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Acoustic Doppler Current Profiler data collected on *Polarstern* Cruise ANT-XIII/2 04 Dec 1995 - 24 Jan 1996

J T Allen[1], H Fischer[3], M J Griffiths[2], R T Pollard[1], J F Read[1] & V Strass[3]

1996

[1]George Deacon Division for Ocean Processes
[2] James Rennell Division for Ocean Circulation
Southampton Oceanography Centre
European Way
Southampton SO14 3ZH
UK

[3]Alfred-Wegener-Institut fur Polar- und Meersforschungen, Bremerhaven

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ABSTRACT

Four SeaSoar surveys were carried out from FS *Polarstern* during the ANT XIII/2 cruise, to look at upper ocean dynamics in areas of high biological productivity. *Polarstern* was also fitted with a 150kHz RDI Acoustic Doppler Current Profiler, and the backscatter data collected from the ADCP during the SeaSoar surveys are presented in this report. some current vector plots are also given. All calibrations are preliminary.

KEYWORDS
ADCP
BACKSCATTER
CRUISE XIII/2 1995
CURRENT VECTORS
"POLARSTERN"

ISSUING ORGANISATION

Southampton Oceanography Centre
European Way
Southampton SO14 3ZH
UK

Director: Professor John Shepherd

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Introduction

The Acoustic Doppler Current Profiler (ADCP) has become a commonplace instrument found on most oceanographic research vessels. Generally mounted in a hole in the hull of the vessel, it is designed to send a pulsed sound signal into the water column and derive information about the water current velocities by analysis of the return echoes from particles in suspension in the water. The ADCP instrument has four transducer heads, arranged in a square formation, each looking downwards (or upward in many mooring applications) and diagonally outwards at a small angle from vertical. Simultaneously the transducer heads emit a pulse of sound approximately every second. The return echoes are electronically range gated, according to an expected time of two way travel, into a series of vertical bins. For each bin the frequency of sound of the return signal at each transducer head is compared to the transmitted sound frequency. The apparent change in frequency between the transmitted pulse and the return echo is directly related to the speed at which the reflecting particles in the water are approaching the transducer head, the familiar Doppler effect. By having four transducer heads pointing in different directions the speed of the particles in all three space dimensions can be calculated (i.e. magnitude and direction of the velocity vector). In principle only three transducer heads are necessary, but a fourth gives an estimate of the error in the calculated velocities. Additionally, it has recently been appreciated that the amplitude of the backscattered signal received by the transducer heads holds information about the density of particles in the water column. For a 150 Khz ADCP, particles 3-4 mm in size and larger are responsible for scattering the transmitted signal. This will include some of the larger zooplankton species (Flagg and Smith, 1989; Zhou *et al.*, 1994).

FS *Polarstern* is fitted with an RD Instruments (RDI) 150 KHz hull mounted ADCP. Unusually, the ADCP on FS *Polarstern* is mounted in a water bath sealed off from the open water by a thick glass plate set in to the hole in the hull so as to be flush with the bottom of the hull. This was found necessary as a result of the ship's extensive role as an ice-breaker. It is not obvious from the data that there are any inherent disadvantages with this arrangement. A clear advantage is that the water bath obviates the need to bleed air out of the ADCP chest; an operation frequently required by conventional installations due to the trapping of air bubbles entrained from the ship's bow wave. A side effect is that both the transducer temperature and the electronics temperature are at the temperature of the water bath. The water bath temperature varies slowly due to the poor conduction of heat through the glass plate between the water bath and the water beneath the ship.

Averaging of return signals from a suitable number of transmitted pings and basic interpretation of ensemble averages into velocities relative to the ship is done by an RDI deck unit, firmware version 16.35, and recorded on a PC disk using data acquisition software version 2.48. In parallel with the recording to PC disk, the data were passed to a SUN IPC workstation based RVS level C and converted into a binary format ADCP data stream. Once every 24 hours the previous 24 hours of the data stream were read from the level C into

PSTAR data files. PSTAR is the generic name for our data manipulation software system. The data contained the following fields; bindepth, heading, temperature, EW velocity relative to the ship, NS velocity relative to the ship, vertical velocity, error velocity, amplitude of received signal and percent good pings. In the following section the processing of these data to obtain absolute upper ocean currents is presented. In section 3 the derivation of calibrated backscatter amplitude, or target strength, from the amplitude of the received signal and SeaSoar hydrographic data is presented.

SeaSoar data, Optical Plankton Counter data and underway and navigational data collected simultaneously with the ADCP data are described in companion reports (Griffiths *et al.*, 1996; Pollard *et al.*, 1996; Read *et al.*, 1996).

Upper Ocean Currents

The ADCP data acquisition software was configured as follows:

A salinity of 35.0 and water temperature measured at the transducer heads were used for the calculation of the speed of sound.

Ensemble averages were made over pings contained within a period of 2 minutes.

80 levels of 4 metre depth bins achieved a maximum depth of 333 metres.

Minimum depth of 17 metres (draught ~ 11m, blank beyond transmit = 4 m and 2 m to the mid-point of the first bin).

A greater maximum depth could have been achieved, but below 300 m the percentage of good return signals decreased rapidly and there is a an obvious compromise between depth obtained and the number of pings over which a 2 minute ensemble average is made. The ADCP was not used in bottom tracking mode at any time during the cruise.

Initial calibration of the ADCP by deriving misalignment angle, ϕ, and scaling factor, A, (Joyce, 1989; Pollard and Read, 1989) had been made prior to ANT XIII/2 in bottom tracking mode after leaving Bremerhaven. The values derived were, ϕ=-1.179° (+ve clockwise from GPS heading of the ship's forward axis) and A = 1.011.

The RDI software uses the PC internal clock to time reference the data. However, PC internal clocks generally drift at a rate that is unacceptable over a duration of more than a few days. Early in the cruise a frequent comparison was made between the PC clock and the ship's clock as it had been noticed that the rate of drift of the PC clock was variable. However after a few days the drift settled down to a loss of 4-6 seconds per day.

Initial routine processing of the 24 hr ADCP data files was carried out using the macros adpexec0-2 (Griffiths, 1992); in brief they read in the data from the ADCP data stream, split data into fields which are either dependent or independent of bindepth, convert velocities to cm/s, subtract 60 seconds from the time to locate the centre of each two minute ensemble, correct the time for PC internal clock drift, eliminate RDI absent velocity data values, average data over 10 minute periods, and calibrate relative velocities for misalignment angle and scaling factor.

To get absolute current velocities from the velocities relative to the ship measured by the ADCP the ship's velocity must be removed by adding it to the relative velocities. However, the ship's velocity is at least one order of magnitude larger than the absolute currents and therefore this is the critical step in the processing of ADCP data. For this reason the remainder of the processing will be described in some detail in the next few paragraphs. On the cruise, possible problems with the initial calibration for scaling factor, discussed later, will require reprocessing of the ADCP data after the cruise. Mistakes made in the processing of the navigation data during the cruise will also be corrected in the reprocessing.

The ADCP data is referenced to the heading from the ship's gyro compass. It is well known that ship's gyro compasses suffer from various sources of error including Schüller oscillations, latitudinal drift, inertial lag and quantisation noise. FS *Polarstern* has a 3-D GPS system on board developed by the University of Hannover (Seeber and Wübbena, 1989; Wübbena, 1991) which determines the ship's heading to within 0.1°. Navigation data which included gps_lat, gps_lon, gps_hdg (GPS heading) and gyr_hdg (ship's gyro heading) were recorded every second and read across into PSTAR from the ship's POLDAT system (Read *et al.*, 1996). Gaps in the ship's gyro heading were interpolated across since they were infrequent and of rarely more than a few seconds duration; nonetheless they were unexpected and may be worth investigating in the future.

Directional data only has a 360° range and therefore differences between gyro heading and GPS heading about the origin of the directional range can be numerically very large : e.g.

directional range (0° - 360°)

GPS heading	gyro heading	GPS - gyro
034.0°	034.8°	-0.8°
359.6°	000.4°	359.2°

This would not cause a problem if the one second data were used to correct the ADCP reference axes (the sine, cosine, of -0.8° is the same as the sine, cosine, of 359.2°) , however the one second data are too noisy and must be averaged. Therefore these numerical jumps have to be avoided by changing the angular range of the directions such that the origin is a direction not steamed during the duration of the data section being processed.

Gaps in the GPS heading were also infrequent but typically of longer duration. As a result a more intelligent guess was needed to interpolate across the gaps and produce a correction angle for the gyro heading. The difference between GPS and gyro heading was plotted against gyro heading for a reasonable spread of headings and many days of navigation data (one second data) (presented at the end of this report). This showed that the usual assumption that errors in gyro heading are symmetrical about 180° could be applied. Note however, that the large variation in error at any particular heading may be worth further investigation. The mean heading errors at a heading of 180° and a heading of 0° were calculated, -0.773 (standard deviation 0.1916) and -0.396 (standard deviation 0.1969) respectively. Using a program written by Gwyn Griffiths, Southampton Oceanography Centre, the error function

$$E_g = (\theta_{180} - \theta_0)|\cos\phi| + \theta_0,$$

where, θ_{180}, θ_0 and ϕ are the heading errors at 180° and 0° and the ships heading respectively, was used to interpolate across the gaps in the GPS - gyro correction that resulted from gaps in the GPS heading data. Where the gyro heading in the gap varies from the last gyro heading by more than 1.5 radians (~86°) then the correction is taken as the value of the error function, if less than 1.5 radians then part of the previous correction is used in combination with the error function scaled by the previous correction. The final one second navigation file then contained an extra variable, GPS - gyro heading correction.

The navigational information was then averaged to 30 second intervals. The relative velocities in the 10 minute averaged ADCP data were corrected using the GPS - gyro heading correction in the 30 second averaged navigation file. This was a mistake, the navigation file should have been further averaged to 10 minutes before making the correction (adpexec4ps1 - similar to G. Griffiths original) or to 2 minutes, and the corrections made to the ADCP data before it was averaged to 10 minutes (adpexec2a). However, incorporating a heading correction made little difference, in general, to the velocity vectors and it is not expected that smoothing the heading correction further will significantly change the overall pattern of the flow.

Initially, the ship's speed was calculated from the difference between GPS positions (latitude and longitude) in the 30 second averaged navigation files. GPS position and the ships velocity were added to the 10 minute averaged ADCP data by merging on time with the 30 second navigation file. However this resulted in a noisy absolute current velocity field when the ship's velocities were added to the relative velocities. This mistake was corrected on board as follows. The 10 minute averaged ADCP files had 300 seconds (5 minutes) added to the time field and then GPS positions were added by merging on time with the 30 second navigation file. The 300 seconds was then subtracted from the time field in the 10 minute ADCP files. Our program for calculating ship velocities looks at the difference in position over the preceding time interval and puts the calculated ship speed in at the present time interval. By adjusting the time in the above manner the ship's velocities were calculated from the distance and direction travelled between the positions five minutes after and five minutes before each ADCP profile giving a ten minute averaged ship's velocity at the position of the averaged ADCP profile. The correct GPS positions were then obtained by merging on the true time with the 30 second navigation file. The resulting absolute current velocities again showed the same overall picture where currents were large but now showed sensible currents where before the flow had been dominated by noise in the ship's velocities.

Current vectors at a depth of 153 m are presented at the end of this report for the first north-south transect (transects 1, 2 and 3), for the coarse scale survey (transects 6.1-6.7) and for the fine scale survey (transects 8.1-8.11). In addition, current vectors at a depth of 41 m are presented for the coarse scale survey and the fine scale survey. Comparison of vectors at the two depths shows firstly that generally currents were strongly barotropic in the upper ocean and secondly the occurrence of strong storms where the vectors at 41 m are turned relative to those at 153 m due the presence of wind driven inertial motion. In both the coarse and fine scale surveys the strong eastward southern ocean circulation is clearly apparent. In the coarse scale survey the main current / currents can be seen to meander on what appear to be scales, barely resolved, of 70 - 100 km. In the south - east corner of the fine scale survey, the cyclonic circulation of one of these meanders is clearly visible over six cruise track legs.

Throughout the current vectors there is strong evidence of a preference for the velocities to lie astern of the ships direction, this is particularly evident in the coarse and fine scale surveys where the ship was running in opposite directions from leg to leg. The magnitude of this spurious astern velocity can be estimated at about 1% of the ship's speed, which may imply a 1% error in the calibration scaling factor. It is interesting to note that Pollard and Read (1989) commented that a difference of 1% in the calibration scaling factor can be found between calibrations made in bottom track mode and those made in water track mode. In addition, between legs in the southern part of the fine scale survey, alternating regions of convergence and divergence can be seen. These are perhaps on a similar scale to some of the features seen in the SeaSoar hydrography in this region of the fine scale survey, however the overall conclusion is that the initial calibration of the ADCP needs to be examined and perhaps another calibration made from repeated tracks in opposite directions and/or 90° turns in the ANT XIII/2 ADCP dataset.

Acoustic Backscatter

The amplitude of the backscattered signal received by the transducers from each bin depth was given by the RDI deck unit as an average over the four transducer heads. In the routine processing of the ADCP data a nominal calibration of 0.42 dB per count was applied to convert the amplitude units to decibels (dB). Relative backscatter was then calculated and plotted for the 10 minute averaged ADCP data profiles using adpexec5. This macro invoked the program adprl2 to calculate the average backscatter amplitude for each ten minute vertical profile and then deduct the average from the profile. The relative acoustic backscatter showed qualitatively the distribution of scattering layers and diel migrations of zoo-plankton, but told us little quantitatively about target strength or absolute density of scatterers.

There are two principal components to the calibration of backscatter amplitude, firstly the estimation of the background instrumental noise level at the transducer heads and secondly the determination of the attenuation of the sound signal by the water column. This second component is a function of the hydrography and therefore the determination of absolute backscatter amplitude at a particular bindepth must take account of the integrated attenuation over the water column between that bindepth and the transducer heads. A full description of the procedure for calibration for the background instrumental noise level at the transducer heads is given in RDI Technical note ADCP-09-04 Dec. 1990.

The PSTAR program used to calibrate the backscatter, calamp3.F, is included in appendix A and was written by G. Griffiths, M. Hartman and N. Crisp all at the Southampton

Oceanography Centre. The program uses two files, an ASCII calibration parameter file and a combined ADCP backscatter / SeaSoar hydrography file to which the calibrated backscatter amplitude is written.

The basic calibration file contained the following parameters :

K_s

K1 K2

TE TX

X P DTX

ER

Flag

where, for ANT XIII/2,

K_s = Constant dependent on the system frequency, 4.17×10^5 for VM-150 systems (from RDI)

K1 = Constant dependent upon the power transmitted into the water.

$$K1 = \{[(V_s \times 0.699) - 4.27] / 37.14\}^2 \times K1_c = 137.67$$

$K1_c$ = power into the water and was provided by RDI as a beam by beam measurement, we used the average 7.894 (± 0.378).

V_s = the ship supply voltage of 228 V A/C.

K2 = A dimensionless noise factor for each beam provided by RDI, once again we used the average, 3.14 (± 0.36)

TE = Electronics temperature during calihration, 1.1°C

TX = Transducer temperature during calibration, 1.1°C

X = The bin length was set to 4m

P = The pulse length was also set to 4m

DTX= The transducer depth was 11 metres on FS *Polarstern*.

ER= The echo amplitude, the average of the Automatic Gain control (AGC) over the four transducer heads from the quietest bin or a bin below water depth. First this was measured whilst tied up along side in Cape Town according to RDI instruction in ADCP-09-04 with the advised setup of 128 bins, 1 metre pulse length, and 16 metre bin lengths. However the values obtained were a factor of four higher than those expected and underway with the chosen bin length of 4 metres most of the backscatter amplitudes were less than this noise level. Two possible explanations were considered, that the AGC values are not normalised for bin length (this seems most unlikely) or that a strong multiple echo/external noise in the shallow water of the harbour had resulted in high background AGC values. Therefore, at station 9, the ADCP was setup for 128 four metre bins and the AGC values were recorded for bins 127 and 128, below where percent good pings had fallen to 0%, over averages of 100 pings. The value obtained for ER was 19.2 with a standard deviation of $\pm$ 1.7.

Flag was set to 1 to tell the calibration program that a nominal calibration of 0.42 dB per count had been applied and should be removed before absolute calibration.

To create the merged hydrography and ADCP backscatter files, the two minute time corrected ADCP files were gridded on distance run at 6 km intervals to match the SeaSoar horizontal data averaging. SeaSoar data were then gridded in the vertical to 4 db pressure bins between 17 db and 333 db to match the ADCP vertical resolution. The two files were then joined exactly to create 6 km by 4 m gridded files containing bindepth, distance run, SeaSoar temperature, salinity, ADCP backscatter amplitude and percent good pings. The corresponding time corrected ADCP depth independent bottom files were also gridded on distance run at the same 6 km intervals; this enabled the merging of transducer temperature into the backscatter / hydrography files. Calamp3.F was then used to calculate the absolute backscatter using the RDI derived equation:

$$Ts_n = 10\log\{4.47\times10^{-20}K2.K_s(273+TX)(10^{Kc(ampl-ER)/10} - 1)r^2 / C.P.K1.10^{-2\alpha/10}\}$$

where K_c is the conversion factor (dB/count) given by RDI as {127.3 / (TE + 273)}/10, ampl is the backscatter amplitude in counts, r is the slant range assuming a 30° transducer angle, C is the speed of sound and α is the attenuation parameter. The algorithms for C and α are given in the program and are dependent on the temperature and salinity in the water column.

Contoured sections of absolute backscatter amplitude, relative backscatter amplitude and percent good return pings are presented at the end of this report. The contoured sections for each SeaSoar transect follow the respective ADCP current vector diagram for that transect. Note that gaps in the absolute backscatter amplitude are due to gaps in salinity in the SeaSoar data, remember that total attenuation is an integrated property over the depth of the water column. One clear effect of taking account of the attenuation in the water column is the increased emphasis on the strength of backscattered signal below the thermocline (below 50-100 m for instance). Future work should include the examination of on-station backscatter profiles calibrated with CTD data and their comparison with optical plankton counter and multi-net data.

Data Presentation

Current vectors at a depth of 153 m are presented for the first north-south transect (transects 1, 2 and 3), for the coarse scale survey (transects 6.1-6.7) and for the fine scale survey (transects 8.1-8.11). In addition, current vectors at a depth of 41 m are presented for the coarse scale survey and the fine scale survey.

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Appendix A: calamp3

```
C*****calamp3
C
      PROGRAM CALAMP3ps
C*****MCH Nov 95 (modified from calampl)
C*****asked to include Mr N.Crisps'name as he assisted with
C*****one of the conditional loops so - THANKYOU NICK!
C*****uses a file that contains all the needed information
c
c***** modified on 20/12/95 for Polarstern ANTX111/2
c***** The ADCP sits in a waterbath and therefore TX and TE
c***** are the same and are given by the RDI deck unit.
c***** so the bot file has to be merged with the
c***** adcp/seasoar input
c***** file to give TX.
C
C      See RDI documentation for full details of the
c      calibration equation
C
      IMPLICIT REAL*8 (A-H,O-Z,a-h,o-z)
      REAL*8 KS,K2,KC,K1
C      NOTE that the max no of data cycs for this is 50000
C
      PARAMETER (NSIZ=100000)
      CHARACTER*1 ANS
      CHARACTER*8 PROG
      CHARACTER*48 CALFILE
      DIMENSION AMPL(NSIZ),BINDEPTH(NSIZ),AMPLCAL(NSIZ)
      DIMENSION TEMP(NSIZ),SAL(NSIZ),TXVAR(NSIZ)
      LOGICAL PRNT
C
#include 'datadf2.h'
#include 'psio.h'
C
      integer npos(ifldxx)
      DATA PROG/'CALAMPL'/,CALFILE/'amplcal.dat'/,ANS/'Y'/
      PRNT=.FALSE.
C
      CALL PROGHD(PROG)
C
      WRITE(IOITT,503)CALFILE
  503 FORMAT(' Enter name of file containing calib info eg. ',A12)
      CALL OPENSQ(IOSEQ)
C
      READ(IOSEQ,*)KS
      WRITE(IOITT,505)KS
  505 FORMAT(' Ks = ',E8.2)
C
      READ(IOSEQ,*)K1,K2
      WRITE(IOITT,506)K1,K2
  506 FORMAT(' K1 = ',F8.2, '        K2     = ',F8.2)
      READ(IOSEQ,*)TE,TX1
      WRITE(IOITT,507)TE,TX1
  507 FORMAT(' TE = ',F5.2,' DEG C','     TX1     = ',F6.2,' DEG C')
      READ(IOSEQ,*)X,P,DTX
      WRITE(IOITT,508)X,P,DTX
  508 FORMAT(' X = ',F8.2,' m   ','     P      = ',f6.2,' m',
     &'      DTX = ',f6.2,' m')
      READ(IOSEQ,*)ER
      WRITE(IOITT,509)ER
```

```
  509 FORMAT(' ER = ',F6.2, ' counts')
C      now get the flag, if = 1 then ampl data was nominally calibrated
C      flag set to zero if raw AGC was in the file
      READ(IOSEQ,*)KFLAG
      WRITE(IOITT,511)KFLAG
  511 FORMAT(' KFLAG = ',i4,'  1 = nominal calib  0 = raw')
C
C     Ends input from file -is it ok?
      WRITE(IOITT,512)
  512 FORMAT('  IS ABOVE TABLE OK Y-OR-N (DEFAULT Y)')
      CALL READ80(ANS,1)
      IF(ANS.EQ.'N'.OR.ANS.EQ.'n') CALL PABORT
C
C......Initialise INPUT and OUTPUT files
      CALL OPENIN(INDISK)
      IF(INDISK.EQ.-999) STOP 'No input file'
    5 CALL OPENOT(IODISK)
      IF(IODISK.EQ.-999) STOP 'No output file'
      IF(IODSIK.EQ.INDISK) THEN
      WRITE(IOITT,500)
  500 FORMAT(' Input and output files must be different')
      GOTO 5
      ENDIF
C
      CALL READPR(INDISK,
     & MAGIC,NOFLDS,NORECS,NROWS,NPLANE,ICENT,IYMD,IHMS,
     & FLDNAM,FLDUNT,ALRLIM,UPRLIM,ABSENT,
     & ALAT,ALONG,DEPTHI,DEPTHW,OPWRIT,RAWDAT,PIPEFL,ARCHIV,VERS,
     & DATNAM,PREFIL,POSTFL,PLATYP,PLTNUM,RECINT,PLTNAM,INSTMT,COMENT)
C
      NSTART=1
      NSTOP=NORECS
      WRITE(IOITT,524) NROWS
524   FORMAT(' NROWS = ',I8)
      IF(NSTOP.GT.NSIZ) THEN
      WRITE(IOITT,525) NSTOP
525   FORMAT(' FILE CONTAINS',I8,'  DATA CYCLES -TOO LARGE')
      CALL PABORT
      ENDIF
C
C......Get instructions from user
C......Copy which vars across
      WRITE(IOITT,526)
  526 FORMAT(' Enter vars to be copied across'/
     &'(including those to be processed, if required')
      CALL READNM(FLDNAM,NPOS,NOFLD2,NOFLDS)
C
C......Make up new header
      DO 20 N=1,NOFLD2
      FLDNA2(N)=FLDNAM(NPOS(N))
      FLDUN2(N)=FLDUNT(NPOS(N))
      ABSEN2(N)=ABSENT(NPOS(N))
      ALRLI2(N)=ALRLIM(NPOS(N))
      UPRLI2(N)=UPRLIM(NPOS(N))
   20 CONTINUE
   12 WRITE(IOITT,528)
  528 FORMAT(' Input variable numbers for bindepth,ampl,temp,salin
     &,TX')
      READ(INITT,*) NVARBIN,NVARAMPL,NVARTEMP,NVARSAL,NVARTX
      WRITE(IOITT,530) NVARBIN,NVARAMPL,NVARTEMP,NVARSAL,NVARTX
  530 FORMAT(' bindepth=',I4,' ampl=',I4,'temp=',I4,'salin=',I4
```

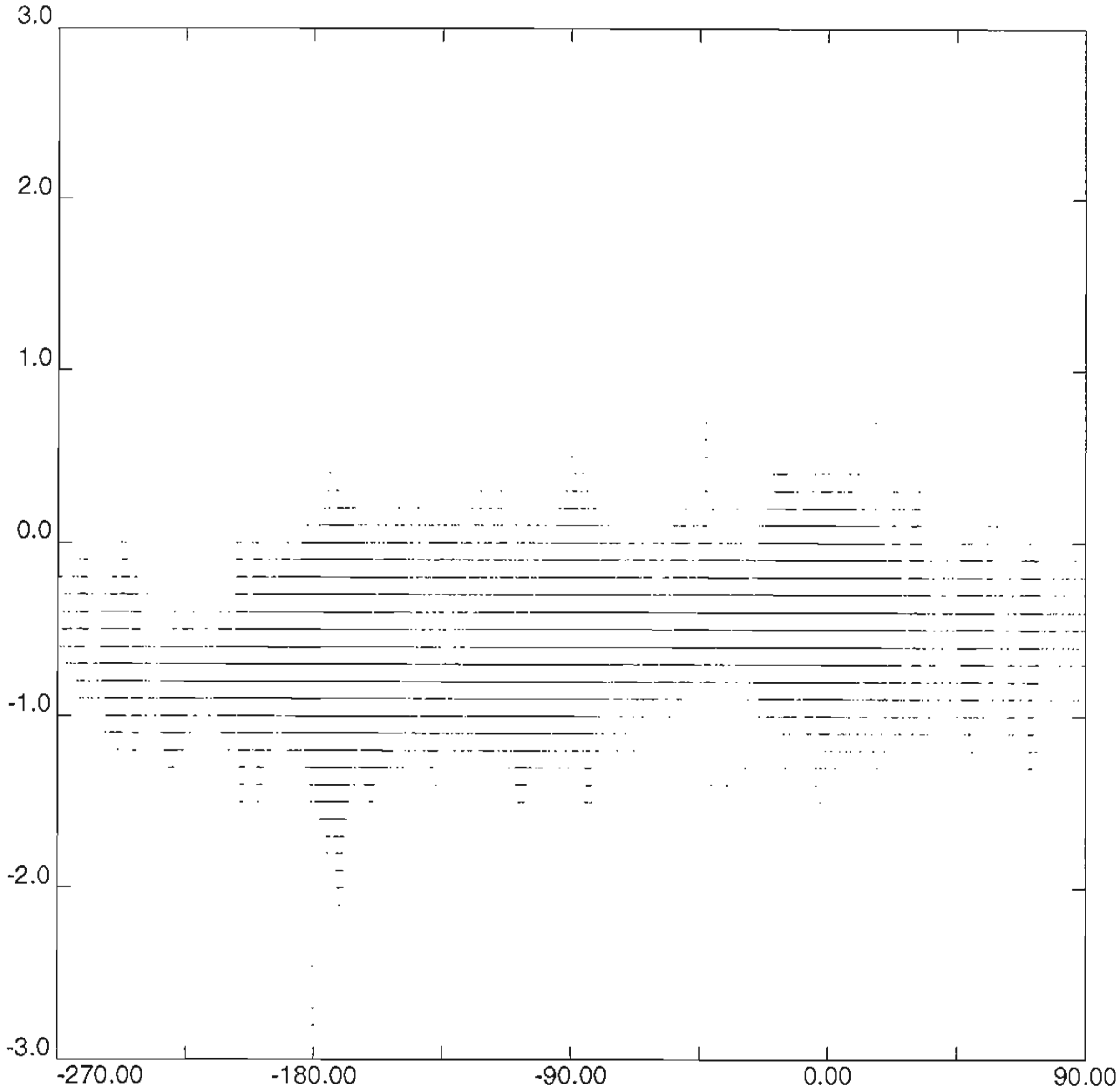
```
     &,'TX=',I4)
C......We're ready to read 2 variables
      ABSBIN=ABSENT(NVARBIN)
      ABSAMPL=ABSENT(NVARAMPL)
      ABSTEMP=ABSENT(NVARTEMP)
      ABSSAL=ABSENT(NVARSAL)
      ABSTX=ABSENT(NVARTX)
      NL = NSTOP
      CALL INDATA (INDISK,NVARBIN,1,NL,BINDEPTH,NOFLDS,NORECS)
      CALL INDATA (INDISK,NVARAMPL,1,NL,AMPL,NOFLDS,NORECS)
      CALL INDATA (INDISK,NVARTEMP,1,NL,TEMP,NOFLDS,NORECS)
      CALL INDATA (INDISK,NVARSAL,1,NL,SAL,NOFLDS,NORECS)
      call indata (indisk,NVARTX,1,NL,txvar,noflds,norecs)
C
C      CALCULATE HERE
C      calculate the parts of the eqn that
C      do not depend on bindepth or AGC
C      F3=(127.3/(TE+273.))/10.
C......Acidity,PH sound frequency,F in kHz
      PH = 8.
      F = 153.
C
C      now for the parts that need AGC and bindepth
      DO 700 N=NSTART,NSTOP
      ROWNUM= N - ((N-1)/NROWS)*NROWS
C
C......conditional testing for absent data in row 1.
C......JFLAG used to set values lower than an absent
C......data point to absent.
      IF (ROWNUM.EQ.1) THEN
        BIN1 = BINDEPTH(N)
        JFLAG = 0
c        TX=TEMP(N)
        TX = txvar(N)
        IF (txvar(N).EQ.ABSTX) THEN
          IF (N.EQ.1) THEN
            TX = TX1
          ELSE
            TX = TOLD
          ENDIF
        ENDIF
        TOLD = TX
        TE=TX
      ENDIF
C      check for abs data at or above data point.
      IF (BINDEPTH(N).EQ.ABSBIN.OR.AMPL(N).EQ.ABSAMPL
     & .OR.TEMP(N).EQ.ABSTEMP.OR.SAL(N).EQ.ABSSAL
     & .OR.JFLAG.EQ.1) THEN
      AMPLCAL(N)=ABSAMPL
      JFLAG = 1
      GOTO 700
      ENDIF
C
      TX=txvar(n)
      TE=TX
c
      T = TEMP(N)
      S = SAL(N)
      D = BINDEPTH(N)
c
      F3=(127.3/(TE+273.))/10.
```

```
c
C
      THETA = 273.+T
      SALI = S/35.
      TSQ = T*T
      TCU = T*TSQ
      DSQ = D*D
      FSQ = F*F
C
C......Calculate speed of sound.
      C = 1412. + 3.21*T + 1.19*S + 0.0167*D
C
C......Boric Acid Contribution.
      P1 = 1.
      PWR = 0.78*PH - 5.
      PWR1 = 4. - 1245./THETA
      A1 = (8.86*10.**PWR)/C
      F1 = 2.8*SQRT(SALI)*10.**PWR1
      F1SQ = F1*F1
      BORIC = A1*P1*F1*FSQ/(FSQ + F1SQ)
C
C......MgSO4 Contribution.
      P2 = 1. - 1.37E-04*D + 6.2E-09*DSQ
      A2 = 21.44*S*(1.+ 0.025*T)/C
      PWR2 = 8.- 1990./THETA
      F2TOP = 8.17 * 10.**PWR2
      F2BOT = 1.+ 0.0018*(S - 35.)
      F2ALL = F2TOP/F2BOT
      F2SQ = F2ALL*F2ALL
      AMGSO4 = A2*P2*F2ALL*FSQ/(FSQ + F2SQ)
C
C......Pure water contribution.
      P3 = 1.- 3.83E-05*D + 4.9E-10*DSQ
C
C......Conditional depending on water temperature.
      IF ( T .LE. 20. ) THEN
         A3 = 4.937E-04 - 2.59E-05*T + 9.11E-07*TSQ - 1.5E-08*TCU
      ELSE
         A3 = 3.964E-04 - 1.146E-05*T + 1.45E-07*TSQ - 6.5E-10*TCU
      END IF
      H2O = A3*P3*FSQ
C
C......Calculate absorption coeff. alphakm in dB/km
      ALPHAKM = BORIC + AMGSO4 + H2O
C
C......Calculate absorption coeff. alpha in dB/m
      ALPHA = ALPHAKM/1000.
C
C      check using flag if ampl in file was approx calib
C      if it was get back to raw by div by 0.42
C      the nominal factor used in adpexec* on Vivaldi
      IF (KFLAG.EQ.1) AMPL(N)=AMPL(N)/0.42
C        calculate range from bindepth, assuming 30 deg transducer angle
      R=(BINDEPTH(N)-DTX)/0.8660
      RSQ=R*R
C......Calculation for 1st bin
      IF (ROWNUM.EQ.1) THEN
        ALPHAR = ALPHA*(BIN1 - DTX)/0.866025
        SUM = ALPHA*(BIN1 + X/2 - DTX)/0.866025
      ELSE
        ALPHAR = SUM + ALPHA*X/(2.*0.866025)
```

```
        SUM = SUM + ALPHA*X/0.866025
      END IF
C
      F1=4.47e-20*K2*KS*(TX+273.)
      F2=C*P*K1
      F4=(-2.*ALPHAR/10.)
      F5=(F1*(10.**(F3*(AMPL(N)-ER)) -1.) * RSQ)
      F6=(F2*(10.**(F4)))
      F7=F5/F6
c       write(ioitt,531)R,RSQ,F5,F6,F7
c      write(ioitt,531)F1,F3,F5,F6,F7
 531   format(5E12.3)
      if(F5.lt.0.0) then
        amplcal(n)=absampl
      else
        AMPLCAL(N)=10.*DLOG10(F7)
      endif
  700 CONTINUE
C
C.....absent value left unaltered
      CALL OTDATA (IODISK,NOFLD2+1,1,NL,AMPLCAL,NOFLD2+1,NORECS)
C
C
C.....Copy requested variables across
      DO 70 N=1,NOFLD2
   70 CALL C2COPY(INDISK,NPOS(N),IODISK,N,1,NORECS,1,NOFLDS,
     &NORECS,NOFLD2+1)
C
C......Finish
      NOFLD2=NOFLD2+1
C      name and units for new variable
      FLDNA2(NOFLD2)='amplcal'
      FLDUN2(NOFLD2)='dB'
      ABSEN2(NOFLD2)=-999.0
      DO 80 N=1,NOFLD2
   80 CALL UPRLWR(IODISK,N,1,NORECS,ALRLI2(N),UPRLI2(N),
     &ABSEN2(N),NOFLD2,NORECS)
C
C......Termination
C
      CALL PFINIS(IODISK,PROG,
     & MAGIC,NOFLD2,NORECS,NROWS,NPLANE,ICENT,IYMD,IHMS,
     & FLDNA2,FLDUN2,ALRLI2,UPRLI2,ABSEN2,
     & ALAT,ALONG,DEPTHI,DEPTHW,OPWRIT,RAWDAT,PIPEFL,ARCHIV,VERS,
     & DATNAM,PREFIL,POSTFL,PLATYP,PLTNUM,RECINT,PLTNAM,INSTMT,COMENT)
C
      STOP
      END
```

```
#!/bin/csh
#
#      Run ucontr a number of times and then run udisp to arrange
#      all plots on one page.
#
   set page_size = "190,240"
   set ratio     = "0.95,0.65"
   set DIR       = "/users/pstar/data/adcp"
#
   if ( $#argv < 1 ) then
     echo "Usage: adpPage page_num [-u] [post]"
     exit(1)
   endif
   set page = $1
   if ( ! -e page$page ) then
     echo "No source file: page$page"
     exit(1)
   endif
   source page$page
#
#      if first argument is -u, miss out ucontr and go straight to udisp.
#
   if ( $1 == -u || $2 == -u ) goto udisp
#
#      colors - extension for colours file for each segment.
#      vars   - cdf variable number of each segment
#      limits - latitude limits for each page.
#
   set num_segs = 3
   set colors   = ( calamp ampl good )
   set vars     = ( 6 2 3 )
   set xvar     = gps_lat

   set seg = 1
   while ( $seg <= $num_segs )

     setenv PICT $seg
     setenv COLS $colors[$seg].cols
#
#      ucontr with no file details (-fle), no axes labels (-lab),
#      no title (-ti) and no colour scale (-sc);  no need to press
#      return after display (-exit).
#
     ucontr -fle -lab -ti -sc -exit << !
adcp.cdf
4
ADCP
1
1
$vars[$seg]
/
/
5
1
$xvar
$limits
7
$start[$seg]/
8
$stop[$seg]/

1
```

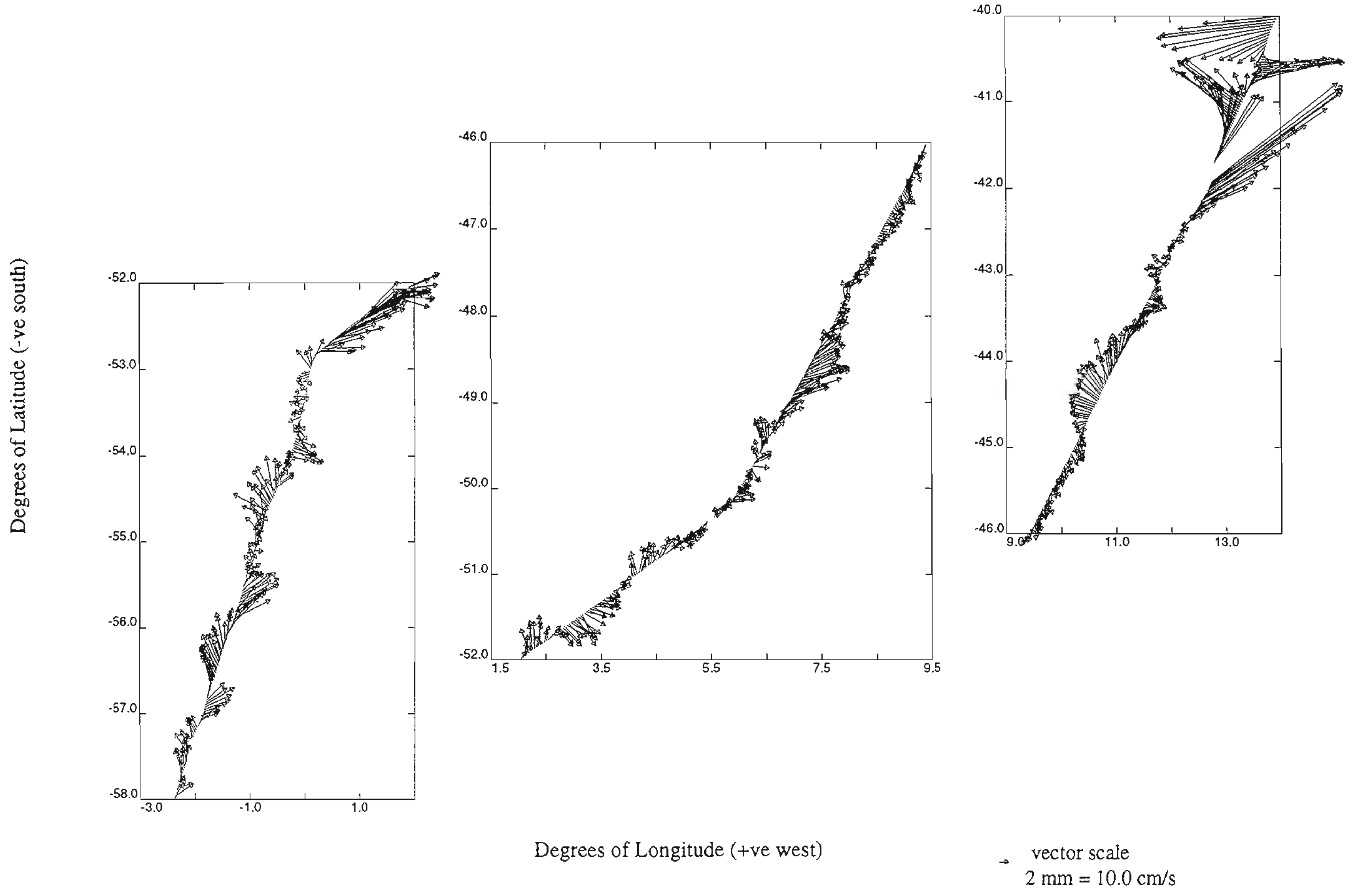
```
10
,,$ticks/
3
$DIR/$file[$seg]
s mx11;e


!

     @ seg = $seg + 1

   end
#
#      Run udisp; if the last argument is 'post' setup
#      driver for postscript.
#
udisp:

   set driver = mx11
   if ( $argv[$#argv] == post ) set driver = hcposta4
#  /users/pstar/users/mike/exec/udisp << !
   udisp << !
0
1,2,3/
3,1
2,1
1,1
3
2
s $driver;e
$page_size/
$ratio
97,251,3,0,1
ADCP $title
97,246,2.5,0,1
Absolute Backscatter Amplitude (dB)
12,210,2,90,1
Depth (metres)
97,172,2,0,1
Latitude (degrees)
-1/
$ratio
97,166,2.5,0,1
Relative Backscatter Amplitude (dB)
12,130,2,90,1
Depth (metres)
97,92,2,0,1
Latitude (degrees)
-1/
$ratio
97,86,2.5,0,1
Percent Good Pings (%)
12,50,2,90,1
Depth (metres)
97,12,2,0,1
Latitude (degrees)
-1/
!
```

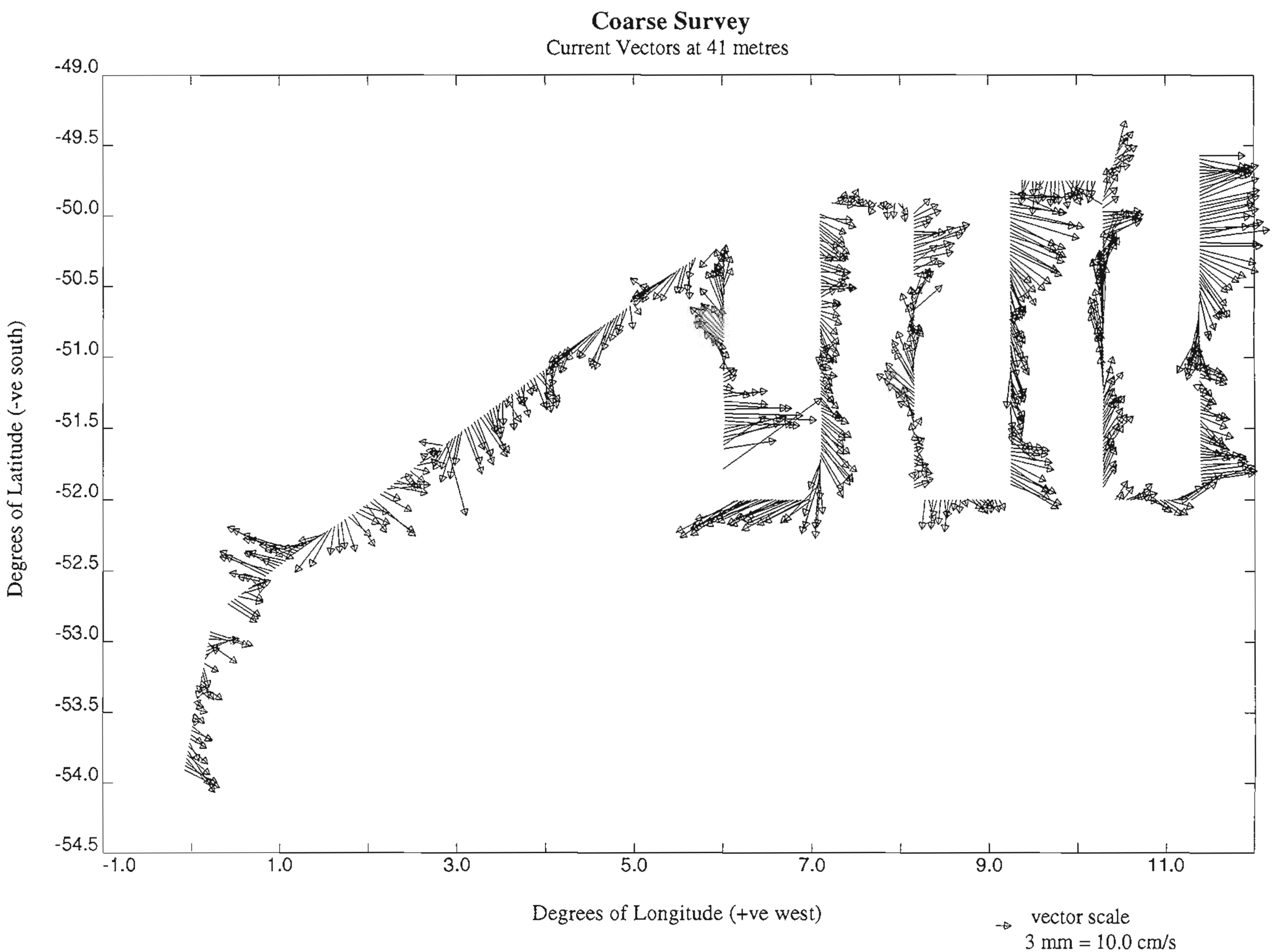


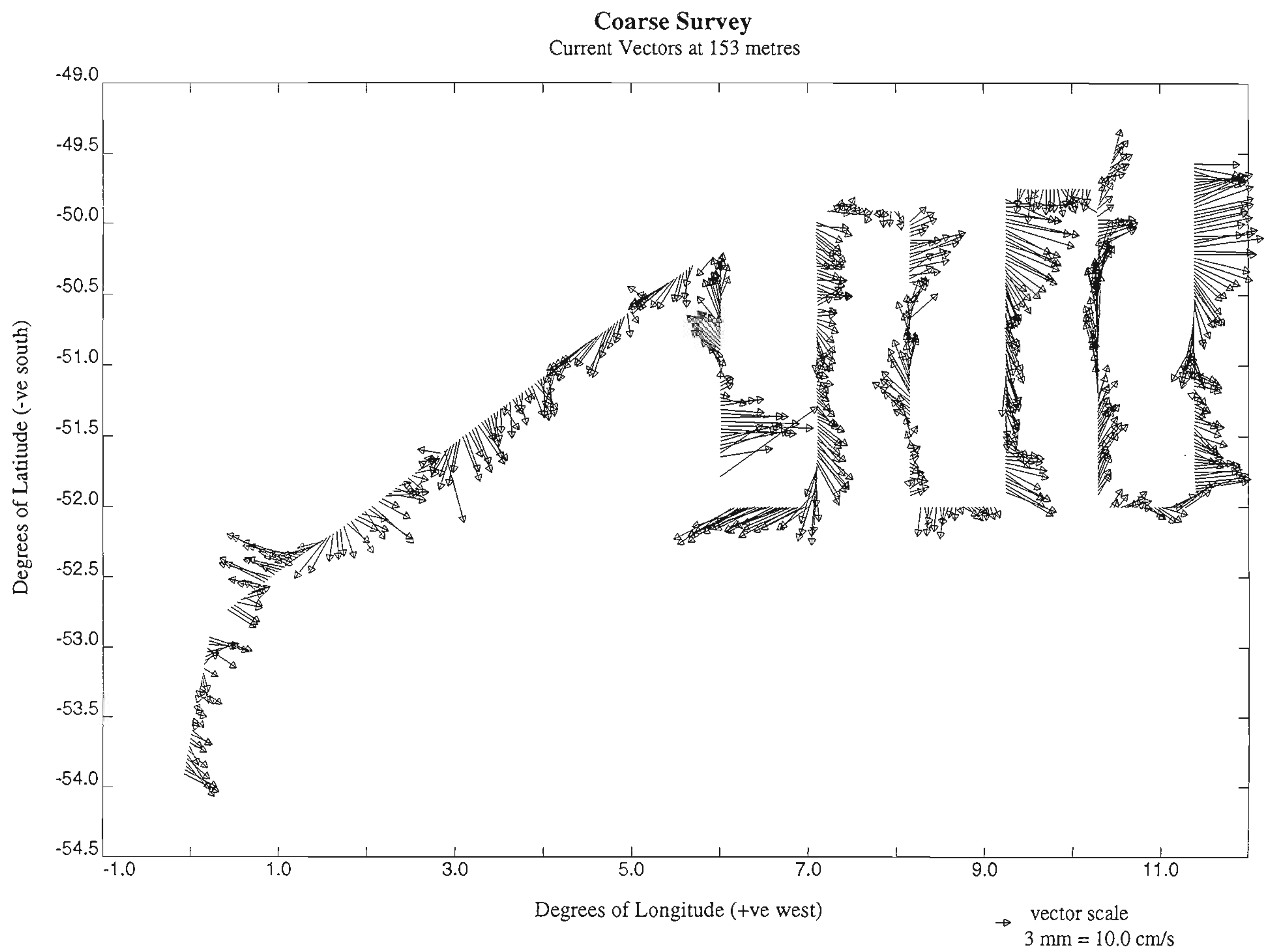
Scatter plot of the difference between GPS heading and ship's gyro heading (Y - axis) against ship's gyro heading (X - axis). Note the quantisation noise of 0.1° that is present in both ship's gyro and GPS headings.

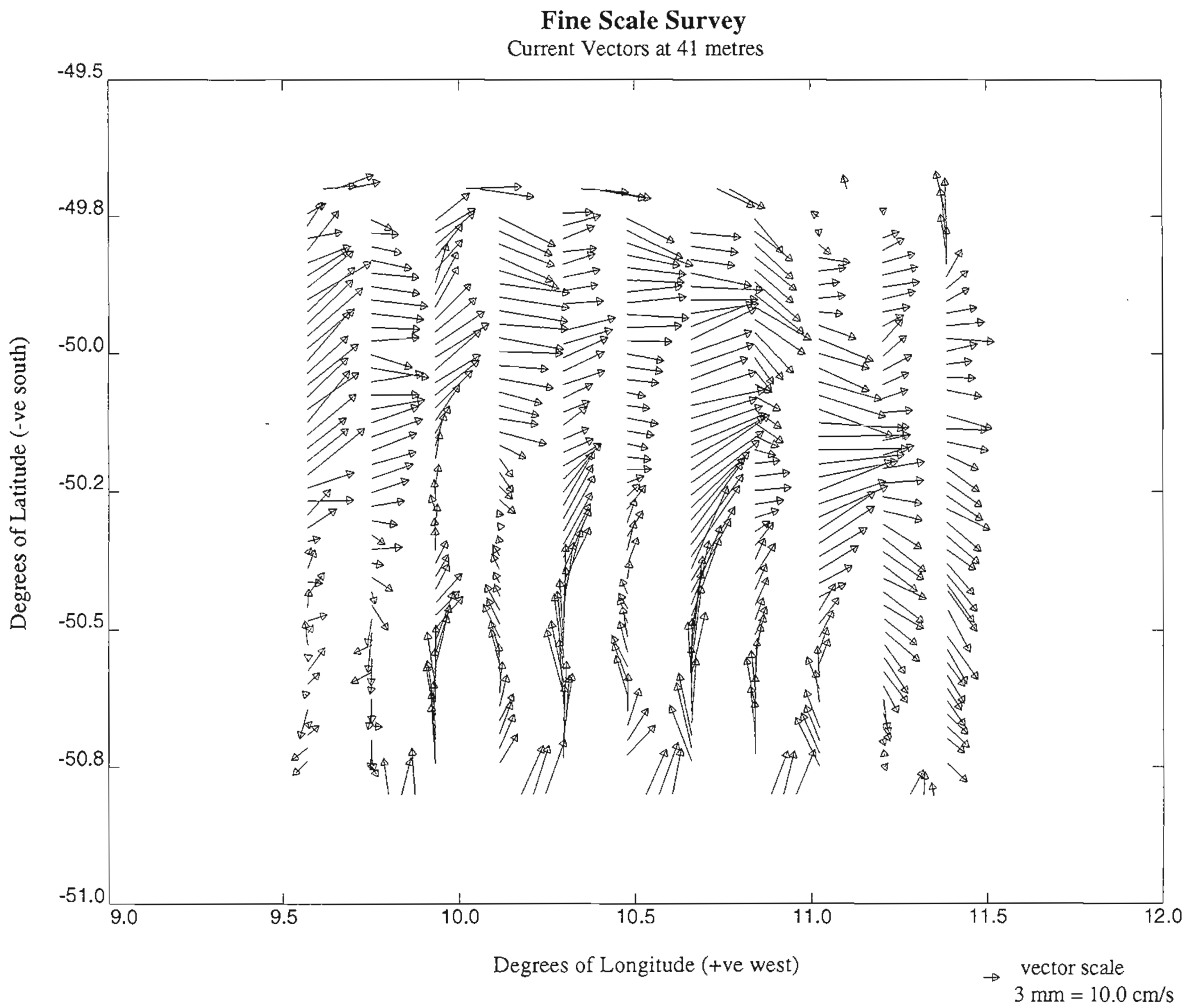
ADCP runs 2 and 3

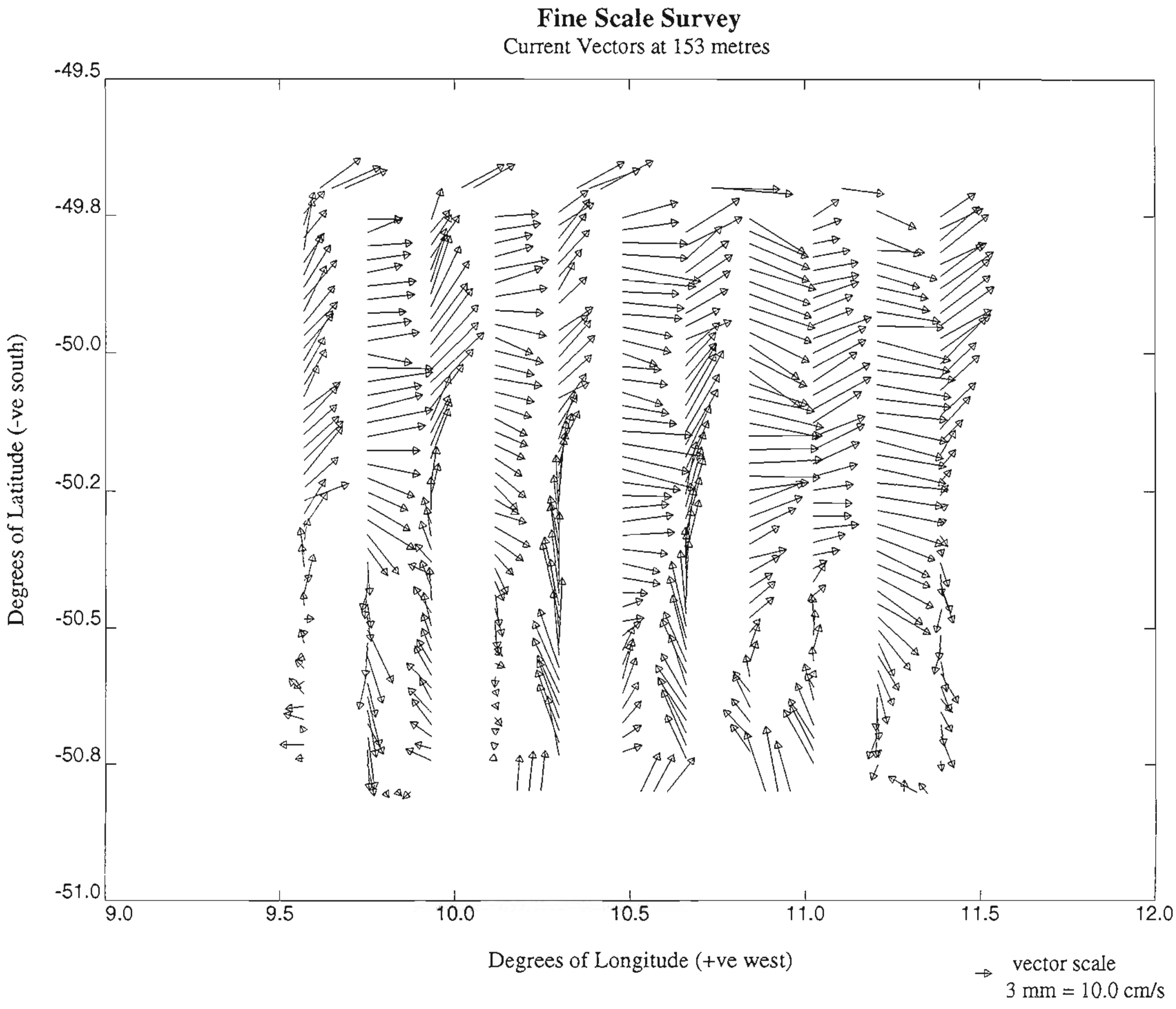
Current Vectors at 153 metres




Coarse Survey
Current Vectors at 41 metres
-49.0
-49.5
-50.0
-50.5
-51.0
-51.5
-52.0
-52.5
-53.0
-53.5
-54.0
-54.5
Degrees of Latitude (-ve south)
-1.0
1.0
3.0
5.0
7.0
9.0
11.0
Degrees of Longitude (+ve west)
vector scale
3 mm = 10.0 cm/s

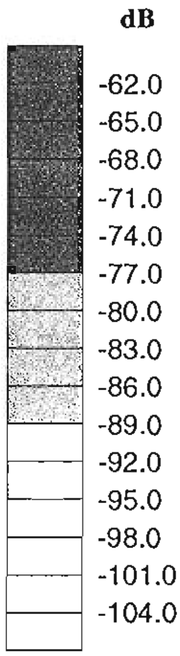

Coarse Survey
Current Vectors at 153 metres
-49.0
-49.5
-50.0
-50.5
-51.0
-51.5
-52.0
-52.5
-53.0
-53.5
-54.0
-54.5
Degrees of Latitude (-ve south)
-1.0
1.0
3.0
5.0
7.0
9.0
11.0
Degrees of Longitude (+ve west)
vector scale
3 mm = 10.0 cm/s


Fine Scale Survey
Current Vectors at 41 metres
-49.5
-49.8
-50.0
-50.2
-50.5
-50.8
-51.0
Degrees of Latitude (-ve south)
9.0
9.5
10.0
10.5
11.0
11.5
12.0
Degrees of Longitude (+ve west)
vector scale
3 mm = 10.0 cm/s

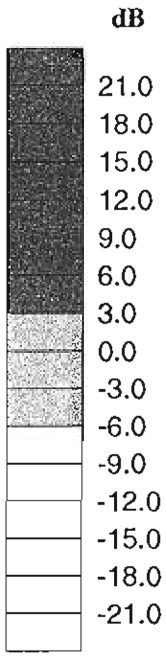

Fine Scale Survey
Current Vectors at 153 metres
-49.5
-49.8
-50.0
-50.2
-50.5
-50.8
-51.0
Degrees of Latitude (-ve south)
9.0
9.5
10.0
10.5
11.0
11.5
12.0
Degrees of Longitude (+ve west)
vector scale
3 mm = 10.0 cm/s

Grey scales for the contoured sections

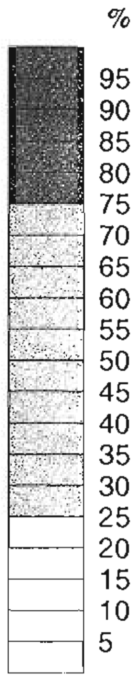
Absolute backscatter amplitude



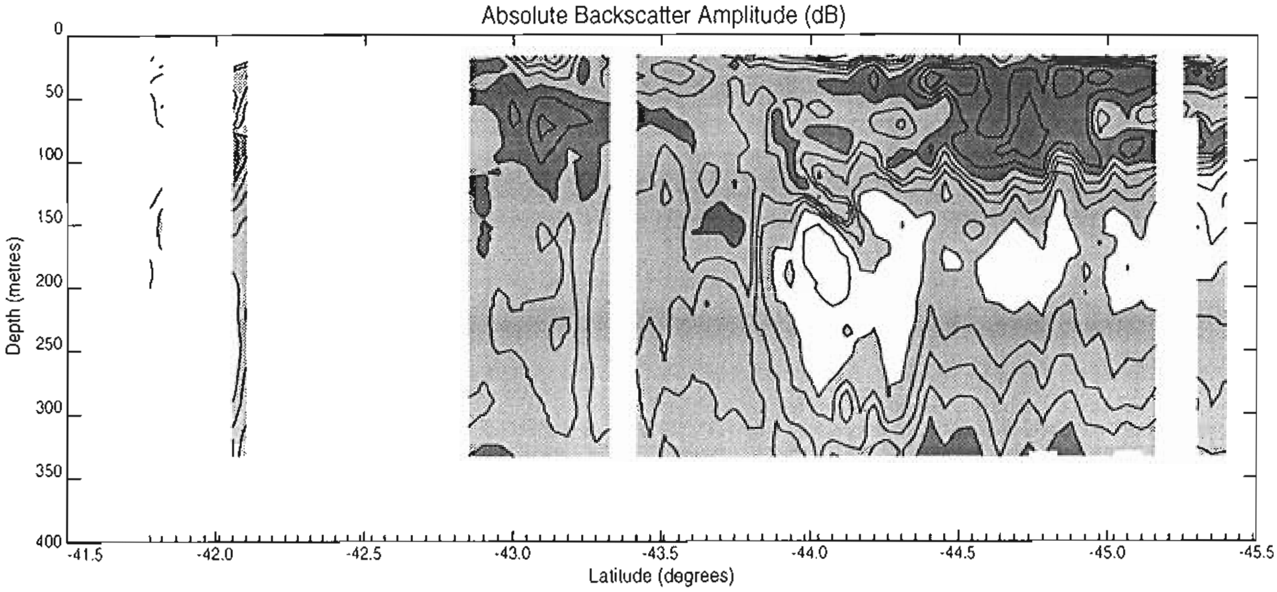
Relative backscatter amplitude

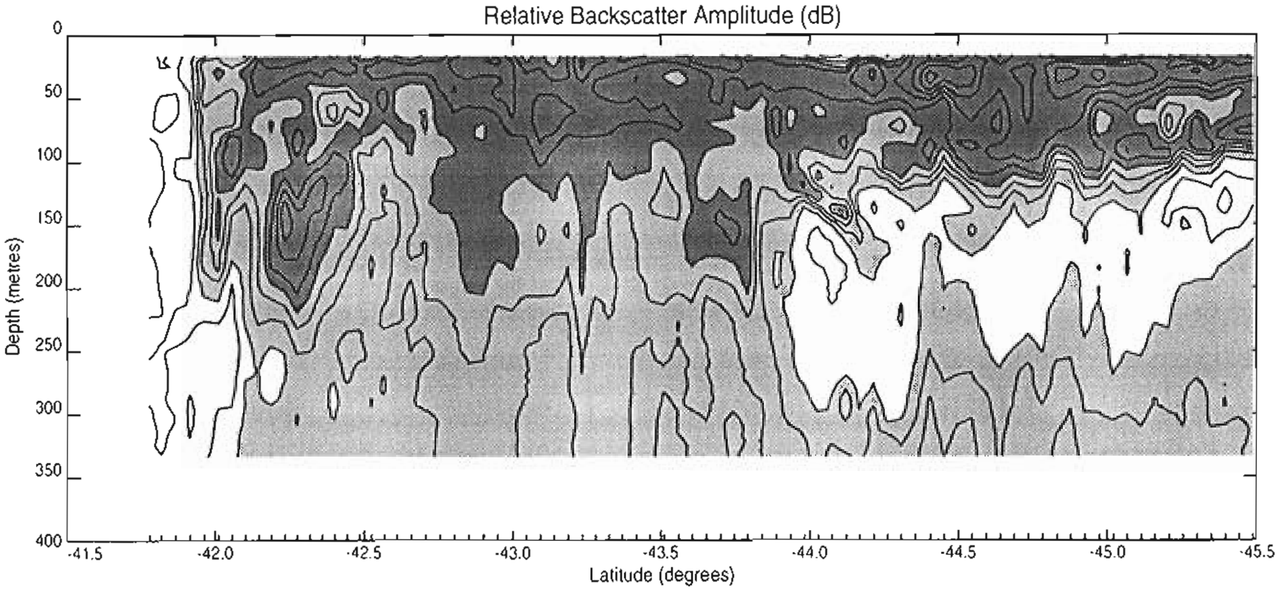


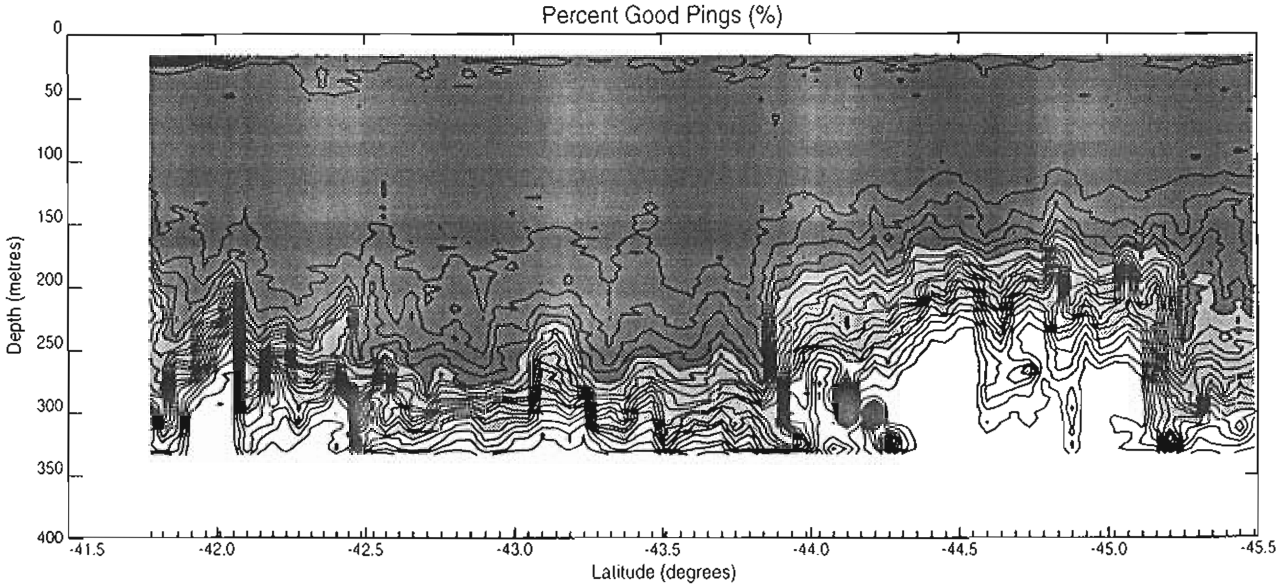
Percent good pings



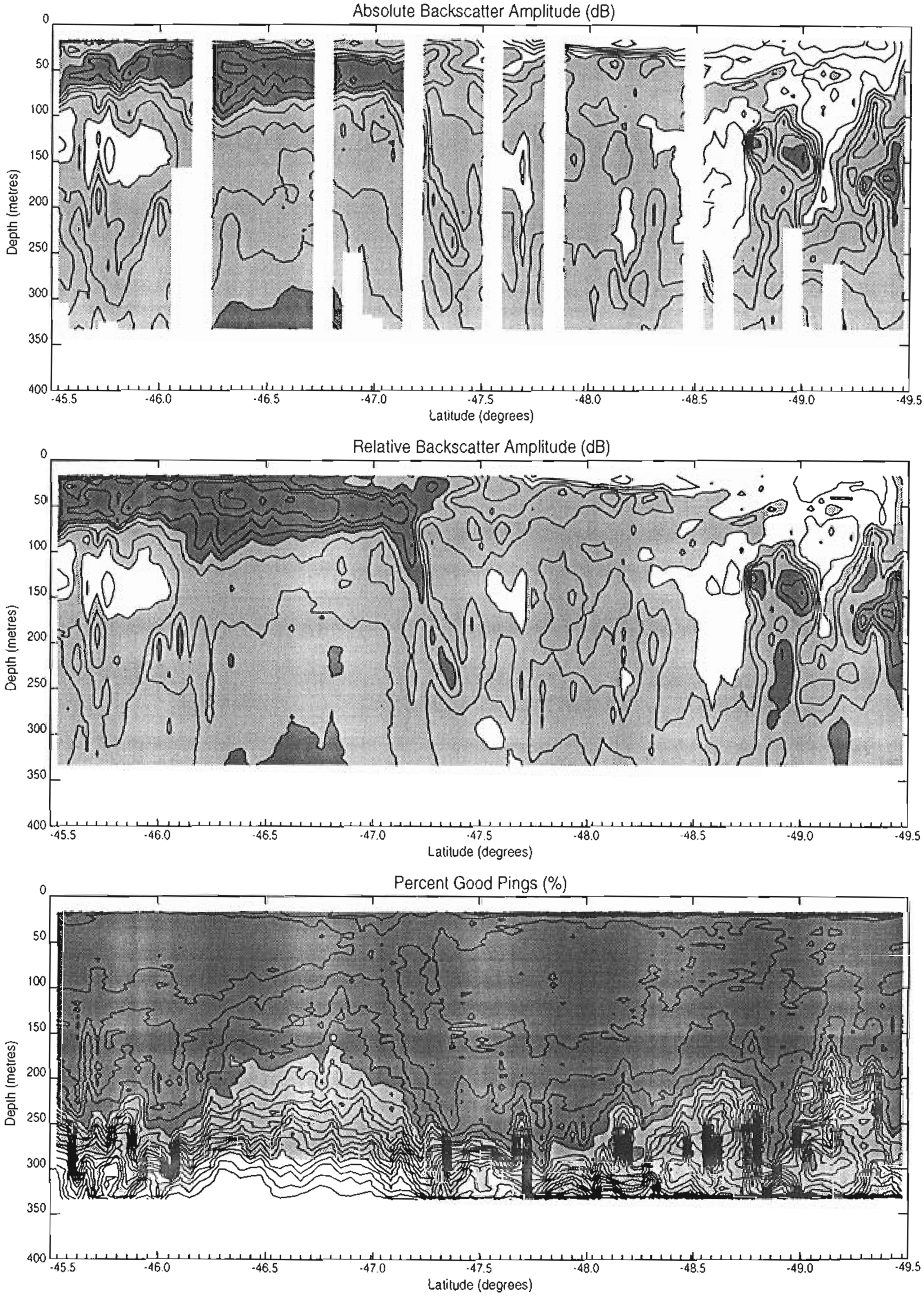
ADCP Run 2


Absolute Backscatter Amplitude (dB)
Depth (metres)
0
50
100
150
200
250
300
350
400
-41.5
-42.0
-42.5
-43.0
-43.5
-44.0
-44.5
-45.0
-45.5
Latitude (degrees)

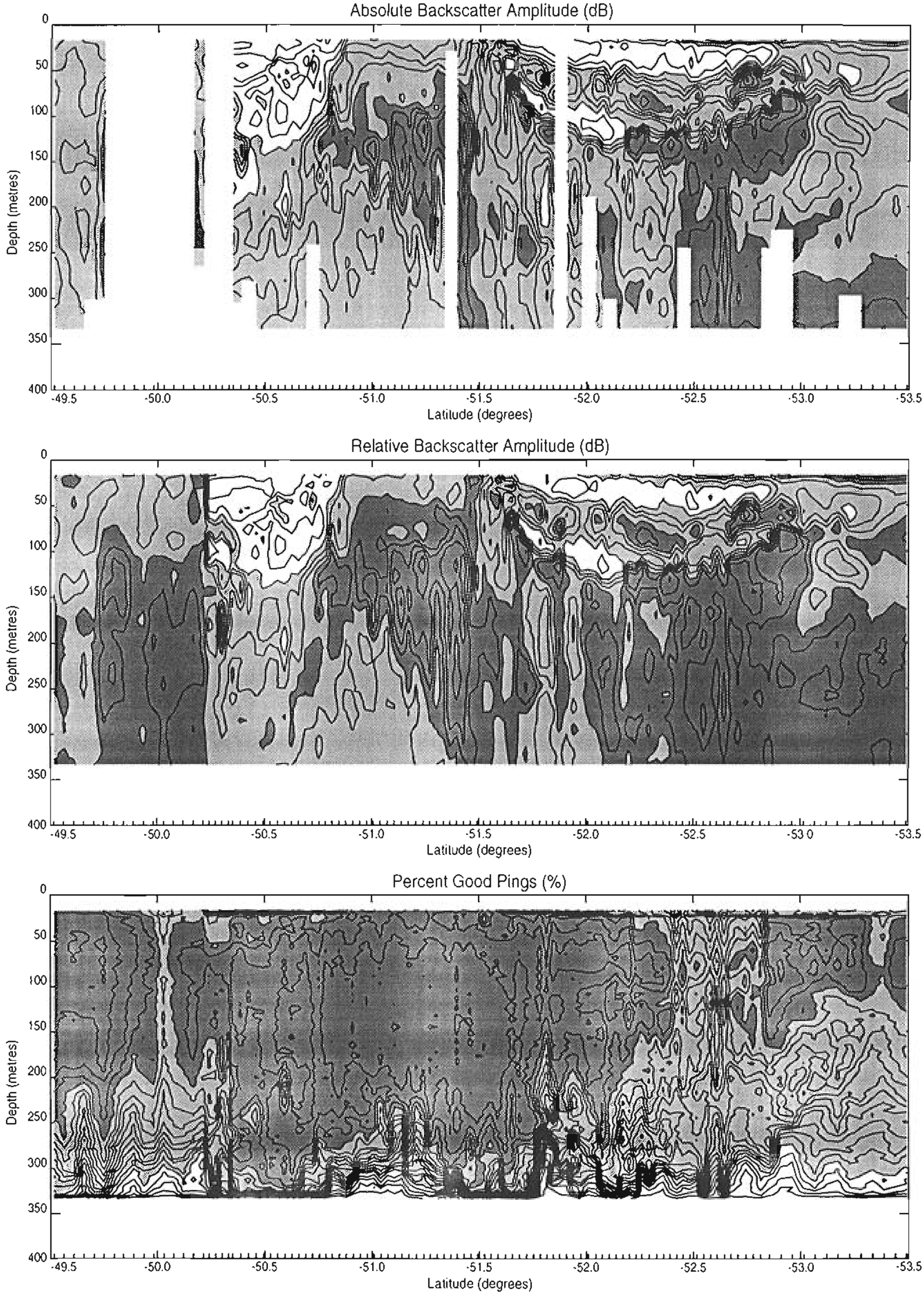

Relative Backscatter Amplitude (dB)
Depth (metres)
0
50
100
150
200
250
300
350
400
-41.5
-42.0
-42.5
-43.0
-43.5
-44.0
-44.5
-45.0
-45.5
Latitude (degrees)


Percent Good Pings (%)
Depth (metres)
0
50
100
150
200
250
300
350
400
-41.5
-42.0
-42.5
-43.0
-43.5
-44.0
-44.5
-45.0
-45.5
Latitude (degrees)

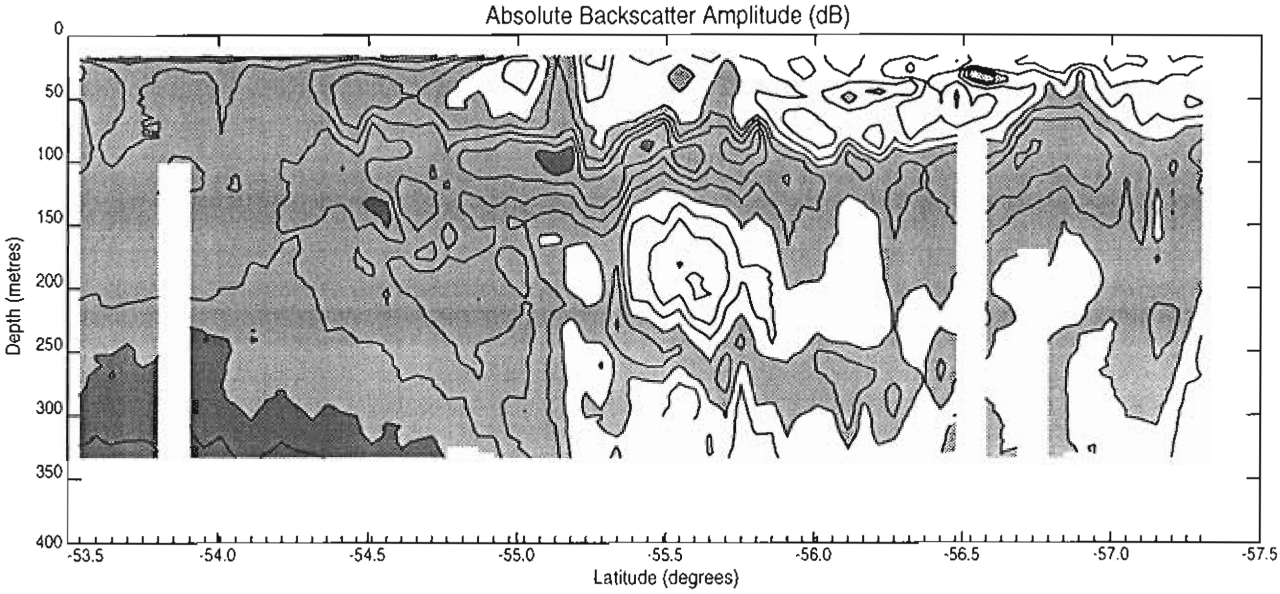
ADCP Run 2

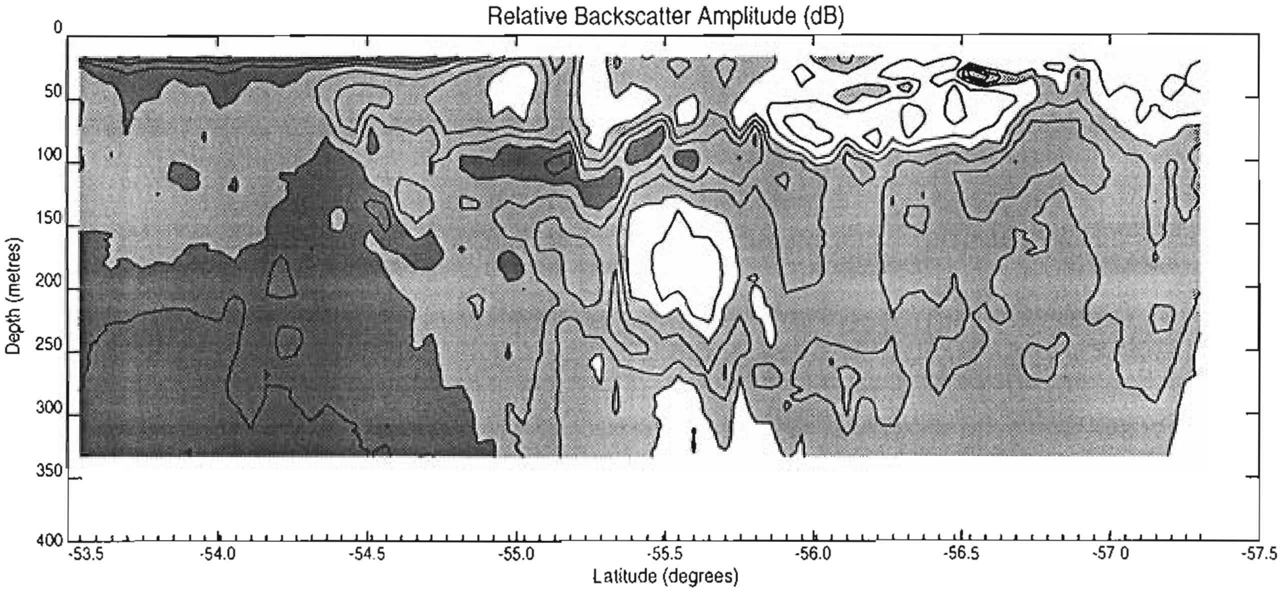

Absolute Backscatter Amplitude (dB)
Depth (metres)
0
50
100
150
200
250
300
350
400
-45.5
-46.0
-46.5
-47.0
-47.5
-48.0
-48.5
-49.0
-49.5
Latitude (degrees)
Relative Backscatter Amplitude (dB)
Depth (metres)
Latitude (degrees)
Percent Good Pings (%)
Depth (metres)
Latitude (degrees)

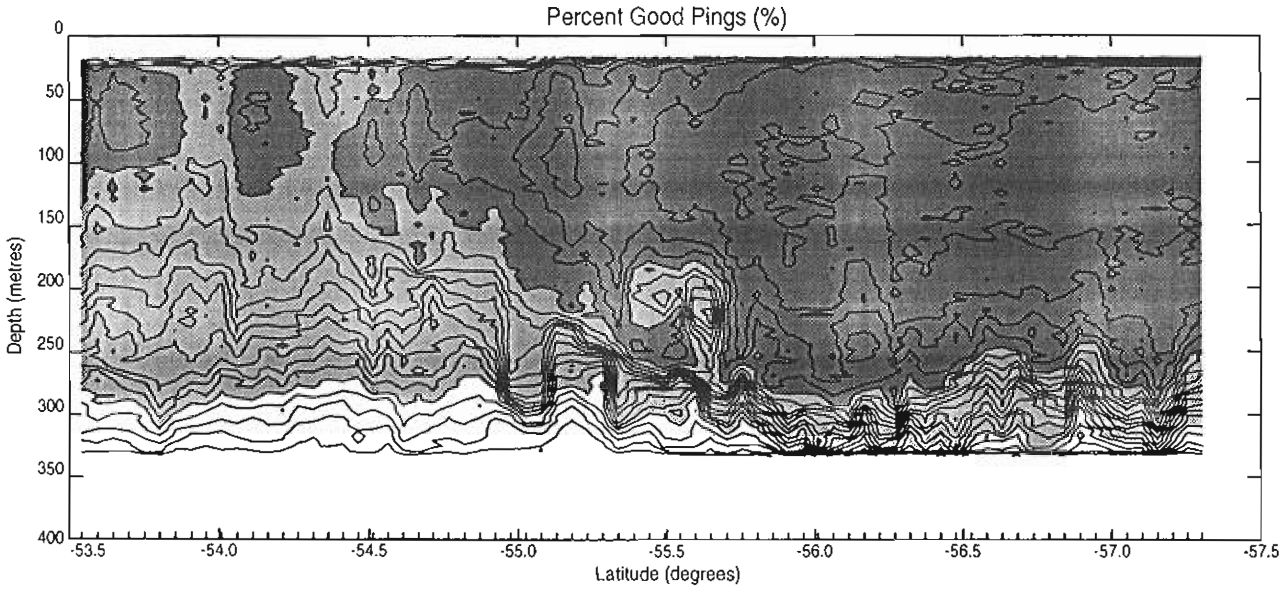
ADCP Run 2 & 3


Absolute Backscatter Amplitude (dB)
Relative Backscatter Amplitude (dB)
Percent Good Pings (%)
Depth (metres)
0
50
100
150
200
250
300
350
400
Latitude (degrees)
-49.5
-50.0
-50.5
-51.0
-51.5
-52.0
-52.5
-53.0
-53.5

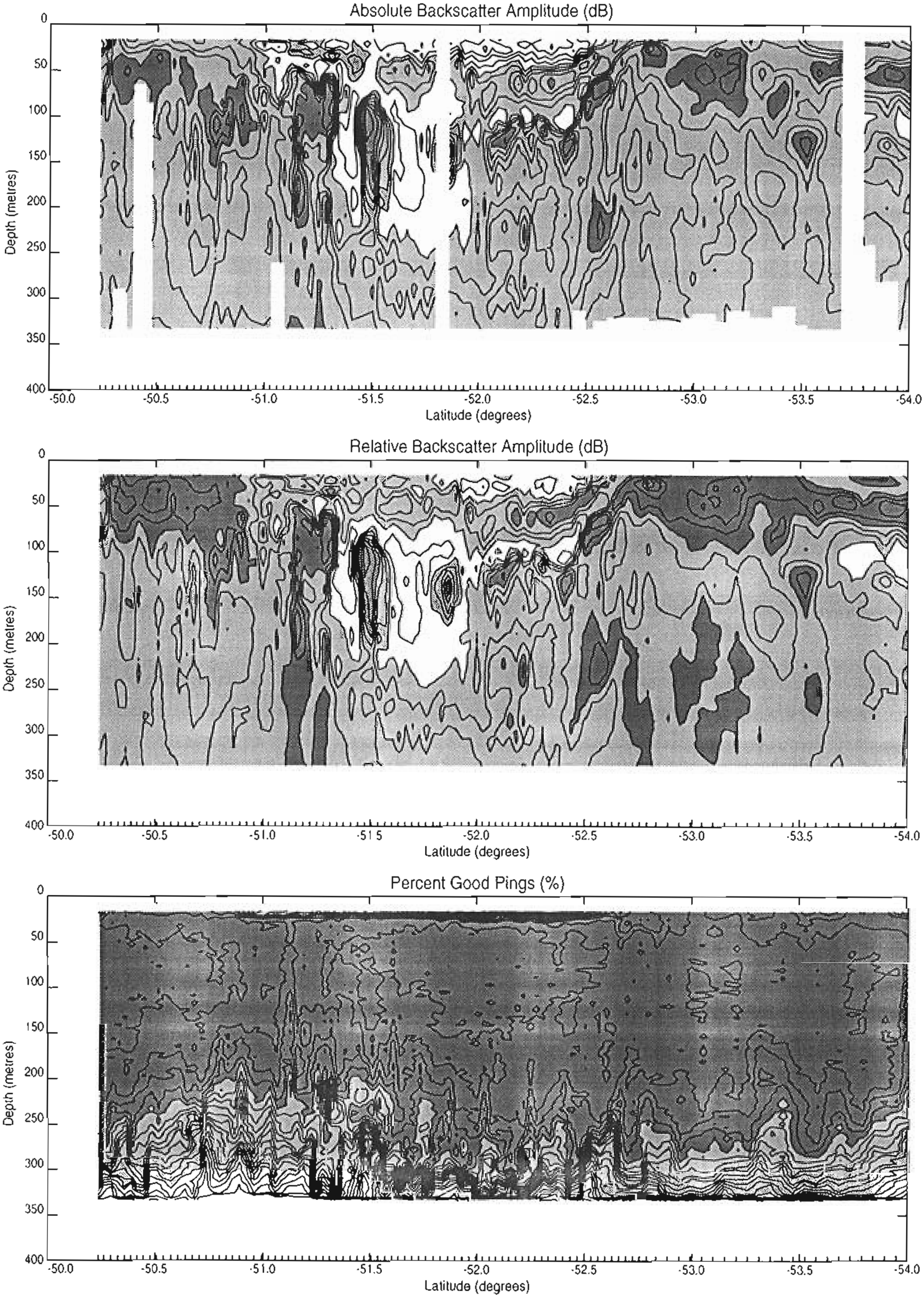
ADCP Run 3


Absolute Backscatter Amplitude (dB)
Depth (metres)
0
50
100
150
200
250
300
350
400
-53.5
-54.0
-54.5
-55.0
-55.5
-56.0
-56.5
-57.0
-57.5
Latitude (degrees)


Relative Backscatter Amplitude (dB)
Depth (metres)
0
50
100
150
200
250
300
350
400
-53.5
-54.0
-54.5
-55.0
-55.5
-56.0
-56.5
-57 0
-57.5
Latitude (degrees)


Percent Good Pings (%)
Depth (metres)
0
50
100
150
200
250
300
350
400
-53.5
-54.0
-54.5
-55.0
-55.5
-56.0
-56.5
-57.0
-57.5
Latitude (degrees)

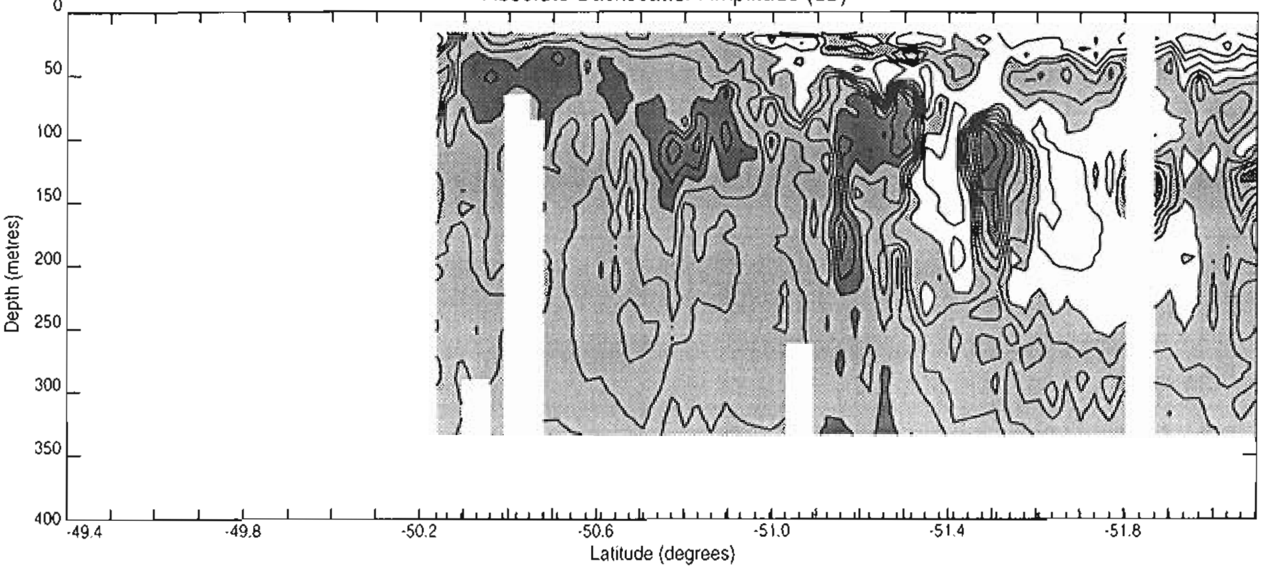
ADCP Run 6.1



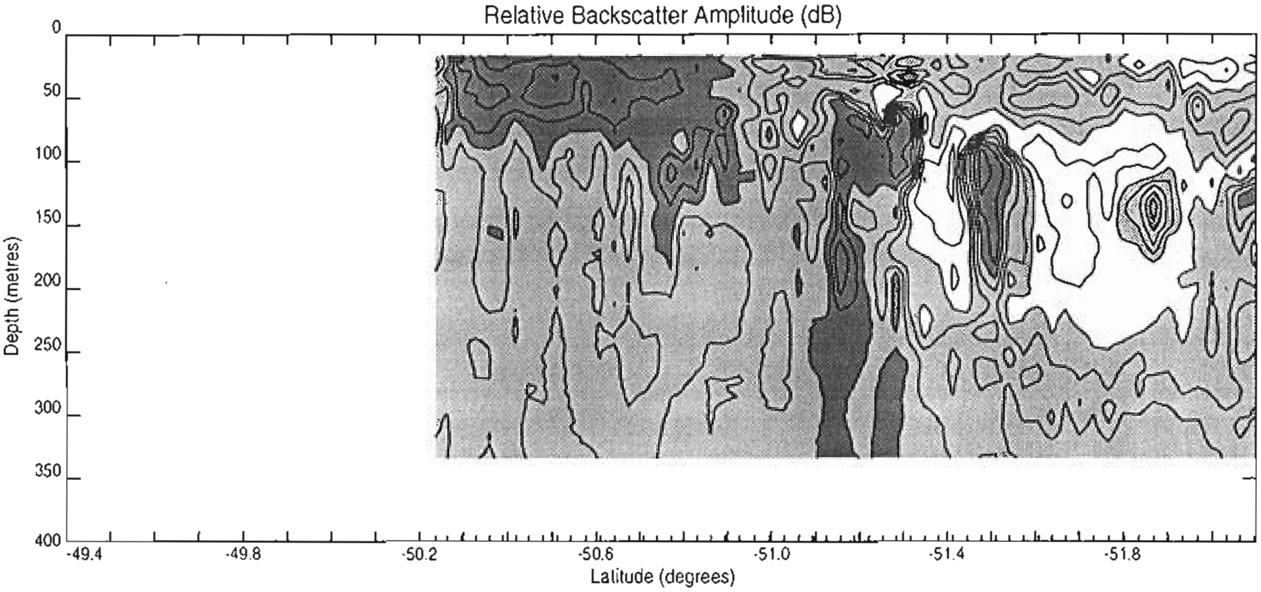
Absolute Backscatter Amplitude (dB)
Depth (metres)
0
50
100
150
200
250
300
350
400
-50.0
-50.5
-51.0
-51.5
-52.0
-52.5
-53.0
-53.5
-54.0
Latitude (degrees)
Relative Backscatter Amplitude (dB)
Percent Good Pings (%)

ADCP Coarse Survey Run 6.1

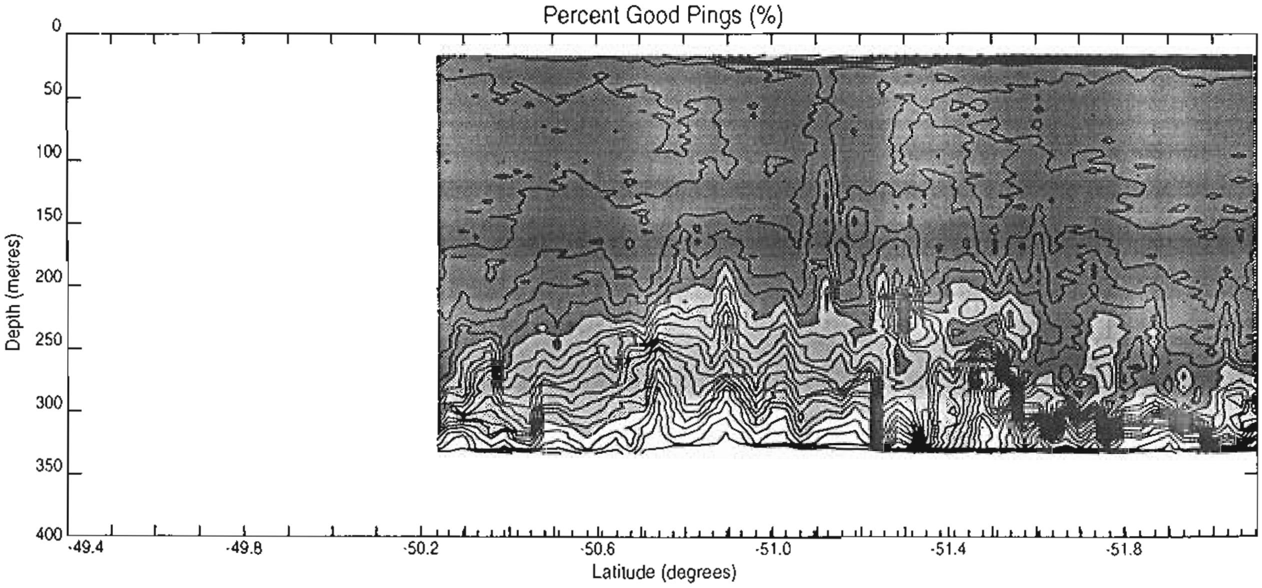
Absolute Backscatter Amplitude (dB)



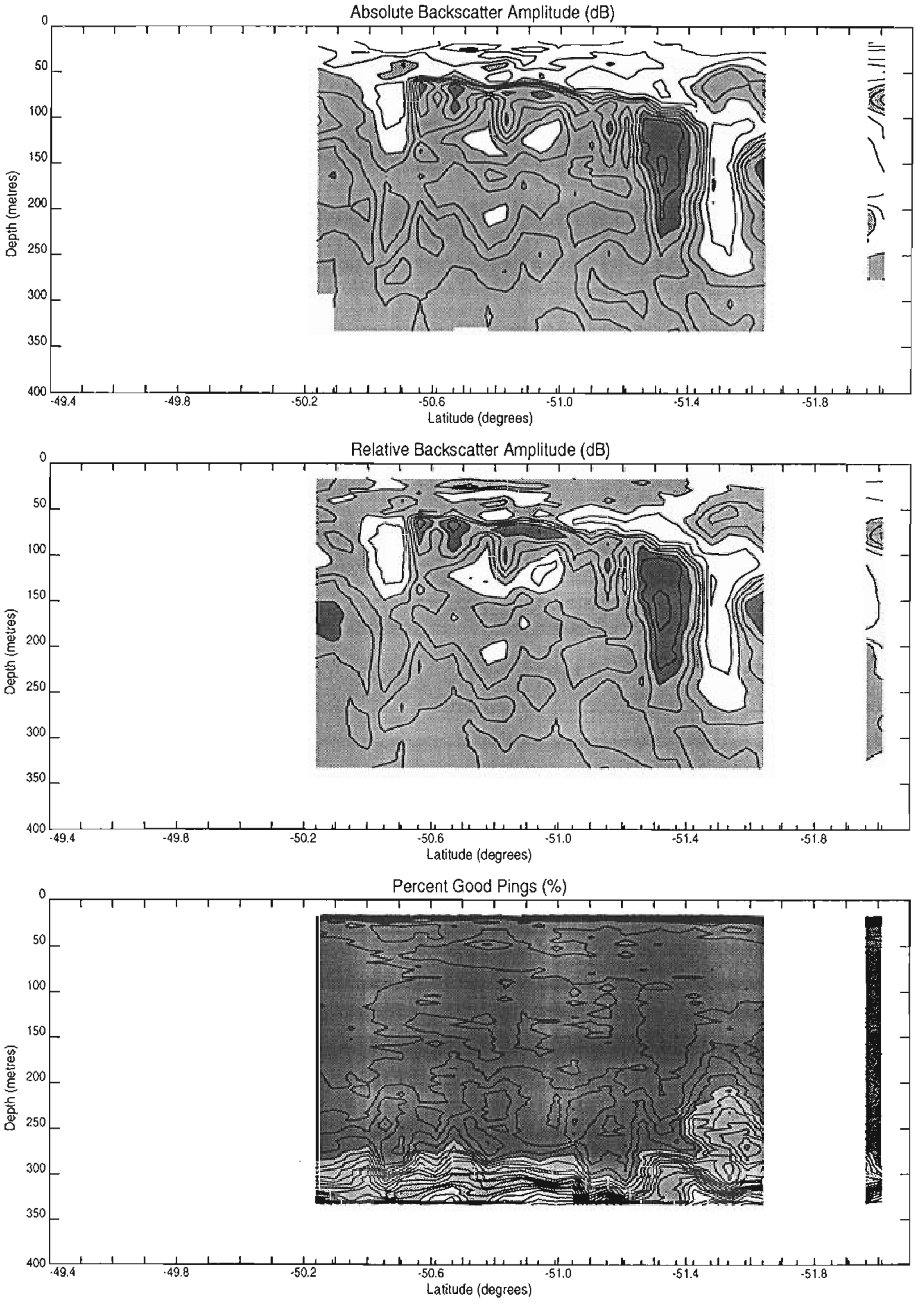
Relative Backscatter Amplitude (dB)



Percent Good Pings (%)

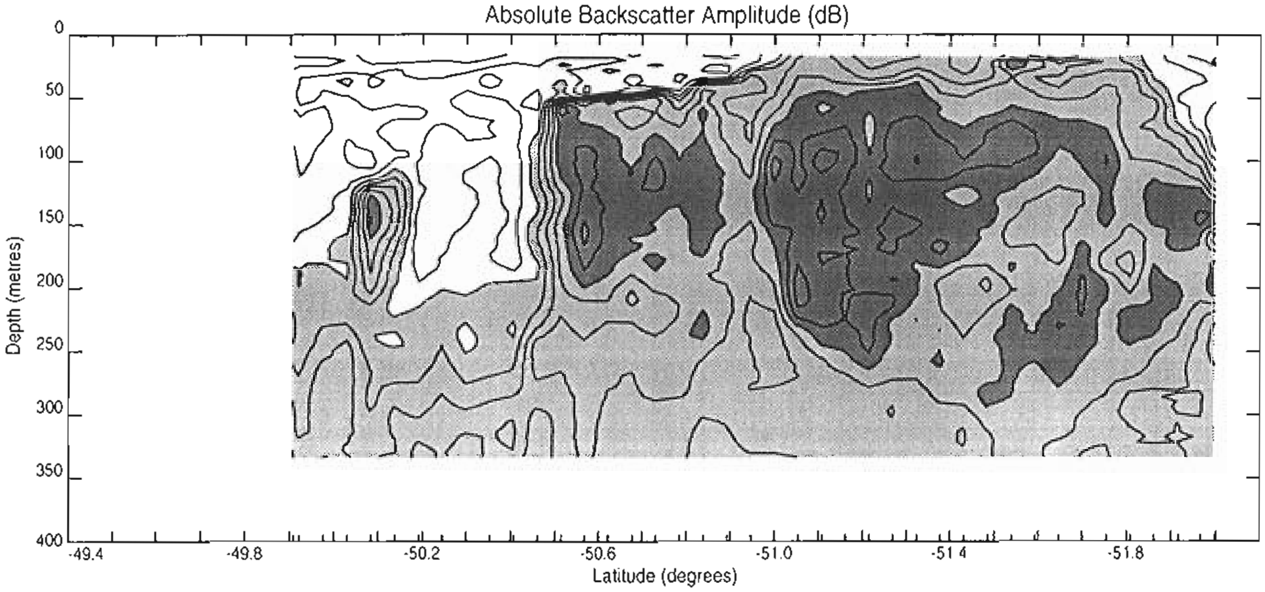


ADCP Coarse Survey Run 6.2

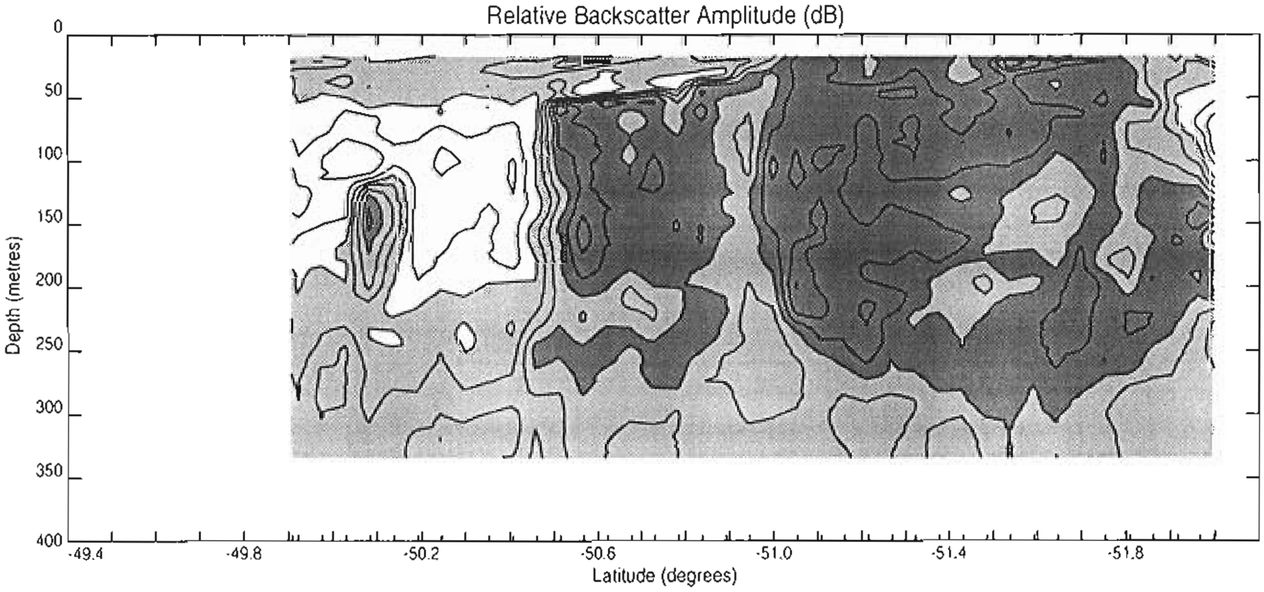


ADCP Coarse Survey Run 6.3

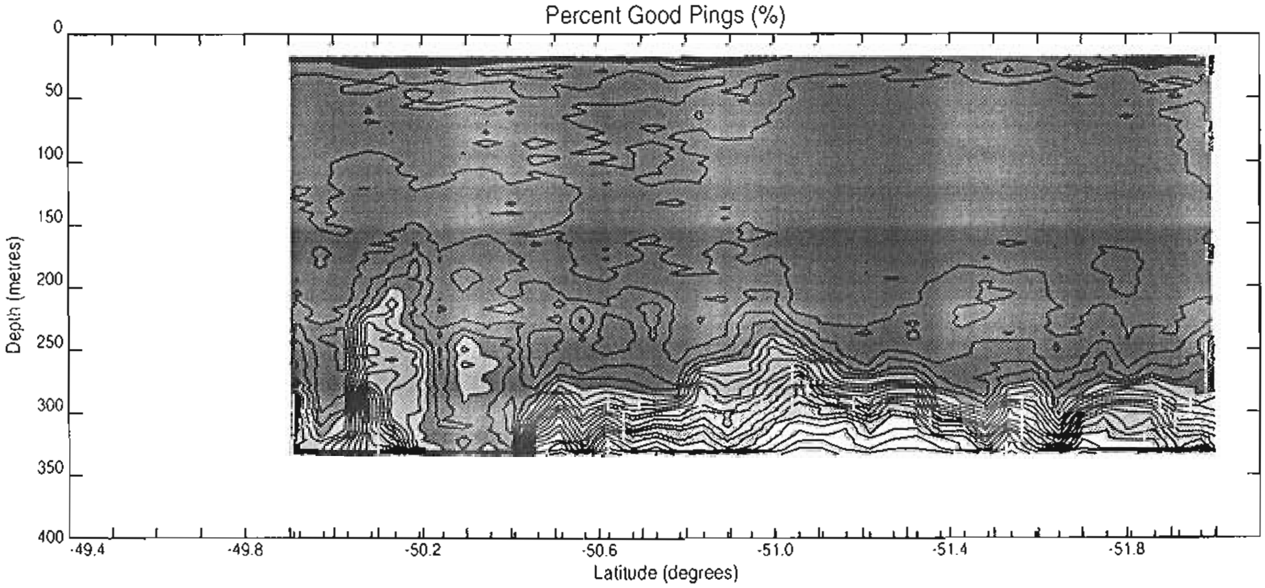
Absolute Backscatter Amplitude (dB)

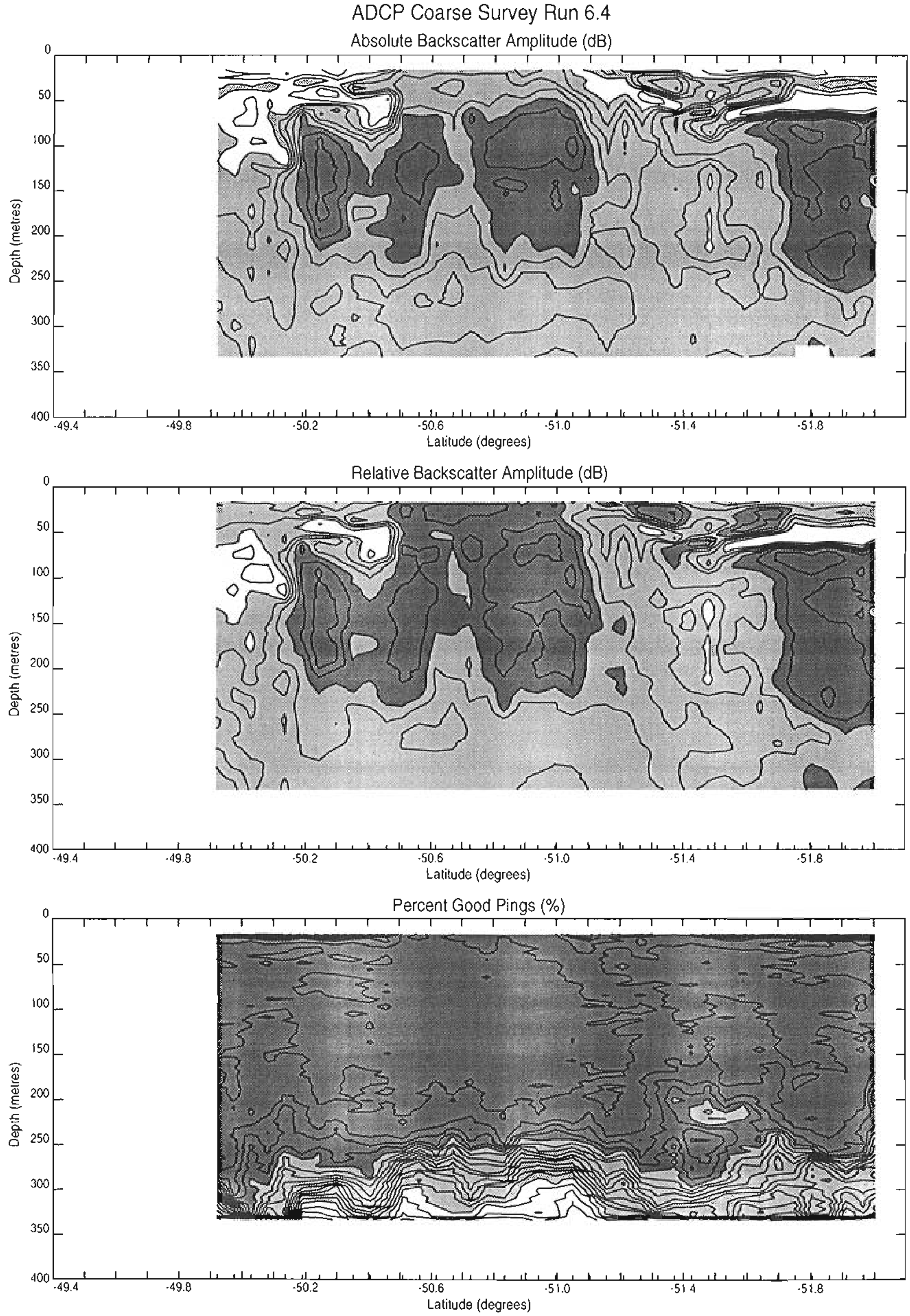


Relative Backscatter Amplitude (dB)

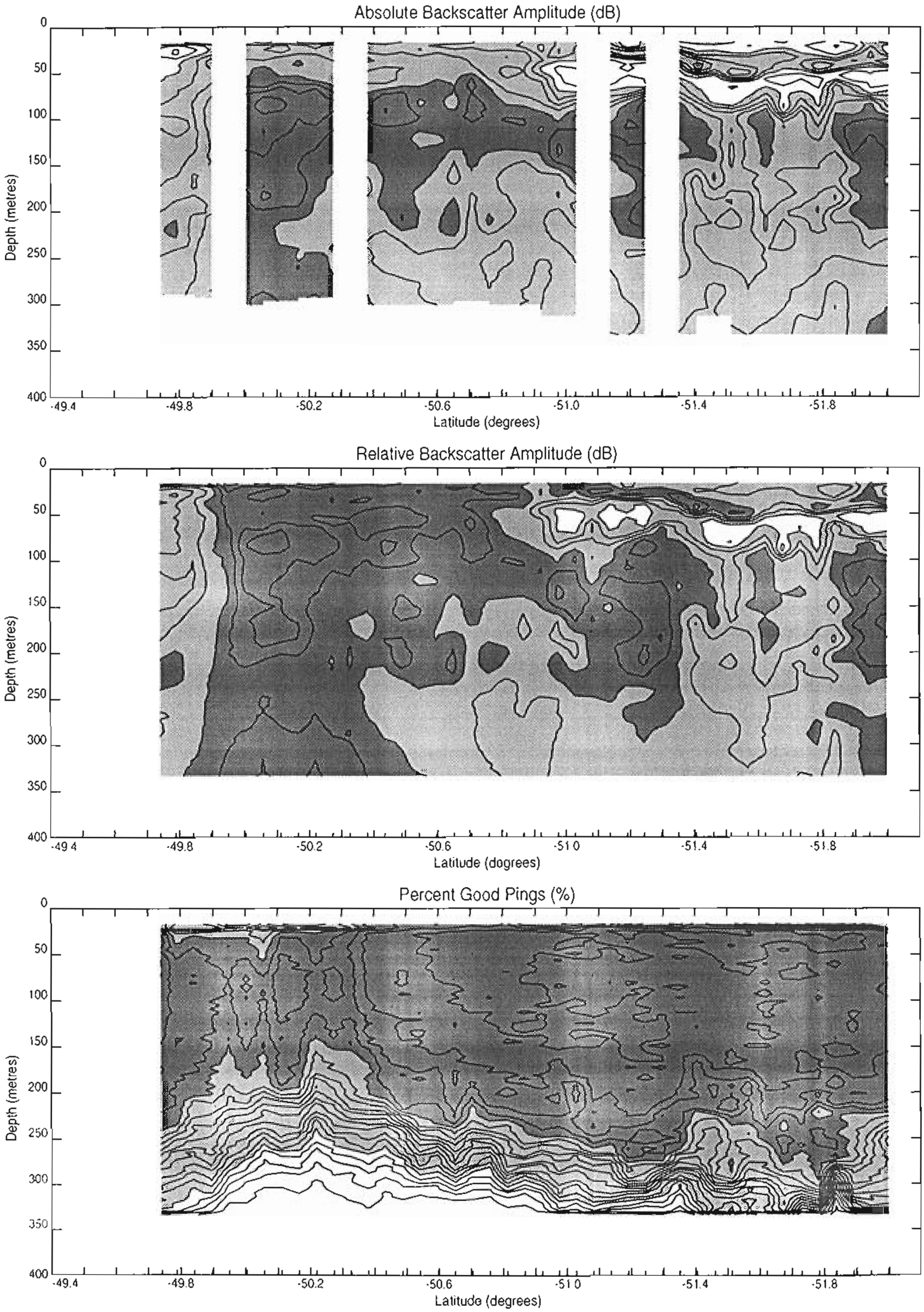


Percent Good Pings (%)

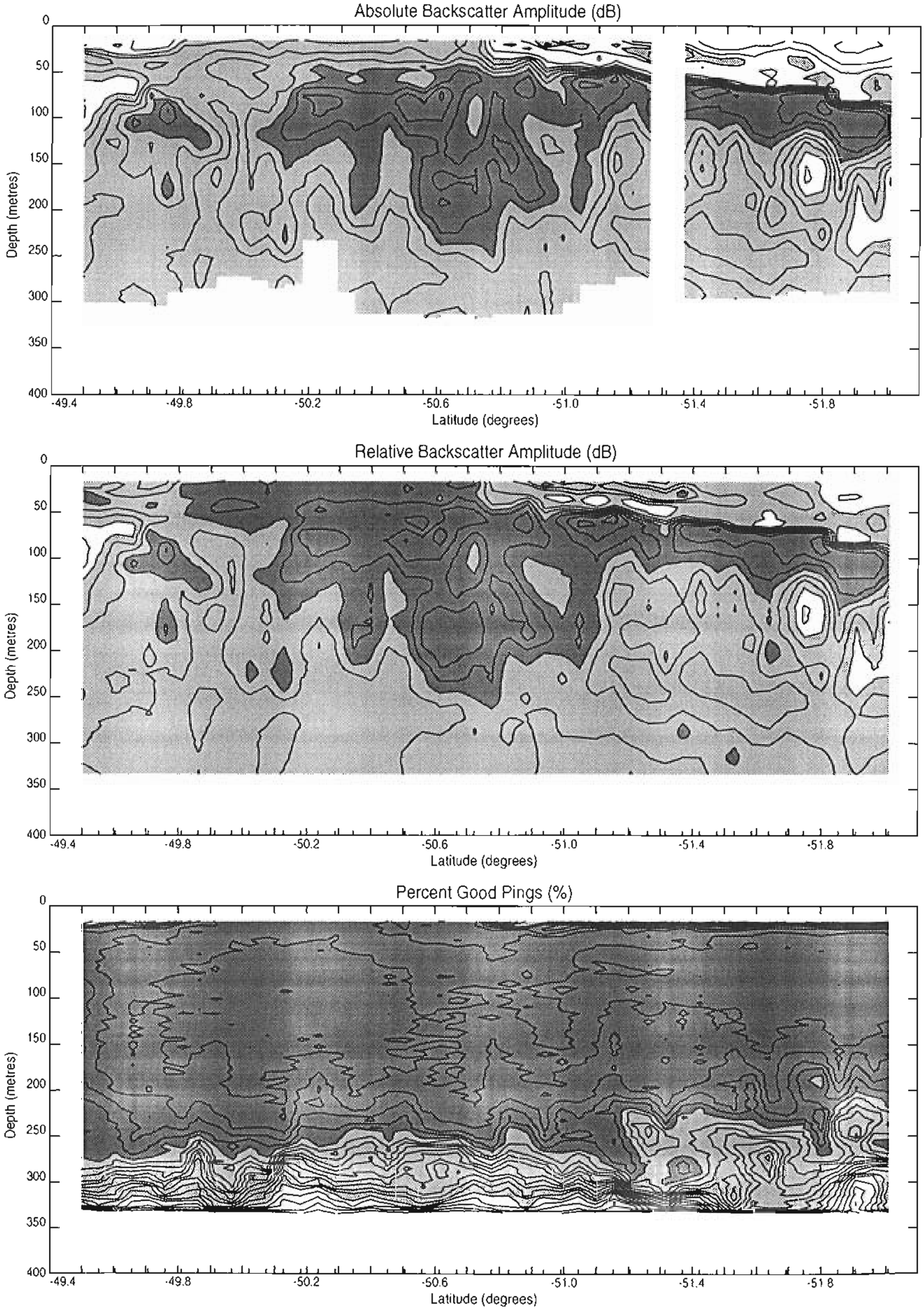



ADCP Coarse Survey Run 6.4
Absolute Backscatter Amplitude (dB)
Relative Backscatter Amplitude (dB)
Percent Good Pings (%)
Depth (metres)
0
50
100
150
200
250
300
350
400
-49.4
-49.8
-50.2
-50.6
-51.0
-51.4
-51.8
Latitude (degrees)

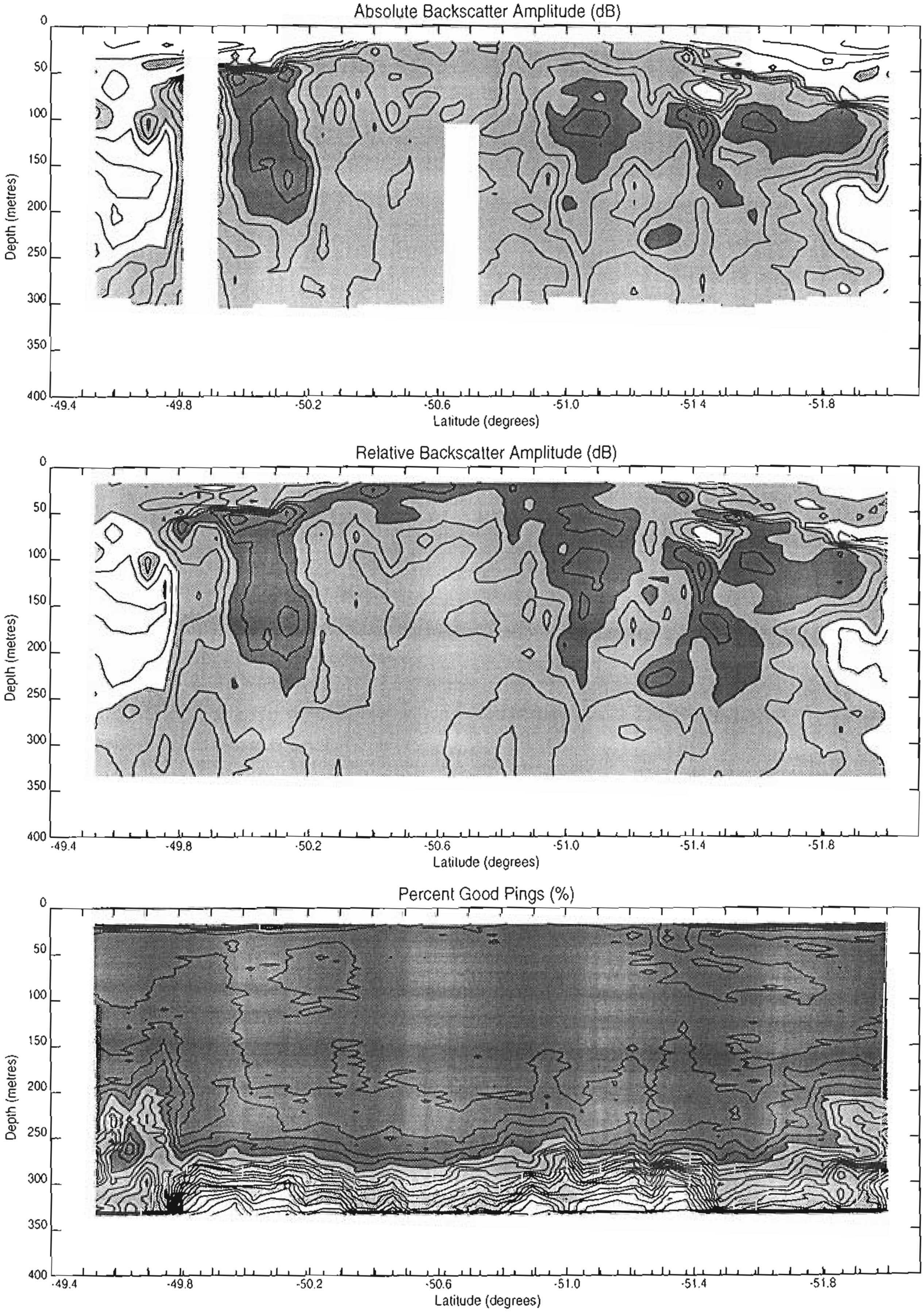
ADCP Coarse Survey Run 6.5



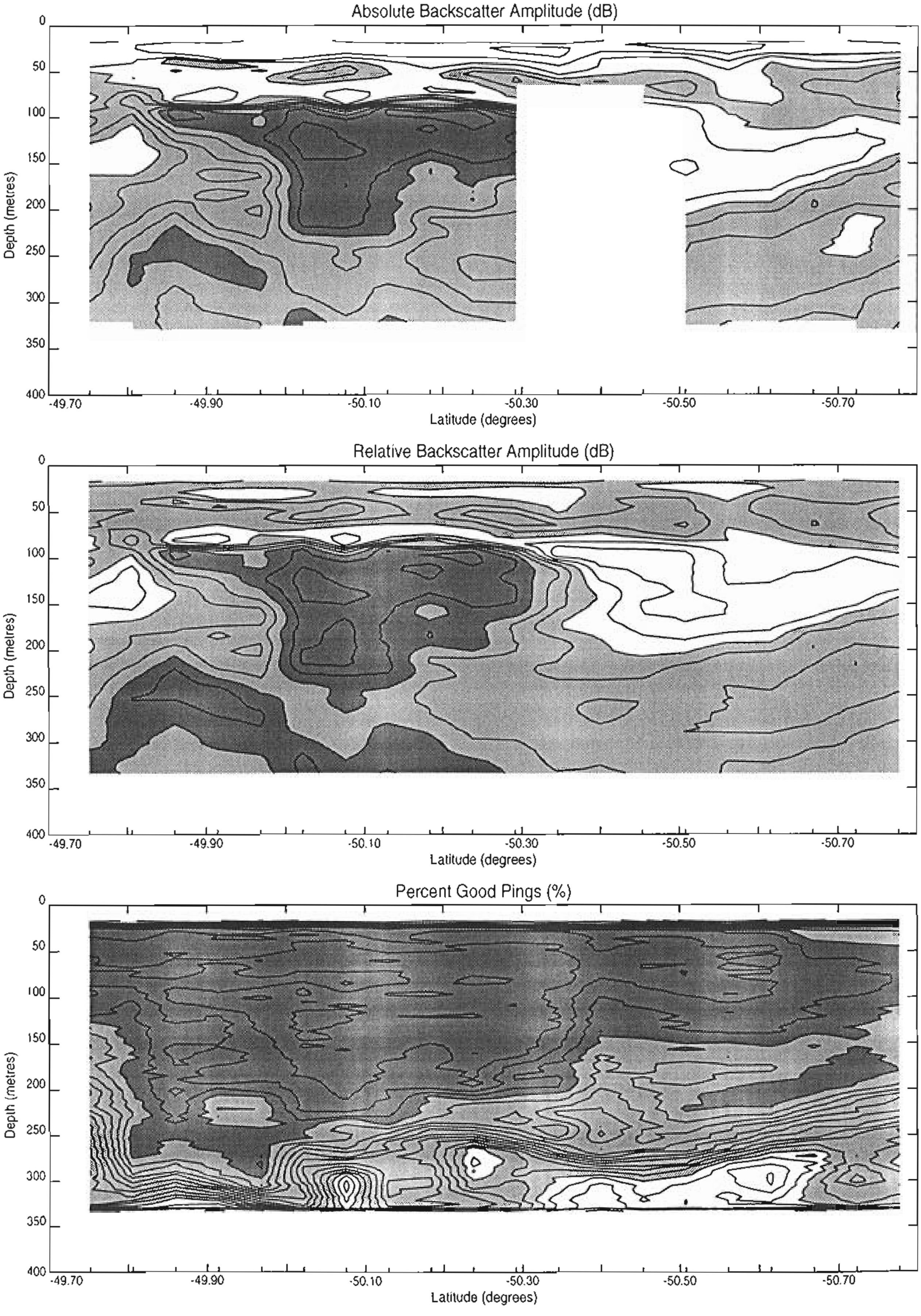
ADCP Coarse Survey Run 6.6



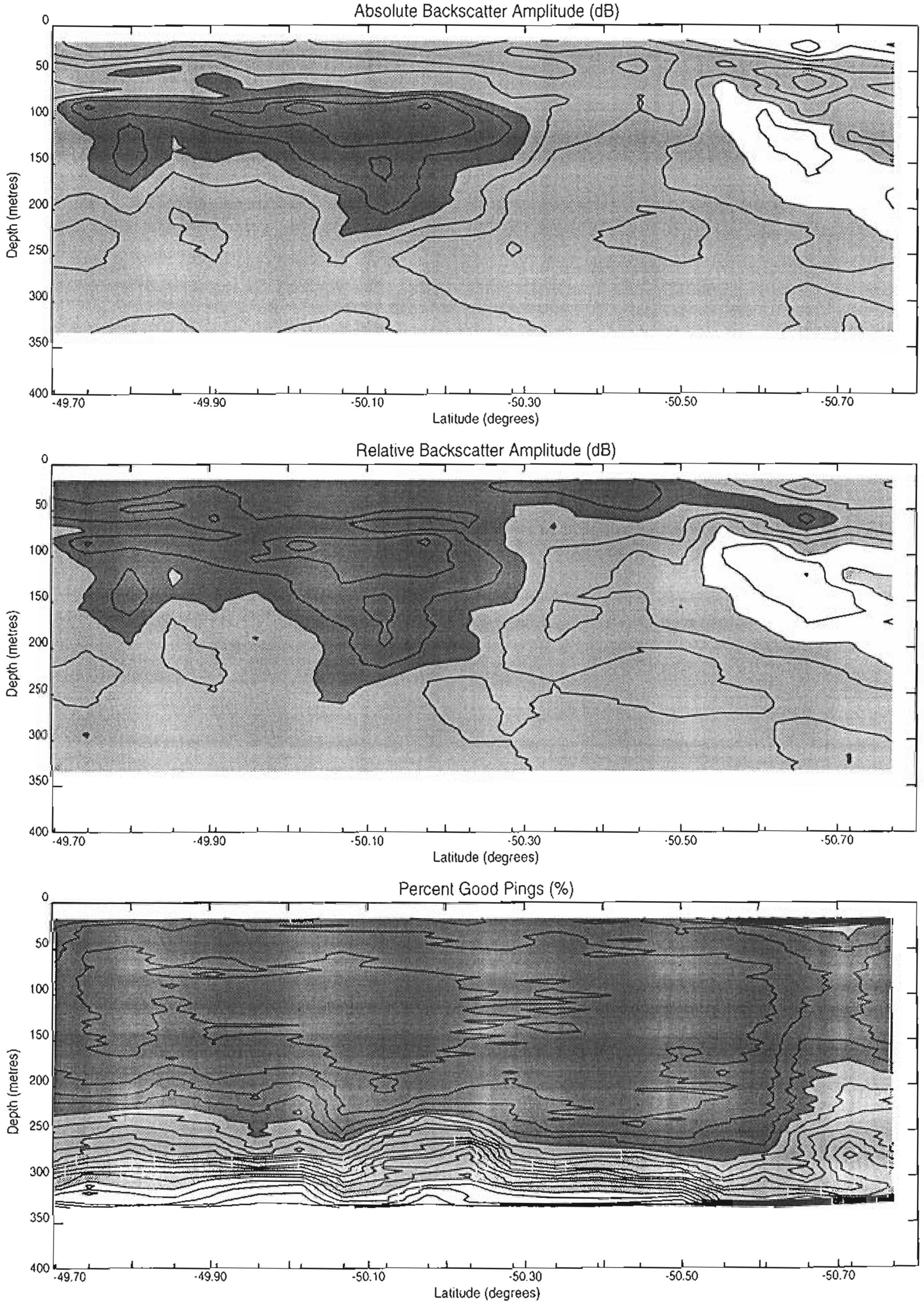
ADCP Coarse Survey Run 6.7



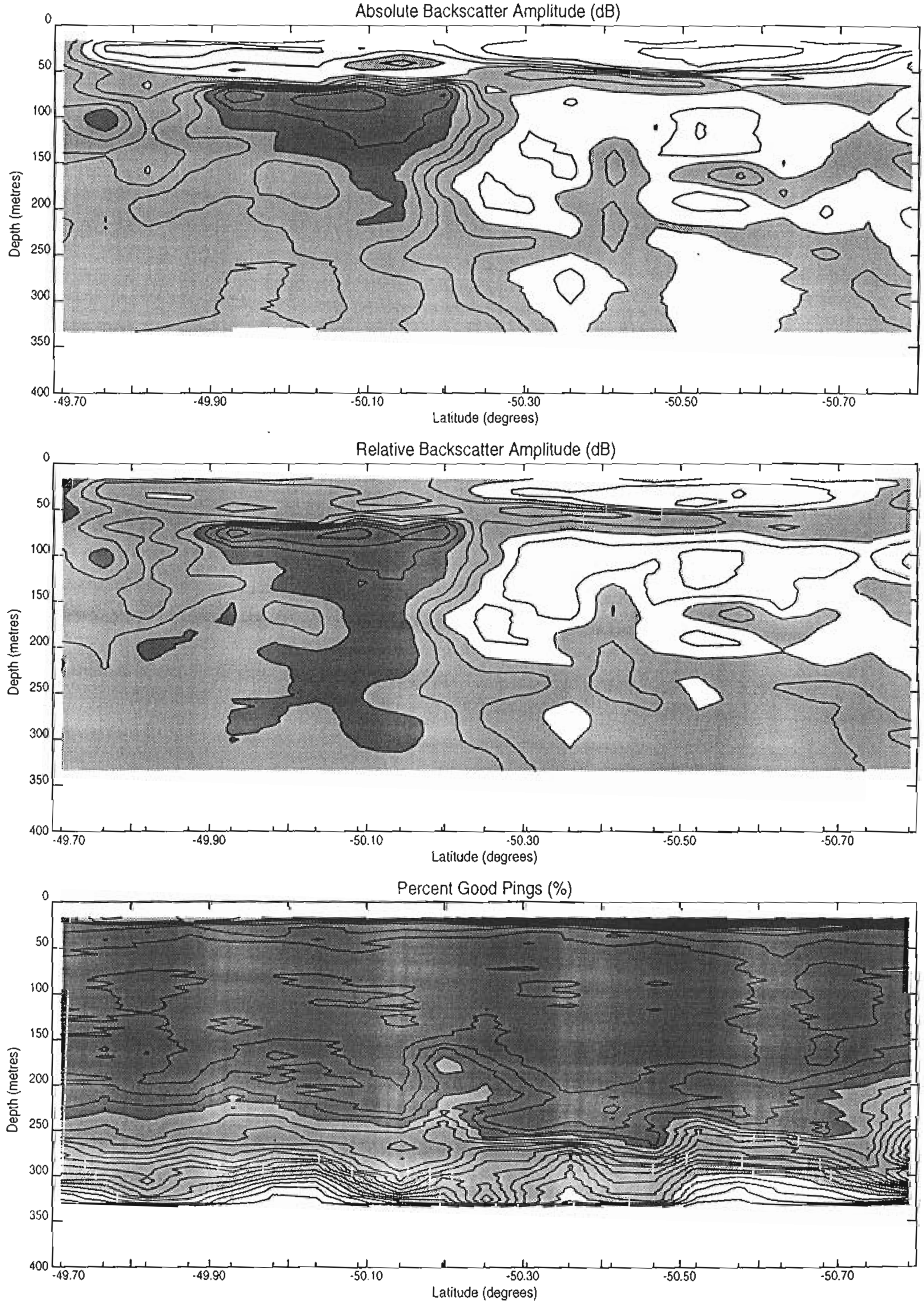
ADCP Fine Scale Survey Run 8.1



ADCP Fine Scale Survey Run 8.2

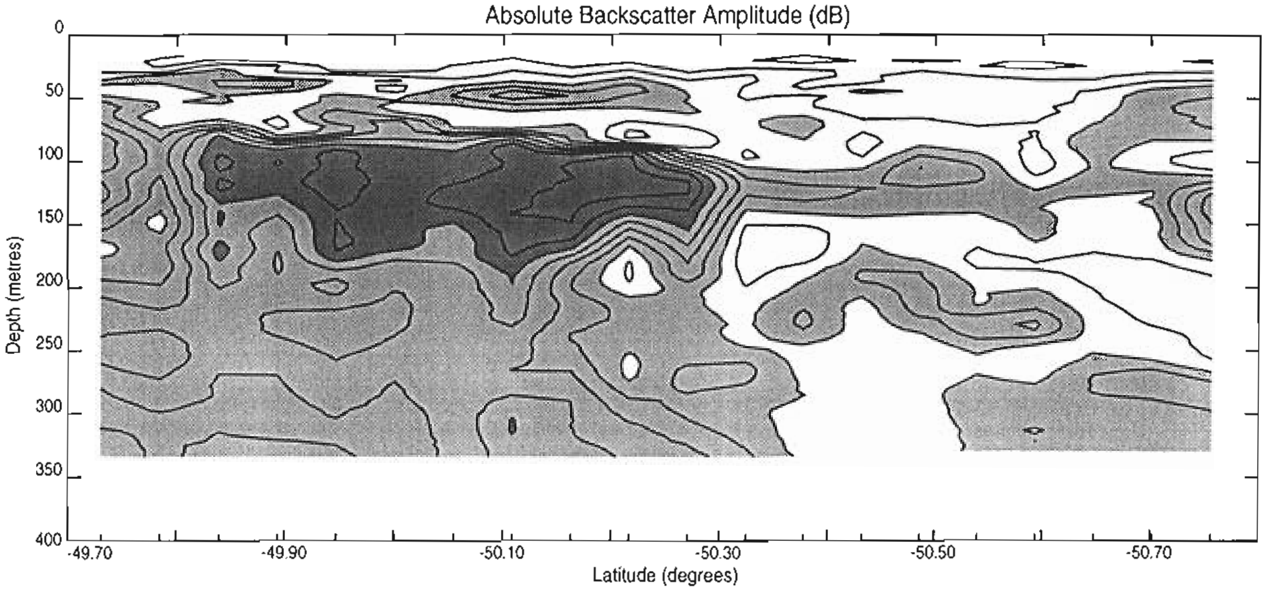


ADCP Fine Scale Survey Run 8.3

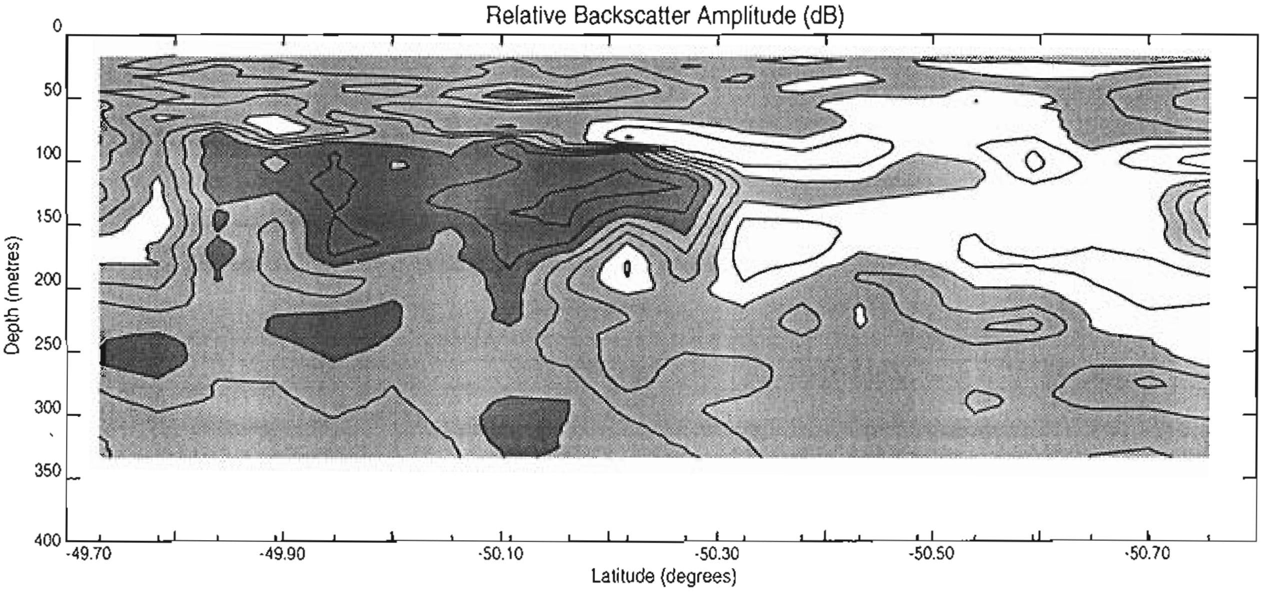


ADCP Fine Scale Survey Run 8.4

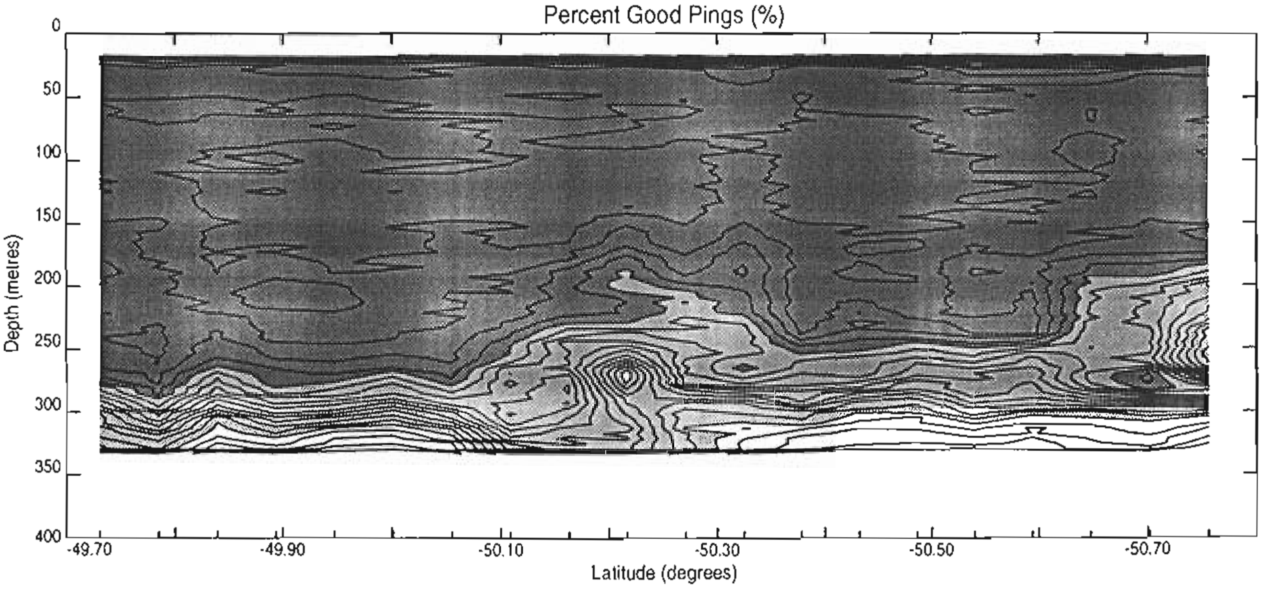
Absolute Backscatter Amplitude (dB)



Relative Backscatter Amplitude (dB)

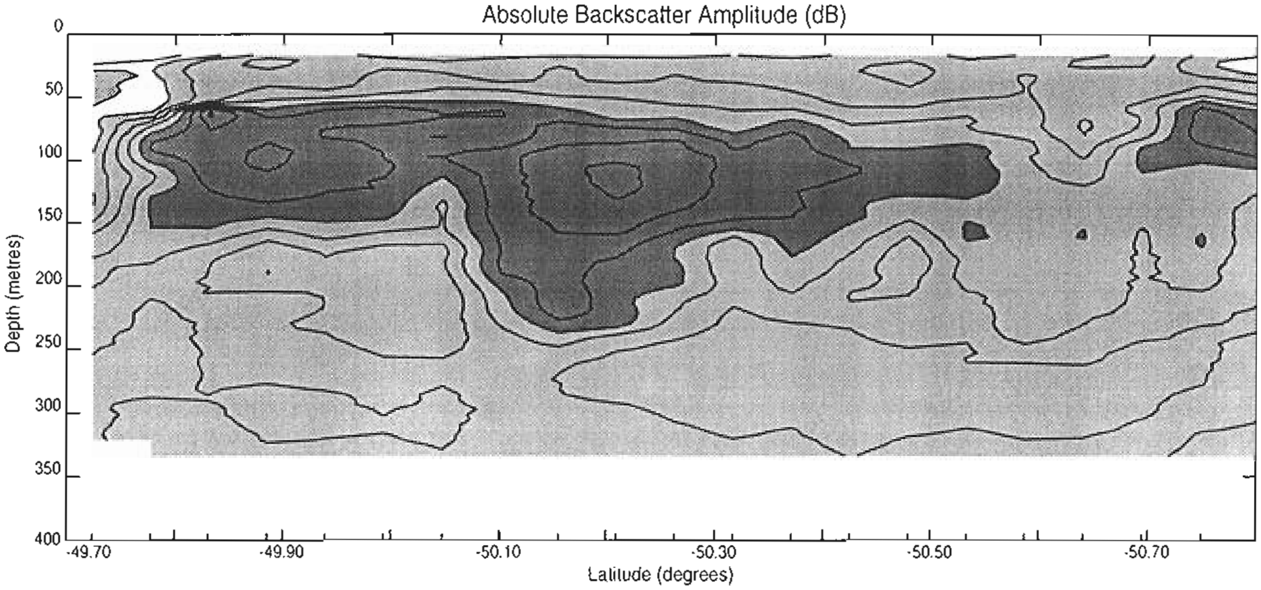


Percent Good Pings (%)

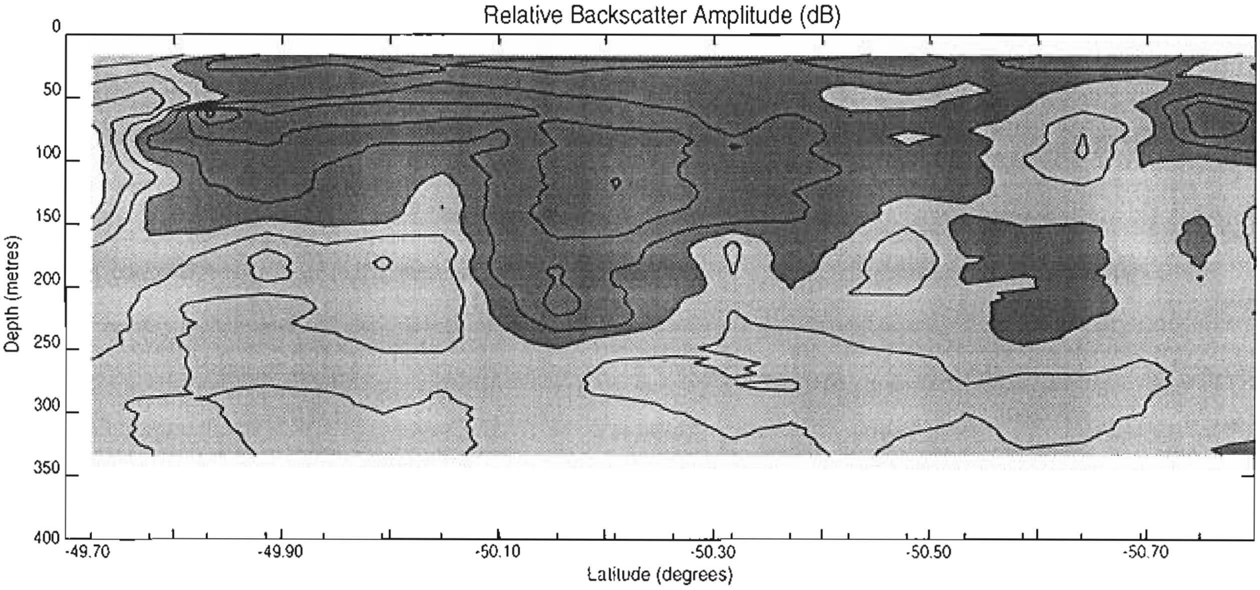


ADCP Fine Scale Survey Run 8.5

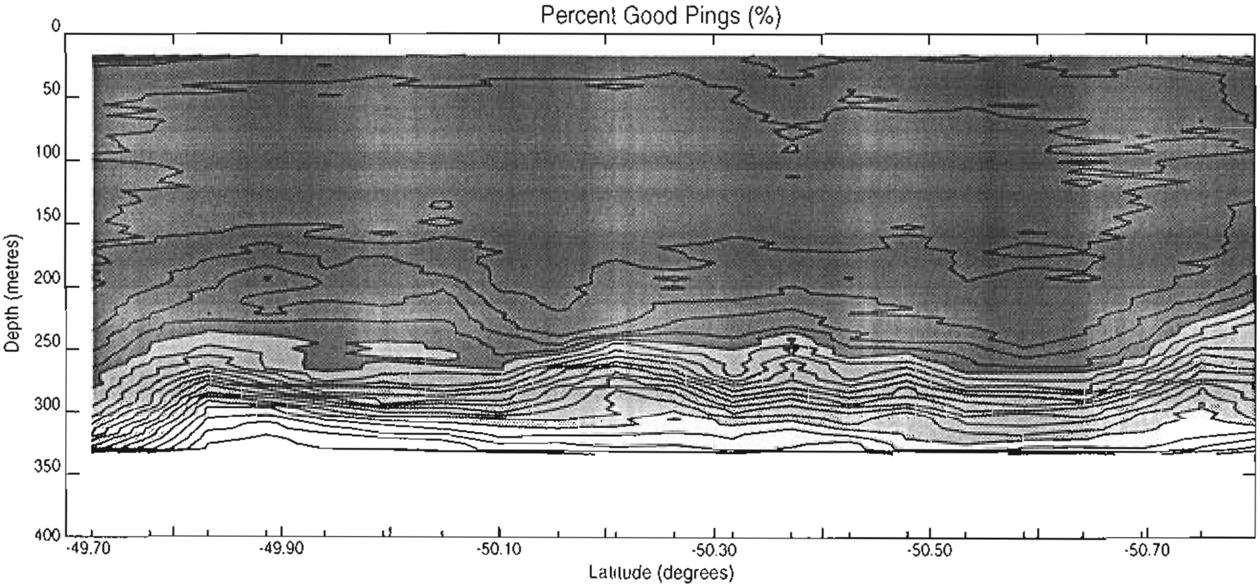
Absolute Backscatter Amplitude (dB)



Relative Backscatter Amplitude (dB)

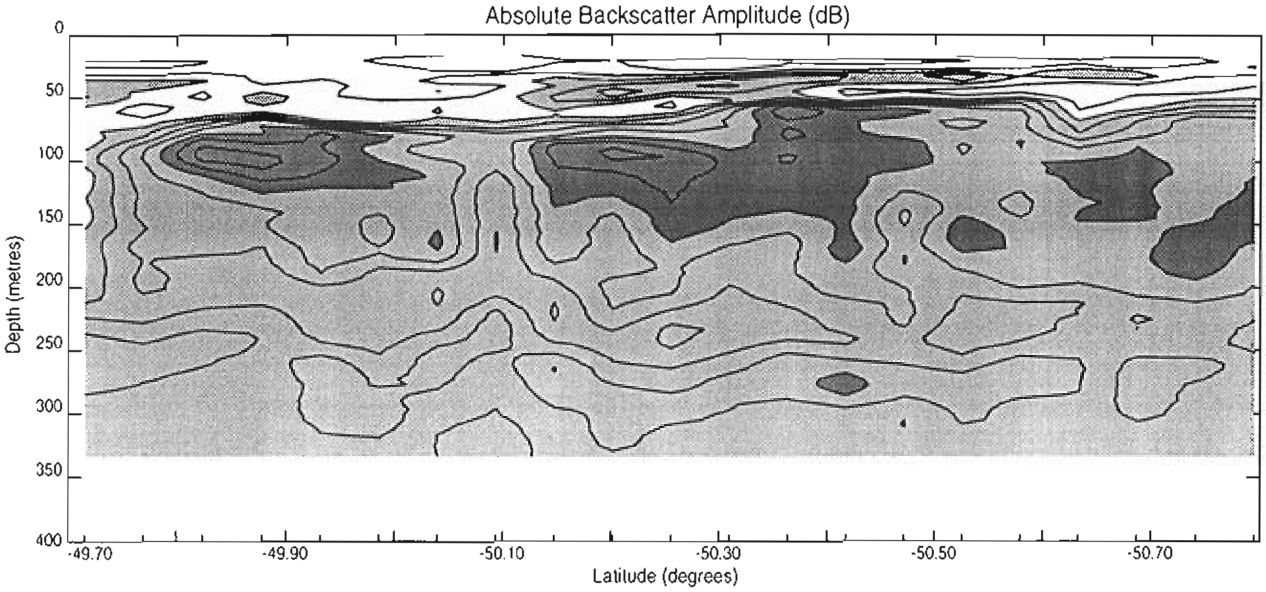


Percent Good Pings (%)

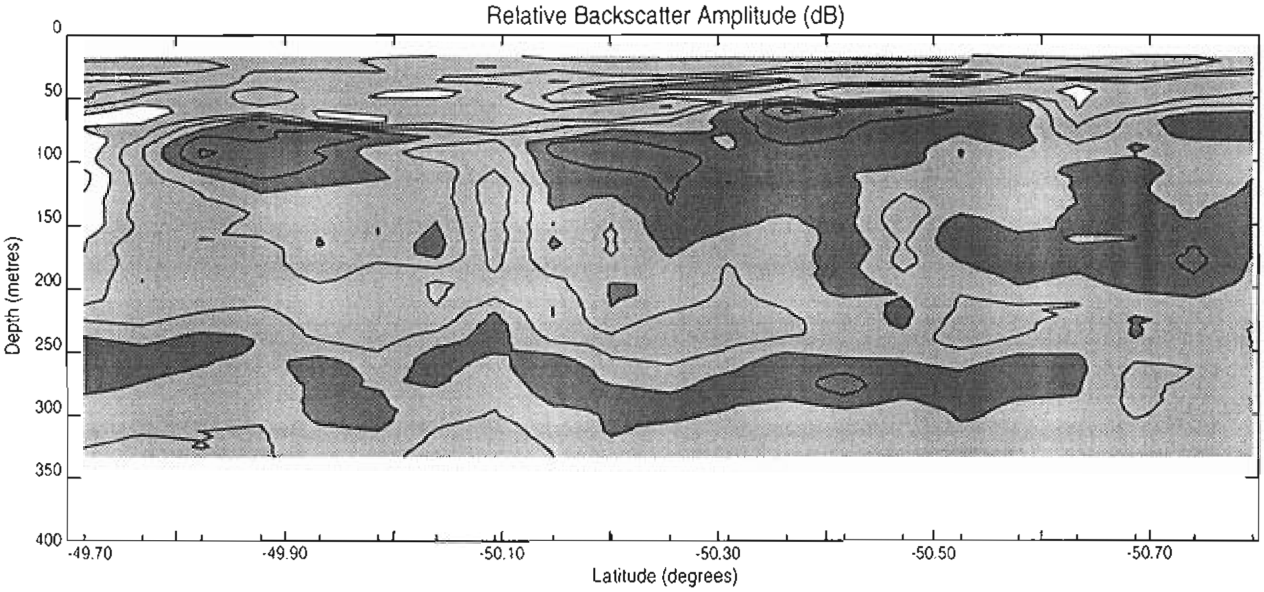


ADCP Fine Scale Survey Run 8.6

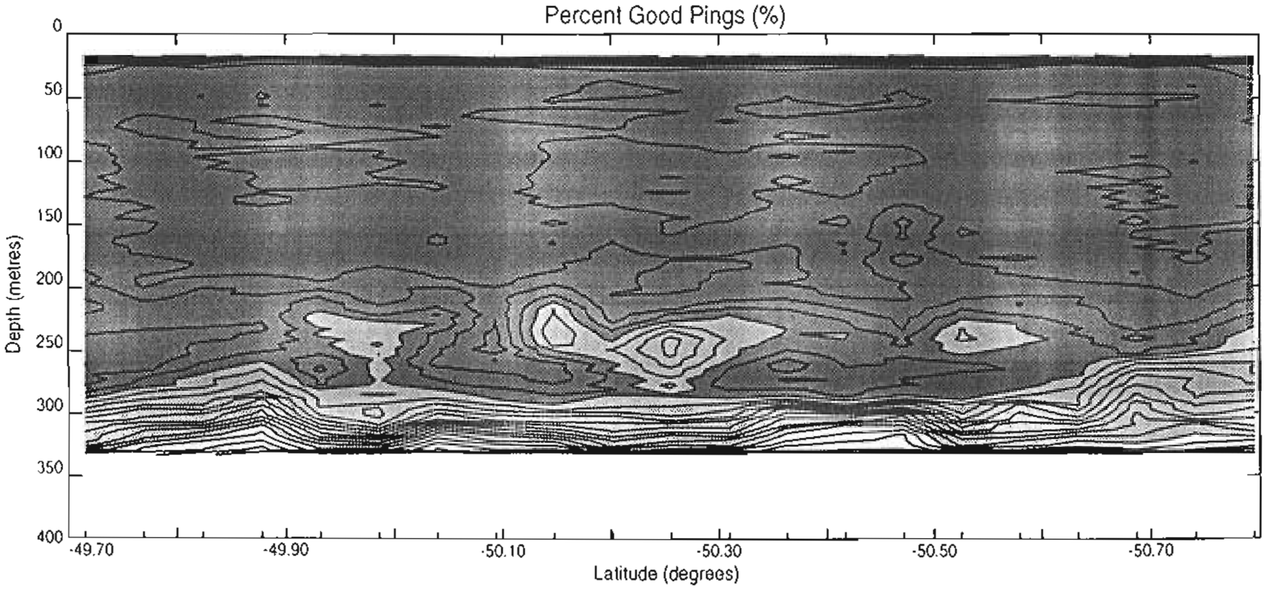
Absolute Backscatter Amplitude (dB)



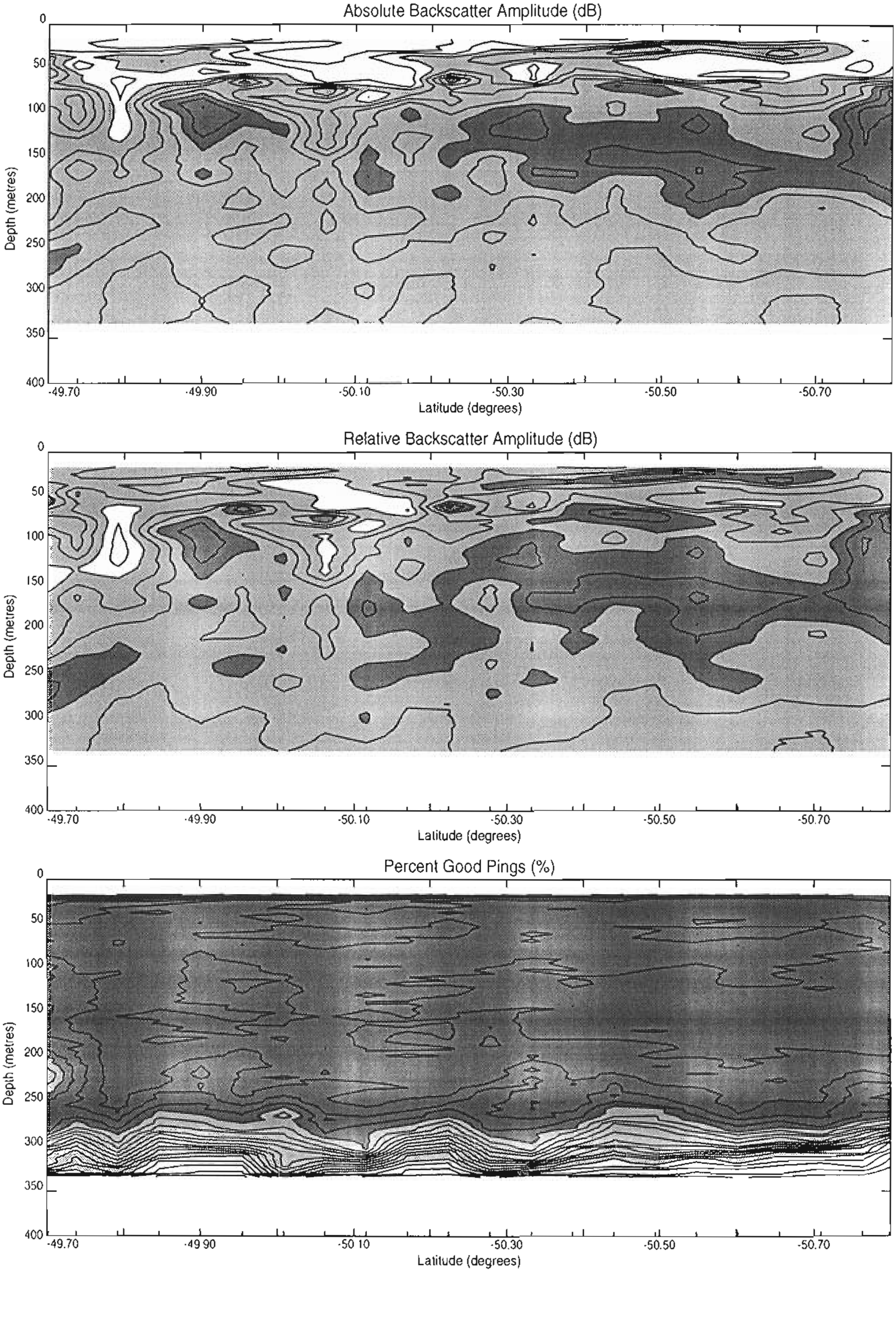
Relative Backscatter Amplitude (dB)



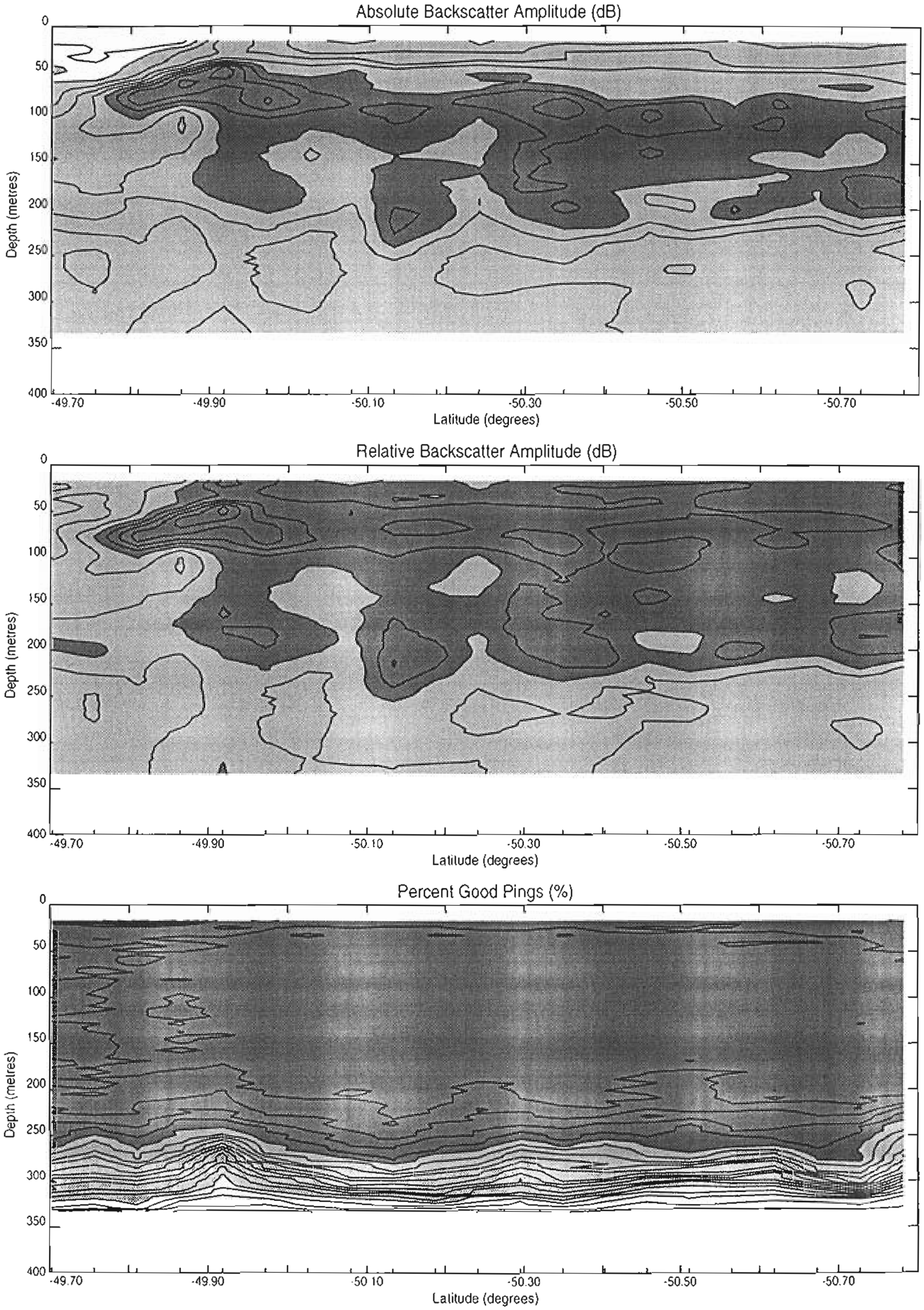
Percent Good Pings (%)



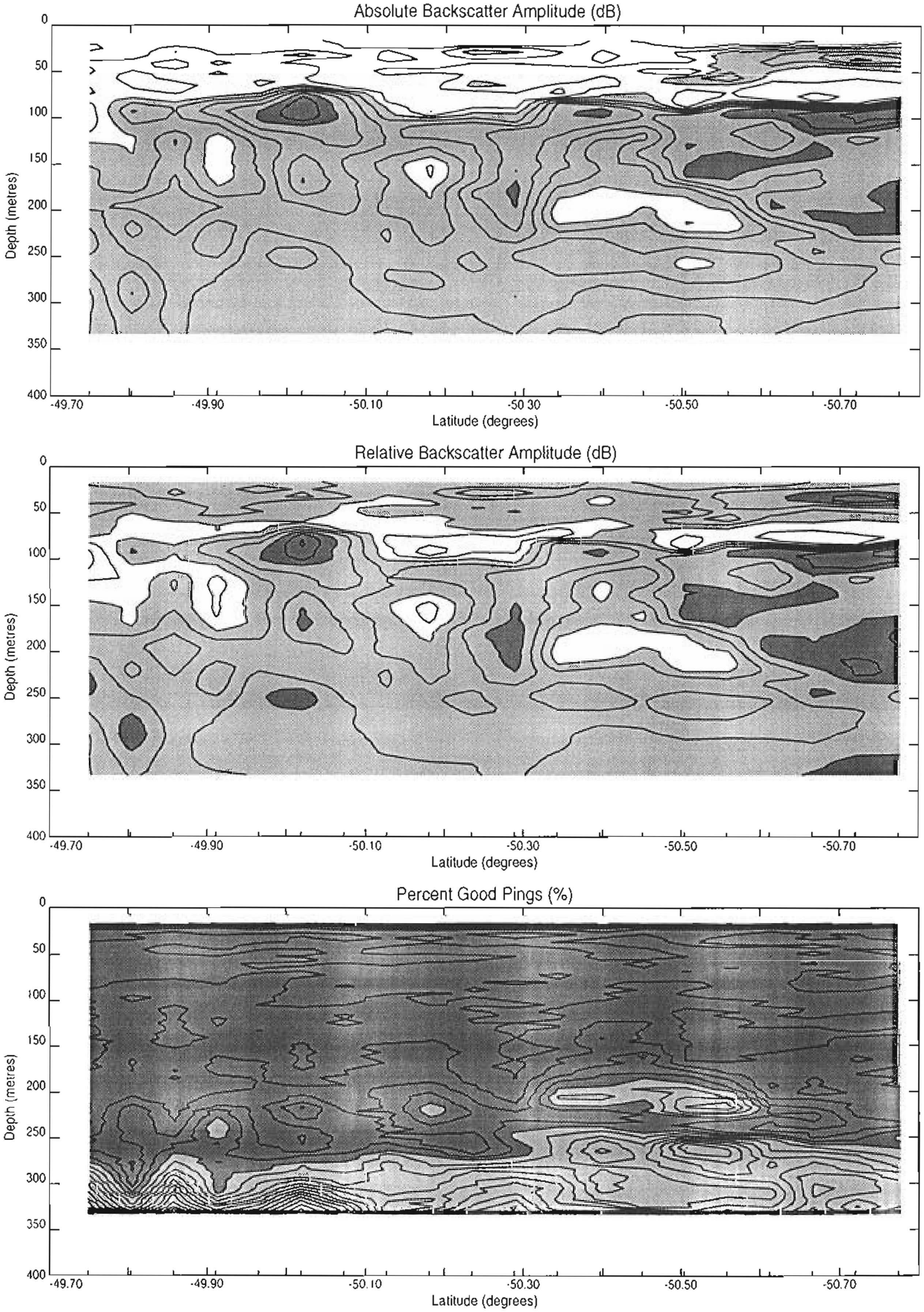
ADCP Fine Scale Survey Run 8.7



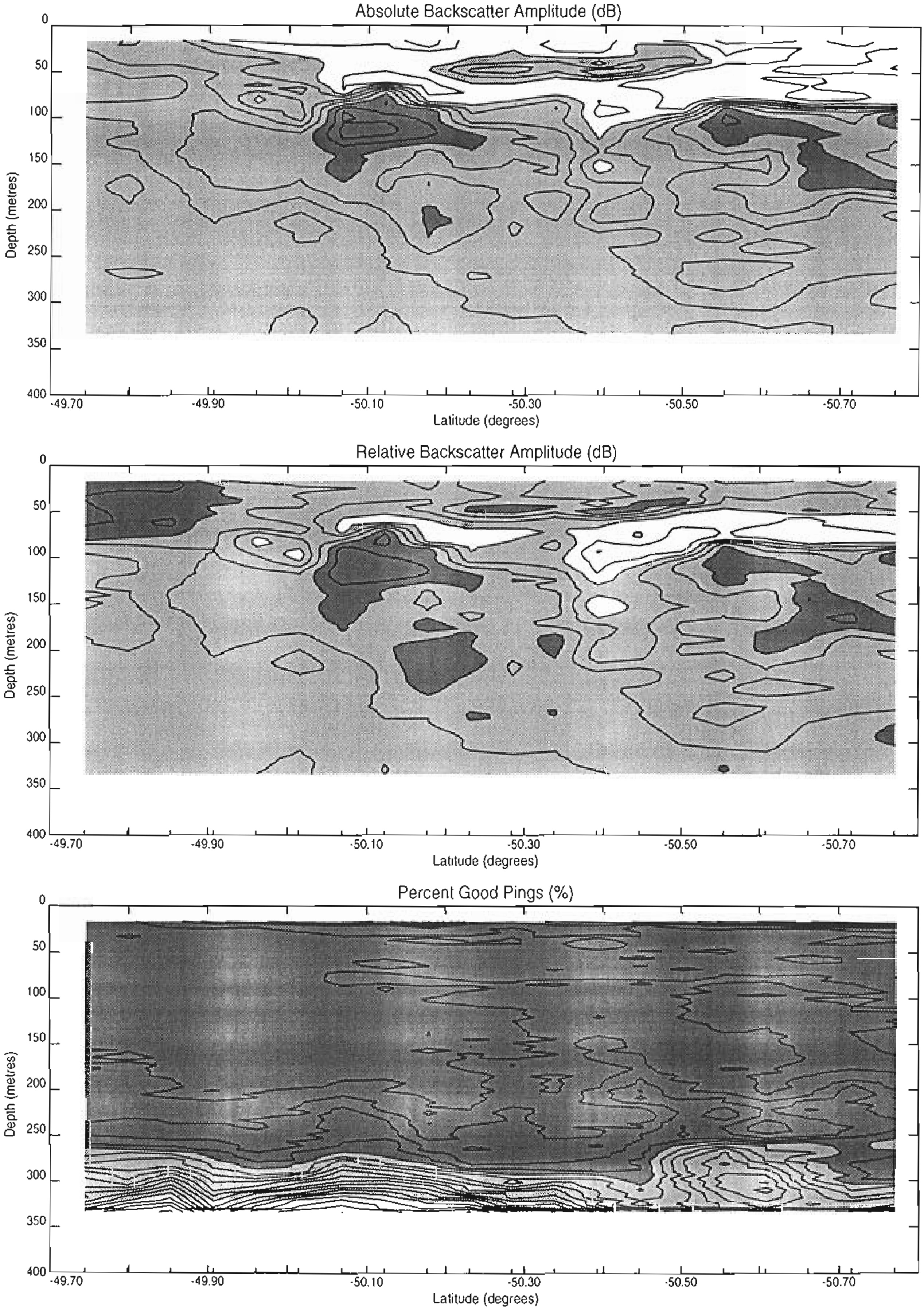
ADCP Fine Scale Survey Run 8.8

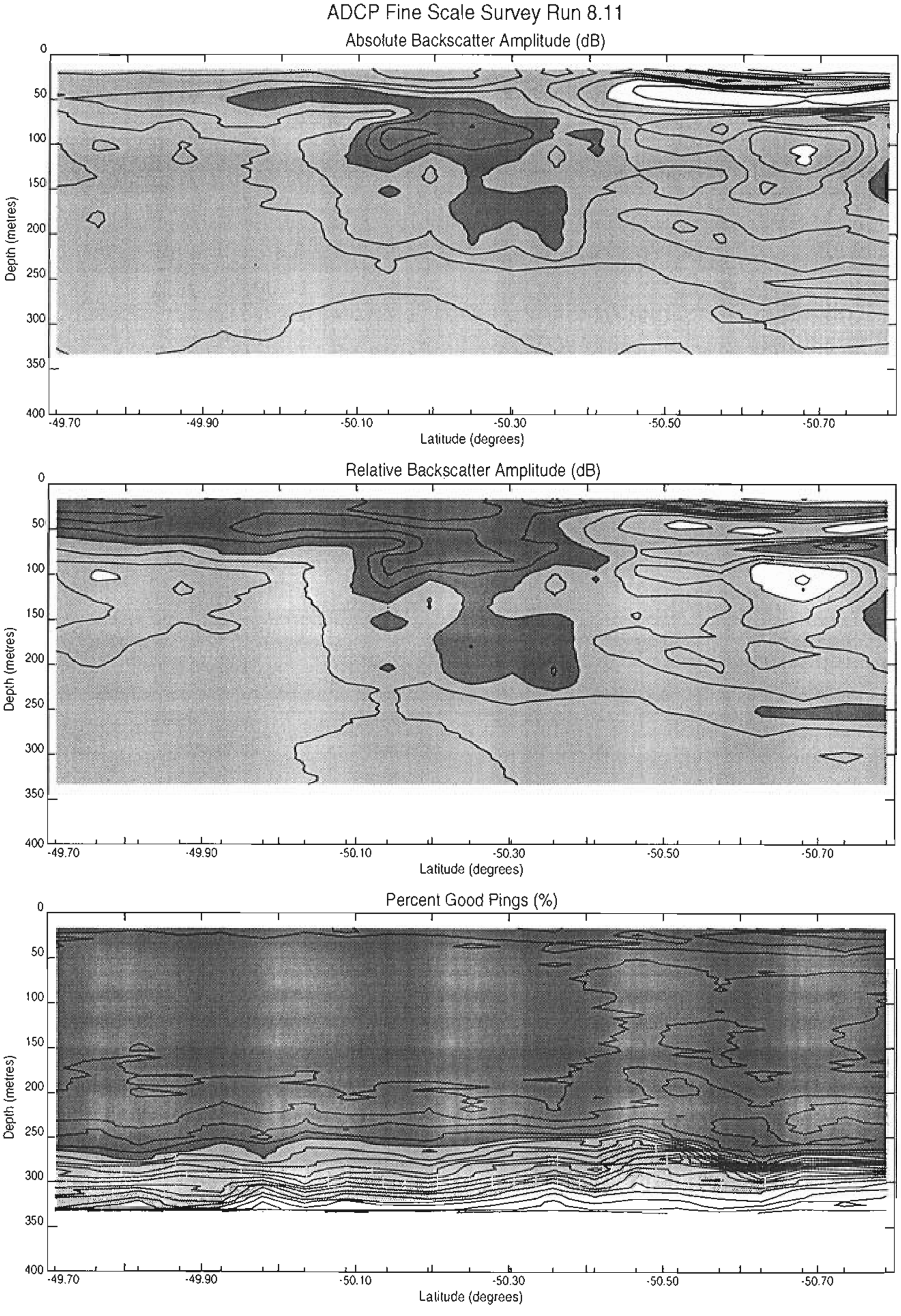


ADCP Fine Scale Survey Run 8.9



ADCP Fine Scale Survey Run 8.10




ADCP Fine Scale Survey Run 8.11
Absolute Backscatter Amplitude (dB)
Relative Backscatter Amplitude (dB)
Percent Good Pings (%)
Depth (metres)
Latitude (degrees)
0
50
100
150
200
250
300
350
400
-49.70
-49.90
-50.10
-50.30
-50.50
-50.70