2. Underway measurements

2.1 Navigation and VM-ADCP John Allen, Hugh Venables and Robin Pascal

Since the FISHES cruise (D253) in May/June 2001, two RDI Vessel-Mounted Acoustic Doppler Current Profilers (VM-ADCPs) have been in operation on RRS *Discovery*; the narrowband 150kHz VM-ADCP and a 75 kHz Phased Array instrument (Ocean Surveyor). The vast majority of this report duplicates that of Penny Holliday and Helen Johnson for D253.

The 150 kHz ADCP is mounted in the hull 1.75 m to port of the keel, 33 m aft of the bow at the waterline and at an approximate depth of 5 m. The 75 kHz ADCP is also mounted in the hull, but in a second well 4.15 m forward and 2.5 m to starboard of the 150 kHz well.

This section describes the operation and data processing paths for both ADCPs. The navigation data processing is described first since it is key to the accuracy of the ADCP current data.

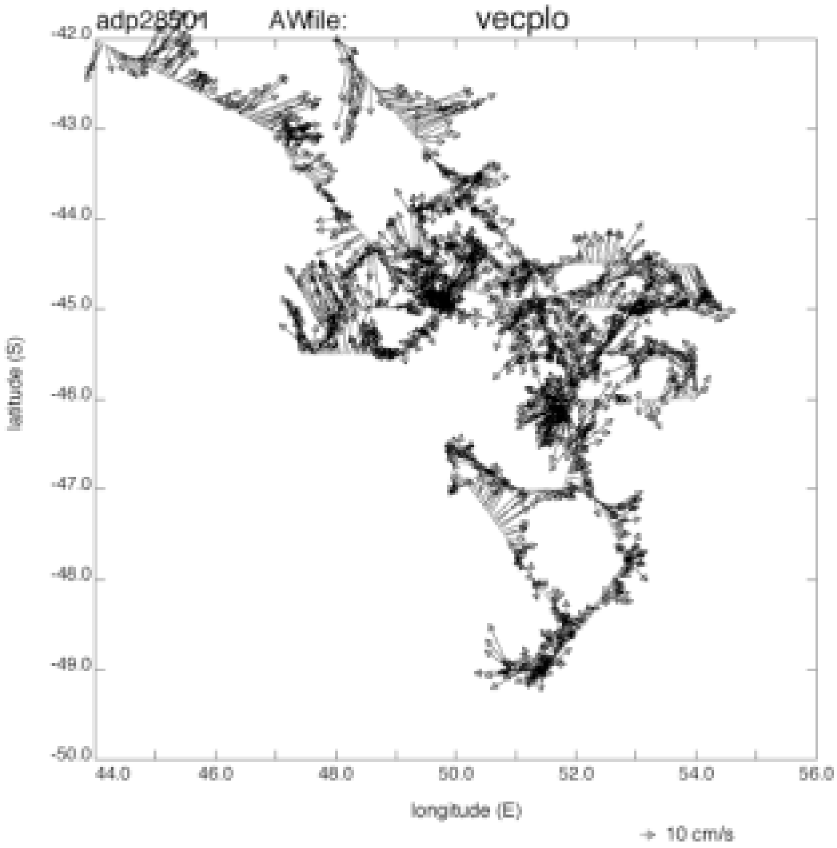

Fig. 2.1 150 kHz ADCP vectors for Di285 at a depth of 103m

An expedient trick to create a vector plot for a complex multidisciplinary cruise like D285, is to append all 24 hour files together, re-grid to 4 km distrun interval along track using padpav and then select a single depth using pcopyg. To a considerable extent this quickly avoids the messy separation of "on-station" data particularly where stations may involve many different deployments and recoveries, some of them non-stationary! In this example (Fig. 2.1), vectors for D285 are plotted for a depth of 103 m for the 150 KHz ADCP data.

Navigation

The ship's best determined position was calculated by the RVS process "bestnav" (10 second averaging period). The main data source for D285 was the GPS Trimble 4000 system. This had been determined to be the most accurate system on a number of preceding cruises, and D285 was no exception. An examination of positional accuracy, whilst tied up alongside Duncan Dock at the beginning of the cruise, showed that the corrected GPS 4000 system provided slightly higher positional accuracy than the Ashtech G12 system, and both were significantly better than the Glonass system. As with preceding cruises, this accuracy was ~1.0-1.5 m for the GPS4000 system and ~ 2.0 m for the G12 system.

Both of these systems had sufficient precision to enable a calculation of ship's velocities to better than 1 cms^{-1}, and therefore below the instrumental limits of the RDI ADCP systems.

If there were gaps in the GPS4000 data, the bestnav process used other inputs as necessary. These were turned to in the strict preference order, Ashtech G12, GPS Ashtech 3D, GPS Glonass (which uses a combination of Russian and American satellite networks). Or, as a last resort, if no GPS was available the Chernikeef electo-magnetic log velocity data and gyro heading would be used to dead-reckon the ship's position.

Data were transferred daily from the RVS Level C bestnav stream to the pstar absolute navigation file, abnv2851. The G12, gps-4000, and gyro (gyronmea) data streams were also transferred daily. Transfer of the gps_glos stream was stopped early on in the cruise as there was no clear purpose in its continued recording.

Scripts:

navexec0: transferred data from the RVS bestnav stream to pstar, calculated the ships velocity, appended onto the absolute (master) navigation file and calculated the distance run from the start of the master file. Output: abnv2851.

gyroexec0: transferred data from the RVS gyronmea stream to pstar, a nominal edit was made for directions between 0-360° before the file was appended to a master file.

gp4exec0: transferred data from the RVS gps_4000 stream to pstar, edited out pdop (position dilution of precision) greater than 5 and appended the new 24 hour file to a master file.

glosexec0: this was identical to gp4exec0 but transferred the RVS gps_glos data stream to pstar.

gpsexec0: this was identical to gp4exec0 but transferred the RVS gps_g12 data stream to pstar.

Heading

The ships attitude was determined every second with the ultra short baseline 3D GPS Ashtech ADU2 navigation system. Four antenna, two on the boat deck, two on the bridge top, measured the phase difference between incoming satellite signals from which the ship's heading, pitch and roll were determined. Configuration settings from previous calibrations (Trials cruise in April 2001) were used throughout the cruise, these were:

Adjusted Relative Antenna Positions (m), which require no pitch or roll offset angle.

	X(R)	Y(F)	Z(U)
1-2 Vector	0.000	6.492	0.167
1-3 Vector	-10.162	0.135	-4.337
1-4 Vector	-10.113	6.431	-4.193

The Ashtech data were used to calibrate the gyro heading information as follows:

ashexec0: transferred data from the RVS gps_ash stream to pstar.

ashexec1: merged the ashtech data from ashexec0 with the gyro data from gyroexec0 and calculated the difference in headings (hdg and gyroHdg); ashtech-gyro (a-ghdg).

ashexec2: edited the data from ashexec1 using the following criteria:

heading 0 < hdg < 360 (degrees)

pitch -5 < pitch < 5 (degrees)

roll -7 < roll < 7 (degrees)

attitude flag -0.5 < attf < 0.5

measurement RMS error 0.00001 < mrms < 0.01

baseline RMS error 0.00001 < brms < 0.1

ashtech-gyro heading -7 < a-ghdg < 7 (degrees)

The heading difference (a-ghdg) was then filtered with a running mean based on 5 data cycles and a maximum difference between median and data of 1 degree. The data were then averaged to 2 minutes and further edited for

-2 < pitch <2

0 < mrms < 0.004

The 2 minute averages were merged with the gyro data files to obtain spot gyro values. The ships velocity was calculated from position and time, and converted to speed and direction. The resulting a-ghdg should be a smoothly varying trace that can be merged with ADCP data to correct the gyro heading. Diagnostic plots were produced to check this. During ship manoeuvres, bad weather or around data gaps, there were spikes which were edited out manually (plxyed).

Ashtech 3D GPS coverage was generally good. Dropouts only occurred early on in the cruise; and on only one occasion was it necessary to reset the Ashtech Unit in the Comms Room. Gaps over 1 minute in the data stream are listed below.

time gap : 04 307 10:30:32 to 04 307 10:33:00 (2.5 mins)

time gap : 04 311 11:02:31 to 04 311 12:37:34 (95.0 mins)

time gap : 04 311 12:41:42 to 04 311 13:35:40 (54.0 mins)

time gap : 04 311 13:37:47 to 04 311 14:05:51 (28.1 mins)

time gap : 04 311 14:09:39 to 04 311 15:31:26 (81.8 mins)

time gap : 04 311 15:33:17 to 04 311 15:37:45 (4.5 mins)

time gap : 04 311 16:13:05 to 04 311 16:27:37 (14.5 mins)

time gap : 04 312 06:25:16 to 04 312 08:39:37 (2.2 hrs)

time gap : 04 312 08:50:13 to 04 312 08:51:34 (81 s)

time gap : 04 312 11:53:46 to 04 312 16:00:53 (4.1 hrs)

time gap : 04 351 07:26:51 to 04 351 07:27:59 (68 s)

time gap : 04 351 07:28:00 to 04 351 07:29:12 (72 s)

time gap : 05 014 17:22:44 to 05 014 17:25:19 (2.6 mins)

RDI 150 kHz ADCP

The 150kHz RDI ADCP was logged using RDI Data Acquisition Software (DAS) version 2.48 with profiler firmware 17.20. The instrument was configured to sample over 120 second intervals with 96 bins of 4 m thickness, pulse length 4 m and a blank beyond transmit of 4m. The high vertical resolution was chosen to support the remote detection of zooplankton patchiness. Early in the cruise the ADCP was switched to bottom and water track mode over shallow ground to enable calibration. After closely inspecting the data from the two ADCPs without configuring them to synchronise their pings over the ensemble period, it was decided to leave them in this mode as little evidence of interference could be seen. To synchronise the instruments, the 150 kHz instrument has to be set as the “master” and the 75 as the “slave”, as recommended by RDI and discussed by Penny Holliday in the D253 cruise report. The result is that each ADCP has only 40 water track pings in the 2 minute period. With no obvious evidence of interference this seemed an unacceptable compromise. Spot gyro heading data were fed into the transducer deck unit where they were incorporated into the individual ping profiles to correct the velocities to earth co-ordinates before being reduced to a 2 minute ensemble.

Following advice from RDI, the 150 KHz ADCP on RRS *Discovery* had been refitted in dry dock, several years ago, to a heading offset of ~45°. This offset was accounted for in the DAS software configuration on D285. On some previous cruises the ADCP PC clock had been synchronised with the ship’s master clock, so removing the tedious need for logging the drift of the PC clock and correcting for it in the processing (old adpexec1). Sadly this was not available on D285 and adpexec1 was resurrected.

The ADCP data were logged continually by the level C computer. From there they were transferred once a day to the Pstar data structure and processed using standard processing scripts in Pstar; which are presented below.

Data processing:

adpexec0: transferred data from the RVS level C "adcp" data stream to pstar. The data were split into two; "gridded" depth dependent data were placed into "adp" files while "non-gridded" depth independent data were placed into "bot" files. Velocities were scaled to cm/s and amplitude by 0.42 to db. Nominal edits were made on all the velocity data to remove both bad data and to change the DAS defined absent data value to the pstar value. The depth of each bin was determined from the user supplied information. Output files: adp285##, bot285##

adpexec1: Clock correction applied to both, gridded and non-gridded files. The PC clock was found to have a steady drift, ~ 2 seconds per day, so time checks were made every 24 hours and these offset values were used in adpexec1 to create a clock correction file for calibrating adcp time. Output files: adp285##.corr, bot285##.corr

adpexec2: this merged the adcp data (both files) with the ashtech a-ghdg created by ashexec2. The adcp velocities were converted to speed and direction so that the heading correction could be applied and then returned to east and north. Note the renaming and ordering of variables. Output files: adp285##.true, bot285##.true.

adpexec3: applied the misalignment angle, ø, and scaling factor, A, to both adcp files. The adcp data were edited to delete all velocities where the percent good variable was 25% or less. Again, variables were renamed and re-ordered to preserve the original raw data. Output Files: adp258##.cal, bot258##.cal.

adpexec4: merged the adcp data (both files) with the bestnav navigation file (abnv2581) created by navexec0. Ship's velocity was calculated from spot positions taken from the abnv2851 file and applied to the adcp velocities: the bestnav averaging is now only 10 seconds, and therefore there is no requirement to take spot values from the raw 1 second GPS4000 dataset which still has the rare spike. The end product is the absolute velocity of the water. The time base of the ADCP profiles was then shifted to the centre of the 2 minute ensemble by subtracting 60 seconds and new positions were taken from abnv2851. Output Files: adp285##.abs, bot285##.abs.

A calibration of the 150 kHz ADCP was achieved using bottom tracking data available from our departure across the Agulhas Bank. Using long, straight, steady speed sections of standard two minute ensemble profiles we obtained a calibration of

$\tan\phi = -0.0039\ (\pm s.d. = 0.0080), \therefore\ \phi = -0.22°$ and $A = 1.0034\ (\pm s.d. = 0.0064)$.

Ocean Surveyor 75 kHz ADCP

D253 was the first scientific cruise on which the new RDI Ocean Surveyor 75 kHz Phased Array ADCP was used and thus a new processing path was written. No significant changes were made to this path on D285. The instrument was configured to sample over 120 second intervals with 60 bins of 16m depth, pulse length 16m and a blank beyond transmit of 8m. The instrument is a narrow band phased array ADCP with 76.8 kHz frequency and a 30° beam angle. The PC was running RDI software VmDAS v1.3. Gyro heading, and GPS Ashtech heading, location and time were fed as NMEA messages into the software which was configured to use the Gyro heading for co-ordinate transformation. The software logs the PC clock time, stamps the data (start of each ensemble) with that time, and records the offset of the PC clock from GPS time. This offset was applied to the data in the processing path before merging with navigation. The ADCP was fitted in the forward well as previously noted. It was known to have a heading alignment offset of 60°, this offset was not accounted for in the RDI software configuration. Bottom tracking was switched on early in the cruise and at the end of the first leg for calibration purposes.

The 2 minute averaged data were written to the PC hard disk in files with a .STA extension, eg D285005_000000.STA, D285006_00000.STA etc. Sequentially numbered files were created whenever data logging was stopped and re-started. The software was set to close the file once it reached 100MB in size, though on D285 files were closed after ~24 hours, so they never became that large. All files were transferred to the unix directory /data61/os75 and most were later archived in /data62/D285/os75/raw; .ENX files contain the raw ping by ping profiles ready for averaging and were archived in case they could be useful for looking at deep acoustic backscatter signals. Broadly speaking the new processing path followed the steps outlined for the 150 kHz ADCP. In the following script description, "##" indicates the daily file number.

In parallel with the 150 KHz ADCP, a calibration of the 75 kHz ADCP was achieved using bottom tracking data available from our departure across the Agulhas Bank. Using long, straight, steady speed sections of standard two minute ensemble profiles (.STA files) we obtained a calibration of

$\tan\phi = -1.7508\ (\pm s.d. = 0.0244), \therefore\ \phi = -60.26°$ and $A = 1.0018\ (\pm s.d. = 0.0060)$.

surexec0: data read into pstar format from RDI binary file (psurvey, new program written on D253 by S. Alderson). Water track velocities were written into “sur” file, bottom track into “sbt” files if in bottom track mode. Velocities were scaled to cm/s and amplitude by 0.45 to db. The time variable was corrected to GPS time by combining the PC clock time and the PC-GPS offset. The depth of each bin was determined from the user supplied information. Output Files: sur285##.raw, sbt285##.raw.

surexec1: data edited according to status flags (flag of 1 indicated bad data). Velocity data replaced with absent data if variable “2+bmbad” was greater than 25% (% of pings where >1 beam bad therefore no velocity computed). Time of ensemble moved to the end of the ensemble period(120 secs added with pcalib). Output files: sur285##, sbt285##.

surexec2: this merged the adcp data (both files) with the ashtech a-ghdg created by ashexec2. The adcp velocities were converted to speed and direction so that the heading correction could be applied and then returned to east and north. Note the renaming and ordering of variables. Output files: sur285##.true, sbt285##.true.

surexec3: applied the misalignment angle, ø, and scaling factor, A, to both files. Variables were renamed and re-ordered to preserve the original raw data. Output Files: sur285##.cal, sbt285##.cal.

surexec4: merged the adcp data (both files) with the bestnav navigation file (abnv2581) created by navexec0. Ship's velocity was calculated from spot positions taken from the abnv2851 file and applied to the adcp velocities: the bestnav averaging is now only 10 seconds, and therefore there is no requirement to take spot values from the raw 1 second GPS4000 dataset which still has the rare spike. The end product is the absolute velocity of the water. The time base of the ADCP profiles was then shifted to the centre of the 2 minute ensemble by subtracting 60 seconds and new positions were taken from abnv2581. Output Files: sur285##.abs, sbt285##.abs.

It is still noticeable that the 75 kHz depth penetration during steaming suffered very readily with the onset of anything other than calm conditions. It was postulated on D253 that the forward well is more prone to contamination by bubbles than the aft well, and if the 75 kHz ADCP is to become the standard ADCP for Discovery it may be appropriate to move the 75 kHz to the aft well, we continue to agree.