19.601	59.562
1c	95/02/09	22:13:26	39.926	19.593	59.554	95/02/10	12:59:40	40.541	18.132	58.011
2	95/02/10	22:24:41	40.934	17.474	59.254	95/02/13	10:47:46	43.449	16.942	60.423
3	95/02/14	00:00:11	44.000	16.289	61.586	95/02/15	01:10:11	45.049	16.036	62.005
4	95/02/15	01:15:11	45.052	16.036	62.005	95/02/15	23:58:22	45.999	14.451	65.001
5	95/02/16	12:03:22	46.502	14.905	64.102	95/02/18	23:58:01	48.999	15.472	63.091
6	95/02/19	00:03:02	49.002	15.463	63.086	95/02/21	04:01:47	51.168	18.480	57.301
7	95/02/21	04:06:54	51.171	18.463	57.305	95/02/25	17:29:59	55.729	19.189	58.284
Outbound SW Transects										
Outbound SW Transect_a										
	95/02/10	13:04:39	40.545	18.124	58.024	95/02/10	22:24:41	40.934	17.474	59.254
	95/02/11	16:24:38	41.684	17.368	59.461	95/02/11	17:54:39	41.746	17.259	59.659
	95/02/12	14:49:40	42.618	17.158	59.877	95/02/12	16:14:39	42.677	17.041	60.077
	95/02/13	09:42:47	43.405	16.992	60.323	95/02/14	01:50:11	44.077	16.160	61.826
Outbound SW Transect_b										
	95/02/15	01:40:11	45.070	16.039	62.008	95/02/16	00:58:21	46.040	14.453	65.001
Inbound SW Transects										
Inbound SW Transect_a										
	95/02/16	01:08:32	46.047	14.453	65.001	95/02/16	11:58:21	46.499	14.895	64.101
	95/02/17	06:18:22	47.263	15.010	63.891	95/02/17	08:08:21	47.339	15.117	63.693
	95/02/18	03:08:22	48.131	15.228	63.489	95/02/18	04:53:03	48.204	15.338	63.283
Inbound SW Transect_b										
	95/02/19	00:13:01	49.009	15.445	63.074	95/02/21	03:46:54	51.158	18.510	57.294

Section List for TN045

Sect #	Start Date	Start Time	Year- Day	Lat °N	Long °E	End Date	End Time	Year- Day	Lat °N	Long °E
1	95/02/28	02:44:08	58.134	23.686	58.626	95/03/15	00:05:03	73.004	22.348	59.954
2	95/03/15	00:10:02	73.007	22.350	59.974	95/03/15	06:15:02	73.260	22.487	61.181
3	95/03/15	06:20:02	73.264	22.484	61.184	95/03/18	07:10:02	76.299	19.167	67.166
4	95/03/18	07:15:03	76.302	19.167	67.166	95/03/19	19:10:02	77.799	19.158	67.137
5	95/03/19	19:15:03	77.802	19.158	67.137	95/03/21	11:55:02	79.497	15.380	68.738
6	95/03/21	12:00:02	79.500	15.381	68.737	95/03/22	04:45:02	80.198	14.906	66.870
7	95/03/22	04:50:02	80.201	14.889	66.864	95/03/23	05:00:02	81.208	10.109	64.927
8	95/03/23	05:05:03	81.211	10.106	64.926	95/03/26	09:35:03	84.399	14.460	64.988
9	95/03/26	09:40:02	84.403	14.461	64.986	95/03/28	05:55:01	86.247	14.455	64.933
10	95/03/28	06:00:02	86.250	14.456	64.930	95/03/30	06:00:02	88.250	16.001	61.985
11	95/03/30	05:00:03	88.208	16.000	61.992	95/04/07	12:35:21	96.525	18.245	57.691
12	95/04/02	06:03:14	91.252	17.201	59.763	95/04/04	16:46:21	93.699	17.244	59.682
13	95/04/05	19:16:22	94.803	18.085	58.038	95/04/07	12:35:21	96.525	18.245	57.691
14	95/04/07	16:50:28	96.702	18.445	57.309	95/04/10	04:17:02	99.178	23.656	58.582

Section List for TN046

Sect #	Start Date	Time	Year- Day	Lat °N	Long °E	End Date	Time	Year- Day	Lat °N	Long °E
1	95/04/14	03:59:38	103.166	23.643	58.626	95/04/16	02:26:05	105.101	15.725	61.278
1a	95/04/14	03:59:38	103.166	23.643	58.626	95/04/14	17:45:36	103.740	22.394	60.286
1b	95/04/14	17:59:38	103.750	22.338	60.295	95/04/16	00:11:04	105.008	16.067	61.218
2	95/04/16	02:31:05	105.105	15.725	61.279	95/04/26	15:35:49	115.650	15.656	61.129
3	95/04/26	15:40:48	115.653	15.670	61.118	95/04/27	14:20:49	116.598	18.850	58.580
4	95/04/27	14:25:49	116.601	18.862	58.580	95/04/29	02:10:48	118.091	23.665	58.685

Appendix B. Reference Layer Velocities

This section shows the zonal and meridional reference layer velocities together with the cruise tracks in terms of latitude/longitude time plots for each cruise

95-2-24 14:2

95- 4-28 13: 5

95-9-6 11:49

95-9-6 10:44

Appendix C. Vector Plots and Contoured Sections

Vector plots along sections of the cruises, as indicated in Appendix A, are shown as well as contoured zonal and meridional velocities. The vector plots include currents averaged in layers 20-50m, 50-100m, 100-200m, 200-300m, and 300-400m where the data is available.

TN043

JGOFS Arabian Sea

TN043 Whole Cruise (01/08/95 to 02/04/95)

Current Velocity 20m to 50m

BNL

JGOFS Arabian Sea

TN043 Whole Cruise (01/08/95 to 02/04/95)

Layer: 50m to 100m

BNL

JGOFS Arabian Sea

TN043 Whole Cruise (01/08/95 to 02/04/95)

Layer: 100m to 200m

BNL

JGOFS Arabian Sea

TN043 Whole Cruise (01/08/95 to 02/04/95)

Layer: 200m to 300m

BNL

JGOFS Arabian Sea

TN043 Section 2 to 5 (01/08/95 to 01/15/95)

Current Velocity 20m to 50m

JGOFS Arabian Sea

TN043 Section 2 to 5 (01/08/95 to 01/15/95)

Layer: 50m to 100m

BNL

Tue Jul 25 14:19:09 1995

JGOFS Arabian Sea

TN043 Section 2 to 5 (01/08/95 to 01/15/95)

Layer: 100m to 200m

JGOFS Arabian Sea

TN043 Section 2 to 5 (01/08/95 to 01/15/95)

Layer: 200m to 300m

BNL

Tue Jul 25 14:19:21 1995

JGOFS Arabian Sea

TN043 Section 6 to 7 (01/15/95 to 01/17/95)

Current Velocity 20m to 50m

BNL

Wed Aug 2 19:25:12 1995

JGOFS Arabian Sea

TN043 Section 6 to 7 (01/15/95 to 01/17/95)

Layer: 50m to 100m

BNL

Wed Aug 2 19:25:17 1995

JGOFS Arabian Sea

TN043 Section 6 to 7 (01/15/95 to 01/17/95)

Layer: 100m to 200m

BNL

Wed Aug 2 19:25:22 1995

JGOFS Arabian Sea

TN043 Section 6 to 7 (01/15/95 to 01/17/95)

Layer: 200m to 300m

BNL

Wed Aug 2 19:25:27 1995

JGOFS Arabian Sea

TN043 Section 11 to 21 (01/22/95 to 01/31/95)
Current Velocity 20m to 50m

BNL

Tue Jul 25 14:15:03 1995

JGOFS Arabian Sea

TN043 Section 11 to 21 (01/22/95 to 01/31/95)
Layer: 50m to 100m

BNL

Tue Jul 25 14:15:09 1995

JGOFS Arabian Sea

TN043 Section 11 to 21 (01/22/95 to 01/31/95)

Layer: 100m to 200m

BNL

70°E

65°E

60°E

55°E

Tue Jul 25 14:15:17 1995

JGOFS Arabian Sea

TN043 Section 11 to 21 (01/22/95 to 01/31/95)

Layer: 200m to 300m

BNL

Tue Jul 25 14:15:25 1995

JGOFS Arabian Sea

TN043 Section 22 to 24 (01/31/95 to 02/04/95)

Current Velocity 20m to 50m

JGOFS Arabian Sea

TN043 Section 22 to 24 (01/31/95 to 02/04/95)

Layer: 50m to 100m

BNL

Wed Jul 26 15:18:04 1995

JGOFS Arabian Sea

TN043 Section 22 to 24 (01/31/95 to 02/04/95)

Layer: 100m to 200m

BNL

JGOFS Arabian Sea

TN043 Section 22 to 24 (01/31/95 to 02/04/95)
Layer: 200m to 300m

BNL

ADCP velocity: zonal (U)

Arabian Sea Cruise
TN043 Section 1-2

23.648
58.625

22.484
61.184

BNL

Distance, km

9-AUG-95 10:42:31

Backscattered Intensity
Arabian Sea Cruise TN043
Section 1-2

ADCP velocity: zonal (U)
Arabian Sea Cruise
TN043 Section 3

22.484
61.183

19.167
67.166
BNL

ADCP velocity: meridional (V)

Arabian Sea Cruise
TN043 Section 3

Backscattered Intensity
Arabian Sea Cruise TN043
Section 3

22.484
61.183

19.167
67.166
BNL

11-AUG-95

ADCP velocity: zonal (U) Arabian Sea Cruise TN043 Section 5

ADCP velocity: meridional (V)

Arabian Sea Cruise
TN043 Section 5

Backscattered Intensity
Arabian Sea Cruise TN043
Section 5

19.167
67.166

15.491
68.764
BNL

ADCP velocity: zonal (U)
Arabian Sea Cruise
TN043 Section 6-7

15.493
68.764

10.005
64.904
BNL

ADCP velocity: meridional (V)

Arabian Sea Cruise
TN043 Section 6-7

15.493
68.764

10.005
64.904
BNL

Backscattered Intensity
Arabian Sea Cruise TN043
Section 6-7

ADCP velocity: zonal (U)

Arabian Sea Cruise
TN043 Section 9

9-AUG-95 11:13:22

ADCP velocity: meridional (V)

Arabian Sea Cruise
TN043 Section 9

Backscattered Intensity Arabian Sea Cruise TN043 Section 9

11-AUG-95 10:11:41

ADCP velocity: meridional (V)

Arabian Sea Cruise
TN043 Section 11

14.541
64.970

15.990
62.043
BNL

Distance, km

9-AUG-95 11:19:56

Backscattered Intensity

Arabian Sea Cruise TN043

Section 11

ADCP velocity: zonal (U)

Arabian Sea Cruise

TN043 Section 15-17-19-21

16.416

61.232

18.453

57.299

BNL

ADCP velocity: meridional (V)

Arabian Sea Cruise

TN043 Section 15-17-19-21

16.416

61.232

18.453

57.299

BNL

Backscattered Intensity
Arabian Sea Cruise TN043
Section 15-17-19-21

16.416
61.232

18.453
57.299
BNL

11-AUG-95 09:09:08

ADCP velocity: zonal (U)
Arabian Sea Cruise
TN043 Section 22-23-24

18.453
57.299

23.231
59.146
BNL

9-AUG-95 11:32:53

ADCP velocity: meridional (V)

Arabian Sea Cruise
TN043 Section 22-23-24

18.453
57.299

23.231
59.146
BNL

Backscattered Intensity
Arabian Sea Cruise TN043
Section 22-23-24

18.453
57.299

23.231
59.146
BNL

TN044

JGOFS Arabian Sea

TN044 Whole Cruise (02/08/95 to 02/25/95)
Current Velocity 20m to 50m

JGOFS Arabian Sea

TN044 Whole Cruise (02/08/95 to 02/25/95)

Layer: 50m to 100m

BNL

Tue Jul 25 20:14:49 1995

JGOFS Arabian Sea

TN044 Whole Cruise (02/08/95 to 02/25/95)

Layer: 100m to 200m

BNL

JGOFS Arabian Sea

TN044 Whole Cruise (02/08/95 to 02/25/95)

Layer: 200m to 300m

BNL

Tue Jul 25 20:15:02 1995

JGOFS Arabian Sea

TN044 Section 1 (02/08/95 to 02/10/95)

Current Velocity 20m to 50m

BNL

Tue Jul 25 20:02:43 1995

JGOFS Arabian Sea

TN044 Section 1 (02/08/95 to 02/10/95)

Layer: 50m to 100m

Tue Jul 25 20:02:49 1995

JGOFS Arabian Sea

TN044 Section 1 (02/08/95 to 02/10/95)

Layer: 100m to 200m

BNL

Tue Jul 25 20:02:54 1995

JGOFS Arabian Sea

TN044 Section 1 (02/08/95 to 02/10/95)

Layer: 200m to 300m

Tue Jul 25 20:02:59 1995

JGOFS Arabian Sea

TN044 Outbound Transect (02/10/95 to 02/16/95)

Current Velocity 20m to 50m

BNL

Tue Jul 25 19:59:49 1995

JGOFS Arabian Sea

TN044 Outbound Transect (02/10/95 to 02/16/95)

Layer: 50m to 100m

BNL

Tue Jul 25 19:59:54 1995

JGOFS Arabian Sea

TN044 Outbound Transect (02/10/95 to 02/16/95)

Layer: 100m to 200m

BNL

Tue Jul 25 20:00:00 1995

JGOFS Arabian Sea

TN044 Outbound Transect (02/10/95 to 02/16/95)

Layer: 200m to 300m

BNL

Tue Jul 25 20:00:05 1995

JGOFS Arabian Sea

TN044 Section 2
Current Velocity 20m to 50m

BNL

JGOFS Arabian Sea

TN044 Section 2
Layer: 50m to 100m

BNL

Mon May 8 16:53:02 1995

JGOFS Arabian Sea

TN044 Section 2
Layer: 100m to 200m

BNL

JGOFS Arabian Sea

TN044 Section 2
Layer: 200m to 300m

BNL

105

JGOFS Arabian Sea

TN044 Section 3
Current Velocity 20m to 50m

BNL

106

JGOFS Arabian Sea

TN044 Section 3
Layer: 50m to 100m

BNL

107

JGOFS Arabian Sea

TN044 Section 3
Layer: 100m to 200m

BNL

108

JGOFS Arabian Sea

TN044 Section 3
Layer: 200m to 300m

BNL

JGOFS Arabian Sea

TN044 Section 5
Current Velocity 20m to 50m

BNL

110

JGOFS Arabian Sea

TN044 Section 5

Layer: 50m to 100m

BNL

JGOFS Arabian Sea

TN044 Section 5
Layer: 100m to 200m

BNL

JGOFS Arabian Sea

TN044 Section 5
Layer: 200m to 300m

BNL

JGOFS Arabian Sea

TN044 Inbound Transect (02/16/95 to 02/21/95)
Current Velocity 20m to 50m

BNL

Tue Jul 25 19:55:41 1995

JGOFS Arabian Sea

TN044 Inbound Transect (02/16/95 to 02/21/95)

Layer: 50m to 100m

BNL

Tue Jul 25 19:55:46 1995

JGOFS Arabian Sea

TN044 Inbound Transect (02/16/95 to 02/21/95)

Layer: 100m to 200m

BNL

JGOFS Arabian Sea

TN044 Inbound Transect (02/16/95 to 02/21/95)

Layer: 200m to 300m

BNL

Tue Jul 25 19:55:57 1995

JGOFS Arabian Sea

TN044 Section 7 (02/21/95 to 02/25/95)

Current Velocity 20m to 50m

BNL

Tue Jul 25 19:51:47 1995

JGOFS Arabian Sea

TN044 Section 7 (02/21/95 to 02/25/95)

Layer: 50m to 100m

BNL

61°E
Tue Jul 25 19:51:52 1995

59°E

57°E

JGOFS Arabian Sea

TN044 Section 7 (02/21/95 to 02/25/95)

Layer: 100m to 200m

BNL

120

Tue Jul 25 19:51:57 1995

JGOFS Arabian Sea

TN044 Section 7 (02/21/95 to 02/25/95)

Layer: 200m to 300m

BNL

Tue Jul 25 19:52:02 1995

Backscattered Intensity

Arabian Sea Cruise TN044

Section 1a

23.650

58.615

22.456

60.209

BNL

ADCP velocity: zonal (U)

Arabian Sea Cruise
TN044 Section 1b-1c

9-AUG-95 12:56:39

ADCP velocity: meridional (V) Arabian Sea Cruise TN044 Section 1b-1c

Backscattered Intensity
Arabian Sea Cruise TN044
Section 1b-1c

ADCP velocity: zonal (U)
 Arabian Sea Cruise
 TN044 Outbound SW Transect_a

ADCP velocity: meridional (V)

Arabian Sea Cruise

TN044 Outbound SW Transect_a

18.124
58.024

16.160
61.826
BNL

Backscattered Intensity
Arabian Sea Cruise TN044
Outbound SW Transect_a

18.124
58.024

16.160
61.826
BNL

ADCP velocity: zonal (U)

Arabian Sea Cruise

TN044 Outbound SW Transect_b

16.039
62.008

14.453
65.001

9-AUG-95 13:44:18

Backscattered Intensity
Arabian Sea Cruise TN044
Outbound SW Transect_b

ADCP velocity: zonal (U)
Arabian Sea Cruise TN044
Section 4

ADCP velocity: meridional (V)
 Arabian Sea Cruise TN044
 Section 4

Backscattered Intensity
Arabian Sea Cruise TN044
Section 4

ADCP velocity: zonal (U)
 Arabian Sea Cruise TN044
 Section 6

15.463 63.086 18.480 57.301 BNL

9-AUG-95 14:11

ADCP velocity: meridional (V)
Arabian Sea Cruise TN044
Section 6

15.463
63.086

18.480
57.301
BNL

Backscattered Intensity
Arabian Sea Cruise TN044
Section 6

15.463
63.086

18.480
57.301
BNL

ADCP velocity: zonal (U)

Arabian Sea Cruise TN044

14.453 Inbound SW Transect_05.338

65.001

63.283

BNL

ADCP velocity: meridional (V)

Arabian Sea Cruise TN044

14.453 Inbound SW Transect_q5.338

65.001

63.283

ADCP velocity: zonal (U)
Arabian Sea Cruise TN044
Inbound SW Transect_b

15.445
63.074

18.510
57.294
BNL

ADCP velocity: meridional (V)

Arabian Sea Cruise TN044

Inbound SW Transect_b

15.445

63.074

18.510

57.294

BNL

144

Depth, m

9-AUG-95 14:C

Backscattered Intensity

Arabian Sea Cruise TN044

Inbound SW Transect_b

15.445

63.074

18.510

57.294

BNL

TN045

JGOFS Arabian Sea

TN045 Whole Cruise (02/28/95 to 04/10/95)

Current Velocity 20m to 50m

BNL

75°E
70°E
65°E
60°E
55°E
Wed Sep 6 13:14:47 1995

JGOFS Arabian Sea

TN045 Whole Cruise (02/28/95 to 04/10/95)

Layer: 50m to 100m

BNL

JGOFS Arabian Sea

TN045 Whole Cruise (02/28/95 to 04/10/95)

Layer: 100m to 200m

BNL

75°E

70°E

65°E

60°E

55°E

Wed Sep 6 13:15:01 1995

JGOFS Arabian Sea

TN045 Whole Cruise (02/28/95 to 04/10/95)

Layer: 200m to 300m

BNL

JGOFS Arabian Sea

TN045 Section 1 (02/28/95 to 03/15/95)

Current Velocity 20m to 50m

BNL

JGOFS Arabian Sea

TN045 Section 1 (02/28/95 to 03/15/95)

Layer: 50m to 100m

BNL

JGOFS Arabian Sea

TN045 Section 1 (02/28/95 to 03/15/95)

Layer: 100m to 200m

BNL

JGOFS Arabian Sea

TN045 Section 1 (02/28/95 to 03/15/95)

Layer: 200m to 300m

BNL

Wed Sep 6 13:28:08 1995

JGOFS Arabian Sea

TN045 Section 2,3,5 (03/15/95 to 03/21/95)
Current Velocity 20m to 50m

BNL

70°E
65°E
60°E
55°E
Wed Sep 6 13:32:54 1995

JGOFS Arabian Sea

TN045 Section 2,3,5 (03/15/95 to 03/21/95)

Layer: 50m to 100m

BNL

Wed Sep 6 13:32:59 1995

JGOFS Arabian Sea

TN045 Section 2,3,5 (03/15/95 to 03/21/95)

Layer: 100m to 200m

JGOFS Arabian Sea

TN045 Section 2,3,5 (03/15/95 to 03/21/95)

Layer: 200m to 300m

BNL

Wed Sep 6 13:33:10 1995

JGOFS Arabian Sea

TN045 Section 6-7 (03/21/95 to 03/24/95)

Current Velocity 20m to 50m

BNL

Wed Sep 6 13:36:30 1995

JGOFS Arabian Sea

TN045 Section 6-7 (03/21/95 to 03/24/95)

Layer: 50m to 100m

BNL

JGOFS Arabian Sea

TN045 Section 6-7 (03/21/95 to 03/24/95)

Layer: 100m to 200m

BNL

JGOFS Arabian Sea

TN045 Section 6-7 (03/21/95 to 03/24/95)

Layer: 200m to 300m

BNL

Wed Sep 6 13:36:45 1995

JGOFS Arabian Sea

TN045 Section 8 (03/24/95 to 03/26/95)

Current Velocity 20m to 50m

JGOFS Arabian Sea

TN045 Section 8 (03/24/95 to 03/26/95)

Layer: 50m to 100m

BNL

Wed Sep 6 13:39:02 1995

JGOFS Arabian Sea

TN045 Section 8 (03/24/95 to 03/26/95)

Layer: 100m to 200m

BNL

Wed Sep 6 13:39:06 1995

JGOFS Arabian Sea

TN045 Section 8 (03/24/95 to 03/26/95)

Layer: 200m to 300m

BNL

Wed Sep 6 13:39:11 1995

JGOFS Arabian Sea

TN045 Section 10-11 (03/28/95 to 04/07/95)

Current Velocity 20m to 50m

BNL

Wed Sep 6 13:43:55 1995

JGOFS Arabian Sea

TN045 Section 10-11 (03/28/95 to 04/07/95)

Layer: 50m to 100m

BNL

Wed Sep 6 13:44:02 1995

JGOFS Arabian Sea

TN045 Section 10-11 (03/28/95 to 04/07/95)

Layer: 100m to 200m

JGOFS Arabian Sea

TN045 Section 10-11 (03/28/95 to 04/07/95)

Layer: 200m to 300m

BNL

170

Wed Sep 6 13:44:13 1995

JGOFS Arabian Sea

TN045 Section 14 (04/07/95 to 04/10/95)

Current Velocity 20m to 50m

JGOFS Arabian Sea

TN045 Section 14 (04/07/95 to 04/10/95)

Layer: 50m to 100m

BNL

Wed Sep 6 13:48:01 1995

JGOFS Arabian Sea

TN045 Section 14 (04/07/95 to 04/10/95)

Layer: 100m to 200m

JGOFS Arabian Sea

TN045 Section 14 (04/07/95 to 04/10/95)

Layer: 200m to 300m

BNL

ADCP Velocity: zonal (U)

Arabian Sea Cruise TN045

22.350 Section 2 22.487

59.974

61.181

ADCP Velocity: meridional (V)

Arabian Sea Cruise TN045

22.350 Section 2 22.487

59.974 61.181

BNL

177

ADCP Velocity: zonal (U)
Arabian Sea Cruise TN045
Section 3

19.167
67.166
BNL

6-SEP-95

ADCP Velocity: meridional (V)
Arabian Sea Cruise TN045
Section 3

Backscatter Intensity
Arabian Sea Cruise TN045
Section 3

22.484
61.184

19.167
67.166
BNL

6-SEP-95

ADCP Velocity: zonal (U) Arabian Sea Cruise TN045 Section 5

ADCP Velocity: meridional (V)

Arabian Sea Cruise TN045

Section 5

Backscatter Intensity
Arabian Sea Cruise TN045
Section 5

ADCP Velocity: zonal (U)
Arabian Sea Cruise TN045
Section 6-7

10.109
64.927
BNL

6-SEP-95

ADCP Velocity: meridional (V)
Arabian Sea Cruise TN045
Section 6-7

15.381
68.737

10.109
64.927
BNL

Backscatter Intensity
Arabian Sea Cruise TN045
Section 6-7

ADCP Velocity: zonal (U)
Arabian Sea Cruise TN045
Section 8

10.106
64.926

14.460
64.988
BNL

ADCP Velocity: meridional (V)
Arabian Sea Cruise TN045
Section 8

Backscatter Intensity
Arabian Sea Cruise TN045
Section 8

10.106
64.926

14.460
64.988
BNL

ADCP Velocity: zonal (U)
Arabian Sea Cruise TN045
Section 10

14.456
64.930

16.001
61.985
BNL

6-SEP-95 17:32:46

ADCP Velocity: meridional (V)
Arabian Sea Cruise TN045
Section 10

14.456
64.930

16.001
61.985
BNL

Backscatter Intensity
Arabian Sea Cruise TN045
Section 10

ADCP Velocity: zonal (U)
Arabian Sea Cruise TN045
Section 11

ADCP Velocity: meridional (V)
Arabian Sea Cruise TN045
Section 11

Backscatter Intensity
Arabian Sea Cruise TN045
Section 11

16.000
61.992

18.245
57.691
BNL

195

25-OCT-95 11:57:26

ADCP Velocity: zonal (U)
Arabian Sea Cruise TN045
Section 14

18.445
57.309

23.656
58.582
BNL

961

Depth, m

6-SEP-95 19:36:09

ADCP Velocity: meridional (V)
Arabian Sea Cruise TN045
Section 14

18.445
57.309

23.656
58.582
BNL

Backscatter Intensity
Arabian Sea Cruise TN045
Section 14

18.445
57.309

23.656
58.582
BNL

TN046

JGOFS Arabian Sea

TN046 Whole Cruise (04/14/95 to 04/29/95)
Current Velocity 20m to 50m

BNL

Wed Sep 6 11:01:23 1995

JGOFS Arabian Sea

TN046 Whole Cruise (04/14/95 to 04/29/95)

Layer: 50m to 100m

BNL

0.0 25.0 50.0
Velocity (cm/s)

Wed Sep 6 11:01:28 1995

JGOFS Arabian Sea

TN046 Whole Cruise (04/14/95 to 04/29/95)

Layer: 100m to 200m

BNL

JGOFS Arabian Sea

TN046 Whole Cruise (04/14/95 to 04/29/95)

Layer: 200m to 300m

BNL

Wed Sep 6 11:01:40 1995

JGOFS Arabian Sea

TN046 Section 1 (04/14/95 to 04/16/95)

Current Velocity 20m to 50m

BNL

Wed Sep 6 11:07:06 1995

JGOFS Arabian Sea

TN046 Section 1 (04/14/95 to 04/16/95)

Layer: 50m to 100m

BNL

70°E
65°E
60°E
55°E
Wed Sep 6 11:07:11 1995

JGOFS Arabian Sea

TN046 Section 1 (04/14/95 to 04/16/95)

Layer: 100m to 200m

BNL

JGOFS Arabian Sea

TN046 Section 1 (04/14/95 to 04/16/95)

Layer: 200m to 300m

BNL

Wed Sep 6 11:07:22 1995

JGOFS Arabian Sea

TN046 Section 2 (04/16/95 to 04/26/95)

Current Velocity 20m to 50m

BNL

JGOFS Arabian Sea

TN046 Section 2 (04/16/95 to 04/26/95)

Layer: 50m to 100m

BNL

209

JGOFS Arabian Sea

TN046 Section 2 (04/16/95 to 04/26/95)

Layer: 100m to 200m

BNL

210

JGOFS Arabian Sea

TN046 Section 2 (04/16/95 to 04/26/95)
Layer: 200m to 300m

BNL

JGOFS Arabian Sea

TN046 Section 3 (04/26/95 to 04/27/95)

Current Velocity 20m to 50m

BNL

Wed Sep 6 11:13:21 1995

JGOFS Arabian Sea

TN046 Section 3 (04/26/95 to 04/27/95)

Layer: 50m to 100m

JGOFS Arabian Sea

TN046 Section 3 (04/26/95 to 04/27/95)

Layer: 100m to 200m

BNL

JGOFS Arabian Sea

TN046 Section 3 (04/26/95 to 04/27/95)

Layer: 200m to 300m

JGOFS Arabian Sea

TN046 Section 4 (04/27/95 to 04/29/95)

Current Velocity 20m to 50m

BNL

Wed Sep 6 11:17:30 1995

JGOFS Arabian Sea

TN046 Section 4 (04/27/95 to 04/29/95)

Layer: 50m to 100m

BNL

Wed Sep 6 11:17:37 1995

JGOFS Arabian Sea

TN046 Section 4 (04/27/95 to 04/29/95)

Layer: 100m to 200m

BNL

Wed Sep 6 11:17:43 1995

JGOFS Arabian Sea

TN046 Section 4 (04/27/95 to 04/29/95)

Layer: 200m to 300m

BNL

70°E
65°E
60°E
55°E
Wed Sep 6 11:17:48 1995

ADCP Velocity: zonal (U)

Arabian Sea Cruise TN046

Section 1a

23.643

58.626

22.394

60.286

BNL

ADCP Velocity: meridional (V)

Arabian Sea Cruise TN046

Section 1a

23.643
58.626

22.394
60.286

BNL

Distance, km

6-SEP-95 19:54:28

Backscatter Intensity
Arabian Sea Cruise TN046
Section 1a

23.643
58.626

22.394
60.286
BNL

6-SEP-95 20:03:20

ADCP Velocity: zonal (U) Arabian Sea Cruise TN046 Section 1b

ADCP Velocity: meridional (V)
Arabian Sea Cruise TN046
Section 1b

22.338
60.295

16.067
61.218
BNL

6-SEP-95 20:

Backscatter Intensity
Arabian Sea Cruise TN046
Section 1b

22.338
60.295

16.067
61.218
BNL

Arabian Sea Cruise TN046

Section 3

ADCP Velocity: meridional (V)

Arabian Sea Cruise TN046

Section 3

Backscatter Intensity
Arabian Sea Cruise TN046
Section 3

ADCP Velocity: zonal (U)

Arabian Sea Cruise TN046

Section 4

18.862
58.580

23.665
58.685
BNL

ADCP Velocity: meridional (V)

Arabian Sea Cruise TN046

Section 4

18.862
58.580

23.665
58.685
BNL

Backscatter Intensity
Arabian Sea Cruise TN046
Section 4

6-SEP-95 20:32:28