Woods Hole Oceanographic Institution

Northwest Tropical Atlantic Station (NTAS): Velocity Data Report for Deployments 1 to 5

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Upper Ocean Processes Group
Woods Hole Oceanographic Institution
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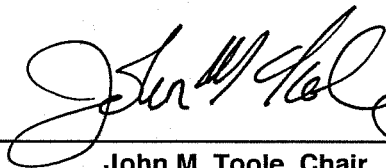Woods Hole, Massachusetts 02543

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Approved for Distribution:

John M. Toole, Chair

Department of Physical Oceanography

Abstract

This report presents velocity data from the Northwest Tropical Atlantic Station (NTAS) deployments 1 through 5, from March 30, 2001, to February 28, 2006. The NTAS project has maintained a series of moorings near 14°50′N, 51°00′W in the northwest tropical Atlantic for air-sea flux measurement. The moorings include a surface buoy outfitted with Air-Sea Interaction Meteorology (ASIMET) systems for determination of bulk air-sea fluxes and oceanographic sensors along the upper 120 m of the mooring line. This report describes and presents the velocity data recovered from current meters and Acoustic Doppler Current Profilers (ADCPs) during the first five years of the NTAS project.

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1   Introduction

The Northwest Tropical Atlantic Station (NTAS) project for air-sea flux measurement was conceived in order to investigate surface forcing and oceanographic response in a region of the tropical Atlantic with strong sea surface temperature (SST) anomalies and the likelihood of significant local air-sea interaction on interannual to decadal timescales. The site, near 15°N, 51°W, was intended to be maintained through successive mooring turn-arounds, and is complementary to other long-term surface moorings in the tropical Atlantic.

The primary scientific objectives of the NTAS project are to determine the in-situ fluxes of heat, moisture and momentum, to use these in-situ fluxes to make a regional assessment of flux components from numerical weather prediction models and satellites, and to determine the degree to which the oceanic budgets of heat and momentum are locally balanced.

To accomplish these objectives, a surface mooring with sensors suitable for the determination of air-sea fluxes and upper ocean properties was deployed. The surface buoy was outfitted with two Air-Sea Interaction Meteorology (ASIMET) systems. Each system measures, records, and transmits via Argos satellite the surface meteorological variables necessary to compute air-sea fluxes of heat, moisture and momentum. The upper 120 m of the mooring line was outfitted with oceanographic sensors for the measurement of temperature and velocity.

This report presents velocity data recovered from current meters and Acoustic Doppler Current Profilers (ADCPs) from the first five NTAS deployments (March 2001 to February 2006). Cruise reports for the first four deployments (NTAS-1 through -4) have been published [*Plueddemann et al.*, 2001, 2002, 2003, 2006], and the fifth is in preparation [*Plueddemann et al.*, 2012].

A location map for the NTAS site is shown in Figure 1a. A Sea-Beam survey undertaken on deployment of NTAS-3 mooring shows the detailed topography of the bottom around the site (Fig. 2).

On each cruise (with the exception of the first!) the replacement mooring was deployed nearby (Fig. 1b) before the extant mooring was recovered. This was done to provide an overlap in the data series from the two buoys. Consistent prevailing currents and winds at the sites ensured that for the majority of the time each buoy was located in the quarter circle directly to the west of its anchor position (Fig. 3).

This report is arranged in sections as follows:

1. The moored arrays and instrumentation are described (Sections 2 and 3). Peculiarities and unique characteristics of the particular deployments are presented here.

2. Methods and processing common to all deployments are discussed (Section 4).

3. The data are presented in the form of tables and figures (Sections 5 and 6). Here are shown:

   - the time-series of northward and eastward velocities for each instrument;

   - progressive vector diagrams of the currents;

   - tabulations of spectral peaks and summary statistics of each instrument;

   - comparisons of the spectra from two or more current meters from each deployment; and

   - vertical profiles of the currents.

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The sites were occupied as shown in Table 1.

Table 1: Site statistics extracted from Cruise Reports and Mooring Logs. Deployment is recorded as the anchor drop time, and recovery as the trigger release time. Note that, since the NTAS-3 buoy was adrift when recovered, the surface meteorological and subsurface instruments were recovered earlier, beginning on 2004-02-19 at 16:49Z. The position was 14°53.7′N, 51°22.817′W, 21.2 n.m. from the anchor position.

	Anchor position		Depth (m)	Deployment (UTC)	Recovery (UTC)	Duration (d:h:m)
NTAS-1	14°49.97′N	51°00.30′W	4982	2001-03-30 23:17	2002-03-06 10:08	340:10:51
NTAS-2	14°44.301′N	50°56.823′W	5043	2002-03-04 22:18	2003-02-16 12:06	348:13:48
NTAS-3	14°49.50′N	51°01.30′W	4977	2003-02-15 05:47	2004-02-23 23:10*	373:17:23*
NTAS-4	14°44.430′N	50°56.034′W	5048	2004-02-21 03:16	2005-03-13 14:20	386:11:04
NTAS-5	14°41.0736′N	51°02.5408′W	5107	2005-03-11 19:35	2006-02-28 12:39	353:17:04
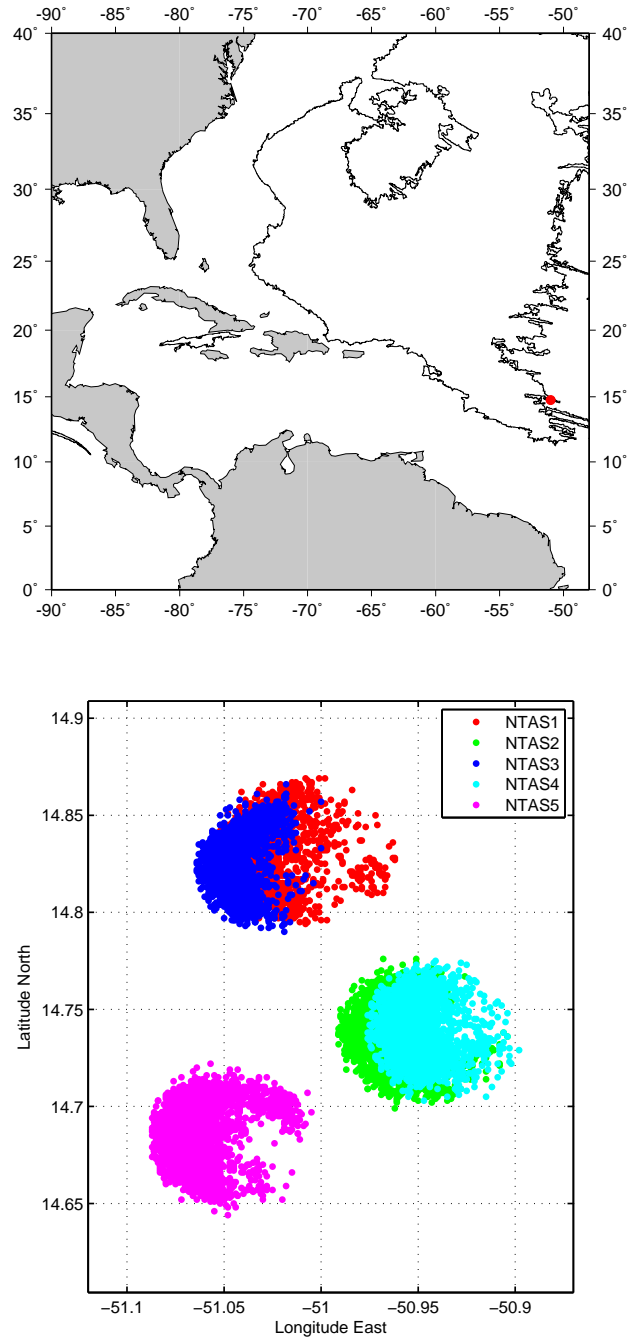
Figure 1: Site map for NTAS. (a) Location. The 5000 m contour is drawn (bathymetry from ETOPO1 [*Amante and Eakins*, 2008]). (b) The relationship among the NTAS sites are shown by plotting the hourly telemetered position during the deployments. Site positions of consecutive buoys are offset because the replacement buoy was deployed before the currently deployed buoy was recovered, to provide an overlap in time of the data collection.
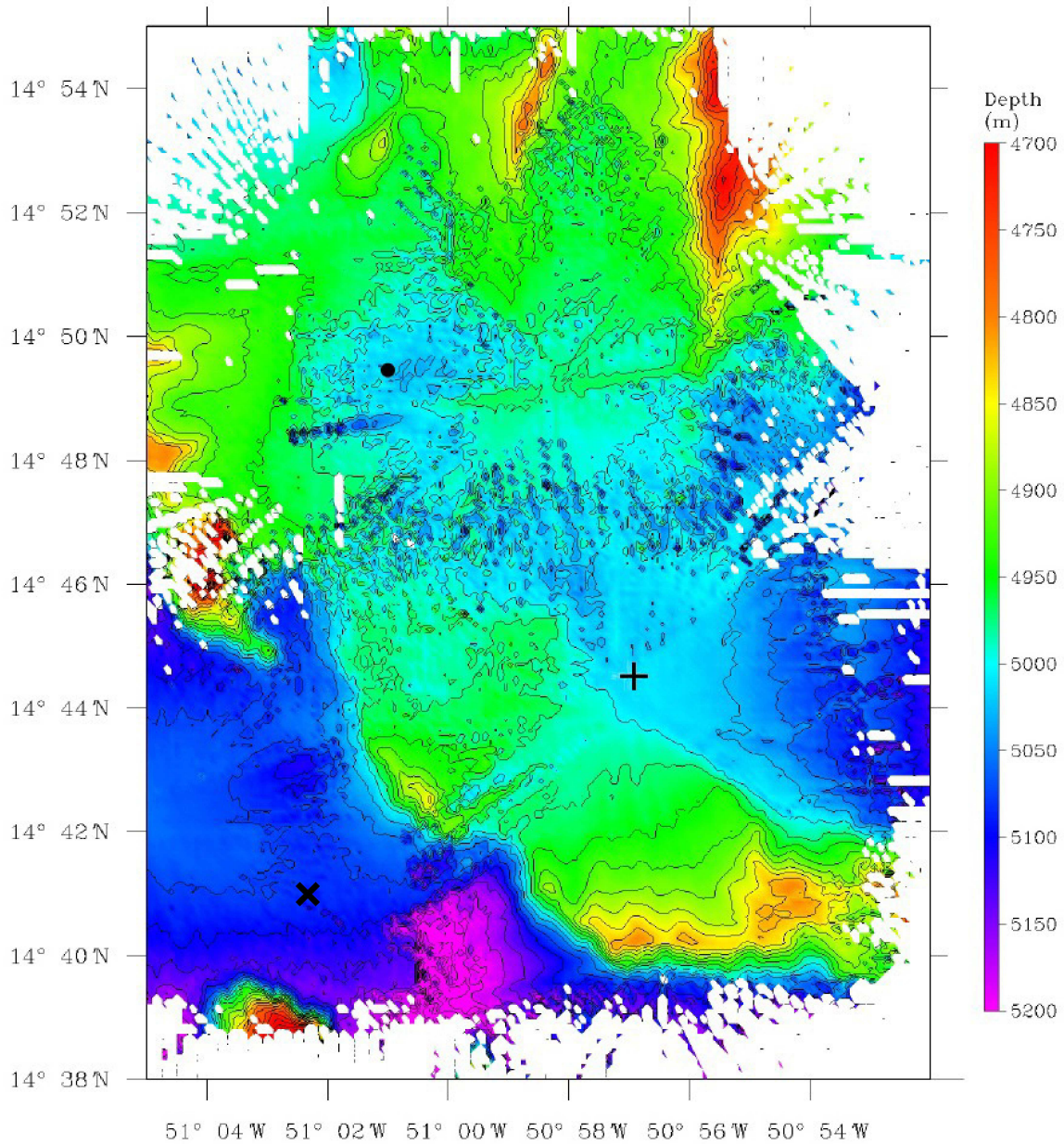
Figure 2: Sea-Beam bathymetry at the NTAS site is shown as determined on the NTAS-3 deployment cruise. The approximate positions of the NTAS-1 and -3 (●), NTAS-2 and -4 (+), and NTAS-5 (×) buoy anchor positions are indicated. Anchor positions of consecutive buoys were offset to allow deployment of the next buoy before recovery of the current one, in order to provide an overlap in time of the data series.
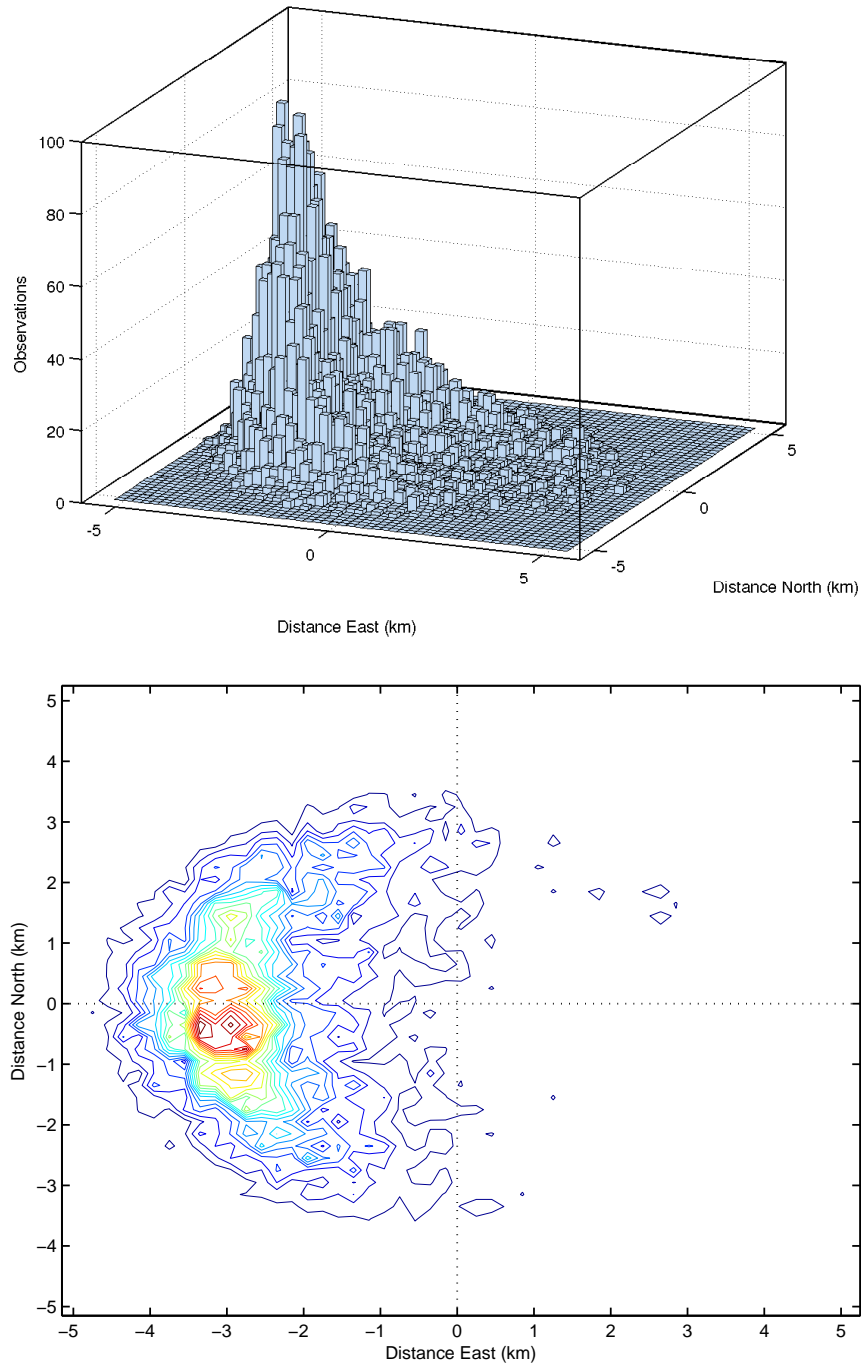
Figure 3: Buoy position relative to the anchor position for all buoy deployments. Position data from each deployment was calculated relative to its anchor positions. The relative position data were binned into a 2-dimensional histogram (`hist3`, *The Mathworks*, 2008). (a) Histogram of the buoy position relative to the anchor position. (b) Contour plot of the histogram data. Anchor position is at (0,0).

2   Deployment Cruises

2.1   NTAS-1 Deployment Cruise

The deployment of NTAS-1 [*Plueddemann et al.*, 2001] was done on R/V *Oceanus*, Cruise 365, Leg 5 (OC365-V). The cruise was completed in 12 days, between 28 March and 8 April 2001. The cruise leg originated from and terminated in Bridgetown, Barbados, West Indies. The NTAS-1 mooring was deployed at 14°49.97′N, 51°00.03′W on 30 March 2001. The NTAS-1 deployment was followed by a 12-hour data intercomparison period, during which meteorological measurements from the NTAS-1 buoy and *Oceanus* were obtained and shipboard CTD casts were completed.

2.2   NTAS-2 Deployment Cruise

The mooring turnaround of NTAS-1/2 [*Plueddemann et al.*, 2002] was done on the NOAA Ship *Ronald H. Brown*, Cruise RB-02-02. The cruise was completed in 7 days, between 2 and 8 March 2002. The cruise leg originated from and terminated in Bridgetown, Barbados. A Sea-Beam bathymetric survey was done over an area of approximately 140 n.m.^{2} (470 km^2), which encompassed the NTAS-1 and NTAS-2 anchor locations. The NTAS-2 mooring was deployed at 14°44.30′N, 50°56.82′W on 4 March 2002. The NTAS-2 deployment was followed by a 24-hour data intercomparison period, during which meteorological measurements from both buoys and the ship were obtained, and shipboard CTD casts were completed. The NTAS-1 mooring was recovered on 6 March 2002.

2.3   NTAS-3 Deployment Cruise

The NTAS-2/3 mooring turnaround [*Plueddemann et al.*, 2003] was done on the WHOI R/V *Oceanus*, Cruise OC-385-5. The cruise was completed in 12 days, between 12 and 23 February 2003. The cruise originated from Bridgetown, Barbados and terminated in Woods Hole. The NTAS-3 mooring was deployed at 14°49.50′N, 51°01.3′W on 15 February 2003. The NTAS-3 deployment was followed by a 24-hour data intercomparison period, during which meteorological measurements from both buoys and the ship were obtained, and shipboard CTD casts were made. The NTAS-2 mooring was recovered on 16 February 2003.

2.4   NTAS-4 Deployment Cruise

The NTAS-3/4 mooring turnaround [*Plueddemann et al.*, 2003] was done on the NOAA Ship *Ronald H. Brown*, Cruise RB-04-01. The cruise was completed in 14 days, between 12 and 25 February 2004. The cruise originated from Charleston, SC, and terminated in Bridgetown, Barbados, West Indies. The NTAS-3 buoy, which went adrift on 16 February 2004 due to a mooring component failure, was located and recovered on 19 Feburary 2004. The NTAS-4 mooring was deployed at 14°44.43′N,50°56.03′W on 21 February 2004. The NTAS-4 deployment was followed by a 30-hour data intercomparison period, during which meteorological measurements from the NTAS-4 buoy and the ship were obtained. Dragging operations were conducted in an unsuccessful attempt to retrieve the remainder of the NTAS-3 mooring.

2.5   NTAS-5 Deployment Cruise

The NTAS-4/5 mooring turnaround [*Plueddemann et al.*, 2012] was done on the NOAA Ship *Ronald H. Brown*, Cruise RB-05-02. The cruise was completed in 14 days, between 9 and 22 March 2005. The cruise originated from Bridgetown, Barbados, and terminated in Charleston, SC. A bathymetric survey of the NTAS-5 deployment region, a 250 n.m.^{2} area (approximate) centered near 14°44′N, 51°00′W, was completed. The NTAS-5 mooring was deployed at 14°41.07′N, 51°02.64′W on 11 March 2005. The NTAS-5 deployment was followed by a 34-hour data intercomparison period, during which meteorological measurements from both buoys and the ship were obtained, and shipboard CTD casts were made. The NTAS-4 mooring was recovered on 13 March 2005. Dragging operations were conducted, resulting in successful retrieval of the mooring line from the NTAS-3 mooring.

Figure 4: Nortek Aquadopp mounted on titanium load bar. No anti-fouling paint or transducer coating has been applied.

3 Moored Arrays and Instrumentation

The general configuration common to all deployments is outlined in the following sections. The general mooring design is described, and the current meter configurations tabulated. Thereafter, unique aspects of the individual deployments are explained.

3.1 Mooring Design

The basic NTAS mooring is an inverse-catenary design of compound construction, utilizing chain, wire rope, nylon and polypropylene. The mooring scope (ratio of total mooring length to water depth) is about 1.25. For NTAS-1 through -4, the surface buoy was 3-meter "discus" design with a foam-filled aluminum hull and a watertight center well housing electronics and batteries. Starting with NTAS-5 a new hull design was used—the Modular Ocean Buoy System (MOBS). The MOBS surface element is a 2.7-meter diameter Surlyn foam buoy with a watertight electronics well and aluminum instrument tower. The ASIMET sensor modules [*Hosom et al.*, 1995] are bolted to the buoy tower at approximately 3 m above the sea surface. Sea surface temperature and salinity are measured by sensors bolted to the bridle legs and cabled to the loggers through a bottom access plate in the buoy well. Further details of the surface instrumentation can be found in the cruise reports [*Plueddemann et al.*, 2001, 2002, 2003, 2006, 2012].

Current meters, current profilers and temperature sensors were attached along the mooring line using load bars or cages (attached in-line between chain or wire sections)and specially designed brackets (clamped along wire rope sections). All instrumentation was in the upper 150 m. Nortek Aquadopp current meters were deployed near the surface on load bars (Fig. 4). RD Instruments ADCPs were deployed in load cages (Fig. 5) at 85 m to 100 m depth with beams pointing upwards. For NTAS-2, a Vector Measuring Current Meter (VMCM) in a load cage (Fig. 6) was deployed near the Aquadopp. Sample intervals ranged from 7.5 minutes (VMCM) to 1 hour (ADCPs).

A summary of the current meter instrument locations, serial numbers, and sample rates is given in Table 2.

(a)
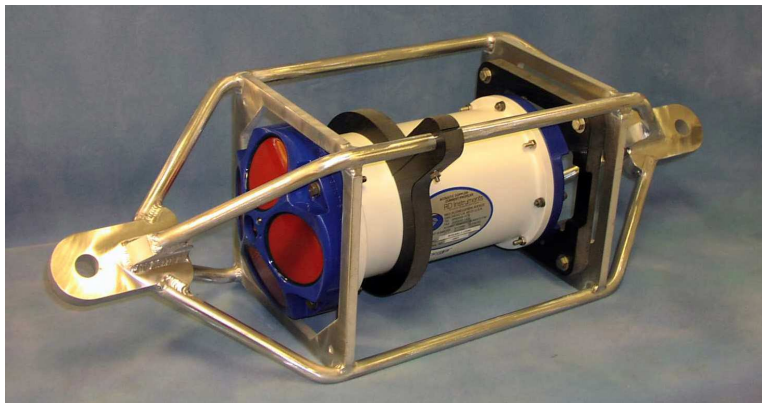
(b)

Figure 5: (a) RD Instruments 300 kHz NarrowBand ADCP mounted in stainless steel load cage. Antifouling paint (blue) has been applied to the upper portion of the cage. (b) RD Instruments 300 kHz Workhorse (BroadBand) ADCP in aluminum load cage. The cage has not been painted and no anti-fouling treatment has been applied to the ADCP.

Figure 6: Vector Measuring Current Meter (VMCM) in mounted in stainless steel load cage. The cage, VMCM sting and VMCM pressure housing have been painted with a white anti-fouling coating.

Table 2: NTAS velocity instrument information. Aquadopp indicates the Aquadopp current meter by Nortek, ADCP indicates an acoustic doppler current profiler by RDI, VMCM is the vector measuring current meter and SN is the instrument serial number. Variables measured were velocity (V), temperature (T), and pressure (P).

Deployment	Depth (m)	Sensor	SN	Variable(s) Measured	Sample Rate
NTAS-1	8	Aquadopp	174	V, T, P	30 min
NTAS-1	100	ADCP	593	V	15 min
NTAS-2	6	Aquadopp	432	T, V, P	60 min
NTAS-2	7.5	VMCM	1	T, V	7.5 min
NTAS-2	100	ADCP	2125	T, V	60 min
NTAS-3	6	Aquadopp	174	T, V, P	60 min
NTAS-3	100	ADCP	2601	T, V	60 min
NTAS-4	6	Aquadopp	432	T, V, P	60 min
NTAS-4	85	ADCP	2125	T, V	60 min
NTAS-5	6	Aquadopp	1226	T, V, P	60 min
NTAS-5	85	ADCP	2601	T, V	60 min

3.2   Aquadopp

The Nortek Aquadopp current meter uses the Doppler technique to obtain velocity estimates within a single range bin along three beams. Two beams point horizontally, separated by 90 degrees in azimuth. A third beam points upwards at 45 degrees at an azimuth between the two horizontal beams. The sample volume is about 1 m away from the instrument. A compass and two axes of tilt are used to convert velocities from instrument coordinates to geographic (earth) coordinates. The Aquadopp also measures temperature and pressure. The plastic instrument housing and pressure sensor are rated to 200 m depth. Aquadopp current meters were deployed at 8 m depth (NTAS-1) and 6 m depth (NTAS-2 through -5). A titanium load bar and bolt-on cage originally designed for use with SeaBird SBE-16 SeaCATs was used to attach the Aquadopp in-line between chain sections of the mooring. Because the cage was not designed specifically for the instrument, the transducers protruded slightly beyond the cage bars (Fig. 4).

The Aquadopp instruments were configured as shown in Table 3.

3.3   Acoustic Doppler current profilers

Acoustic Doppler current profilers (ADCPs) apply Doppler processing to the range-gated return from each acoustic transmission (ping). By utilizing four beams in a "Janus" configuration (separated by 90 degrees in azimuth and inclined at 20 or 30 degrees from the vertical), the along-beam velocities can be converted into horizontal velocities. Combining horizontal velocities with tilt and heading information allows transformation to geographic (earth) coordinates on a ping-by-ping basis. In this manner the instrument produces vertical profiles of horizontal velocity. Vertical resolution is set by the ping duration and temporal resolution is set by the ensemble-averaging interval.

A 300 kHz RD Instruments NarrowBand ADCP was deployed on NTAS-1 at 100 m depth. For NTAS-2 through -5, 300 kHz WorkHorse (broadband) ADCPs were deployed at depths of 85 or

Table 3: Aquadopp instrument configurations for the NTAS deployments.

	NTAS-1	NTAS-2	NTAS-3	NTAS-4	NTAS-5
Aquadopp SN	174	432	174	432	1226
Deployment depth (m)	8	6	6	6	6
Transmission interval (sec)	1	1	1	1	1
Average interval (sec)	60	180	180	180	180
Sample interval (min)	30	60	60	60	60
Blanking distance (m)	0.35	1.0	1.0	1.0	1.0
Diagnostics interval (min)	1440	1440	1440	1440	1440
Diagnostics samples	20	20	20	20	20
Measurement load (%)	4	22	22	17	17
Power level	HIGH-	HIGH-	HIGH-	HIGH-	HIGH-
Compass update rate (sec)	1	1	1	1	1
Coordinate system	earth	ENU	ENU	ENU	ENU
Recorder size (MB)	2	5	2	5	9

Table 4: RDI instrument configurations for the NTAS deployments. (NB—NarrowBand, WH—Work-Horse.)

	NTAS-1	NTAS-2	NTAS-3	NTAS-4	NTAS-5
RDI SN	593	2125	2601	2125	2601
ADCP Type	NB	WH	WH	WH	WH
Deployment depth (m)	100	100	100	85	85
Time between pings (sec)	1	1.25	1	1	1
Pings per ensemble	120	120	120	120	120
Ensemble interval (min)	15	60	60	60	60
Number of depth bins	28	28	28	25	25
Depth bin length (m)	4	4	4	4	4
Pulse length (m)	8	4	4	4	4
Blank after transmit (m)	4	6	6	3	3
Transducer orientation	up	up	up	up	up
Coordinate system	earth	earth	earth	earth	earth
Recorder size (MB)	18	40	40	48	48

100 m. The ADCP instrument was housed in a welded aluminum load cage, and placed in-line between wire sections of the mooring.

The RDI ADCP instruments were set up in the configurations shown in Table 4.

3.4   Vector Measuring Current Meters

Vector Measuring Current Meters (VMCMs) consist of an electronics housing with a "sting" extending from the upper end cap. Two pairs of cosine-response propeller sensors are attached to the sting, oriented in orthogonal horizontal directions. East and North components of velocity are determined from the orthogonal propeller counts (updated every $\frac{1}{4}$ revolution) and the direction from

a flux-gate compass (updated once per second). The cosine response and continuous accumulation of propeller counts enables the VMCM to measure mean flows accurately in the presence of strong oscillatory flows (e.g., surface wave orbital velocities).

   A VMCM was deployed on the NTAS-2 mooring, with the center of the sting at 7.5 m depth. The intent was to allow a comparison of the VMCM velocity to that of the Aquadopp just above it. The VMCM was housed in a stainless steel load cage, and placed in-line between chain sections of the mooring. VMCM velocity accuracy is about $1 \text{ cm} \cdot \text{s}^{-1}$. The record interval was 7.5 min for the NTAS-2 deployment.

3.5   Mooring Diagrams

Sketches showing the detail of near-surface sensors deployed on NTAS-1 through -5 are shown in Figures 7 to 11 (see also Table 2). NTAS-1 used a 300 kHz NarrowBand ADCP with $\sim$100 m profiling range, supplemented by an Aquadopp to provide measurements in the "blind spot" created by side-lobe reflections from the surface. NTAS-2 added a VMCM for comparison with the Aquadopp and the NarrowBand ADCP was replaced by a 300 kHz BroadBand Workhorse. The NTAS-3 configuration was analogous to NTAS-2, but without the VMCM. For NTAS-4 and -5 it was recognized that the Workhorse ADCPs were providing only 75–85 m of profiling range, and their deployment depths were moved shallower.

4   Data Processing Summary

4.1   Aquadopp

After instrument recovery and a time check done by placing the instrument (which includes a temperature sensor) in an ice bath for a known interval, binary files are downloaded from the instrument to a laptop computer using the manufacturers "Aquadopp" software. The resulting file is unpacked into multiple ASCII files using the Aquadopp data conversion utility. Three ASCII files are created:

1. Header file, containing instrument metadata, configuration information and a description of the file format for the data and diagnostics files,

2. Data file, containing velocity, amplitude and ancillary data,

3. Diagnostics file, containing the same variables as the data file, but for short, high-frequency bursts defined in the configuration.

The Aquadopp data file is processed as described below to create the data evaluated in this report. The header file is used to populate metadata fields in the processed data file. The diagnostics file is used for evaluation in the event that processed data are suspect.

   Aquadopp data are processed by two Matlab scripts. The first script loads the ASCII data file, computes decimal year day from date and time, and assigns a subset of relevant data from the Aquadopp file to Matlab variables. The output of the first script is a Matlab file of unpacked, unprocessed data. These data are evaluated for timing problems (gaps or drift) and adjusted if necessary. A second script reads the time-adjusted data, truncates the record at the start and end of

2 ASIMET systems with
BPR, HRH, WND, SWR, LWR
PRC and Argos telemetry

Depth (m)

2.1	MicroCAT SN 1725 and 1726
5	Tidbit, SN 90
7.8	Aquadopp, SN 174
10	Tidbit, SN 94
15	Tidbit, SN 85
20	Tidbit, SN 86
30	Tidbit, SN 84
40	Tidbit, SN 87
50	Tidbit, SN 92
60	Tidbit, SN 93
70	Tidbit, SN 95
80	Tidbit, SN 91
100	Tidbit, SN 88 ADCP, SN 593 (uplooking)
120	Tidbit, SN 89

Note: Two digit Tidbit serial numbers
are all preceded by 3957
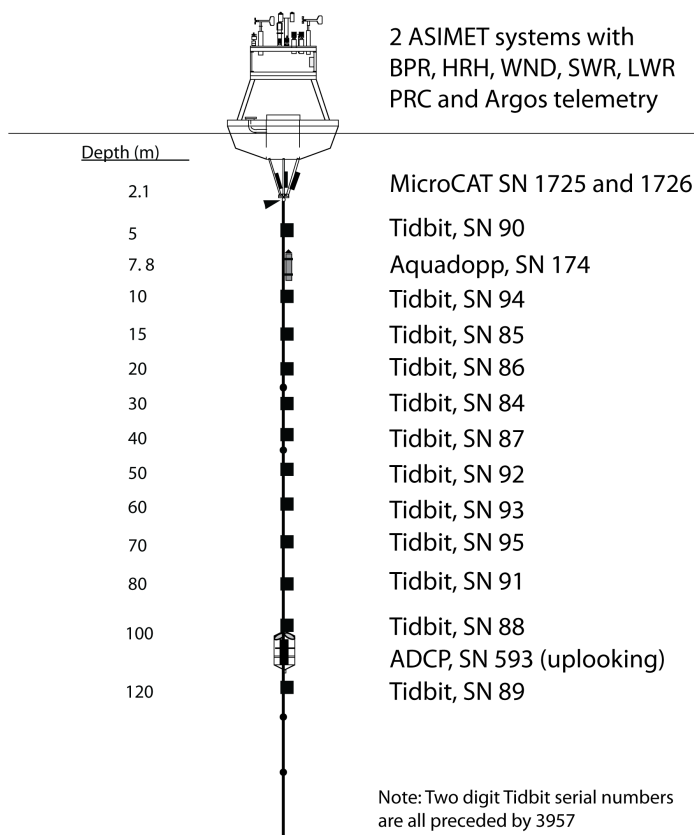
Figure 7: NTAS-1 mooring diagram. Near-surface detail.

deployment, interpolates to a "standard" time base, converts velocities to units of $\mathrm{cm\cdot s^{-1}}$, applies a sound speed correction, applies a magnetic variation correction, and assigns a depth based on the mooring log. Some basic metadata are also assigned at this stage.

4.2 VMCM

After instrument recovery, and before extracting the card from the instrument, the clock is checked by first securing the props, then releasing and spinning them for up to two minutes, and carefully recording the time of these procedures. VMCM data are stored on Intel type II flash memory cards, in 34-byte little endian binary records. The memory cards are removed from the instruments and copied to a laptop equipped with a PCMCIA/PC card slot using a custom version of Linux that includes support for these devices.

The binary files are processed using a pair of Malab scripts developed by the Upper Ocean
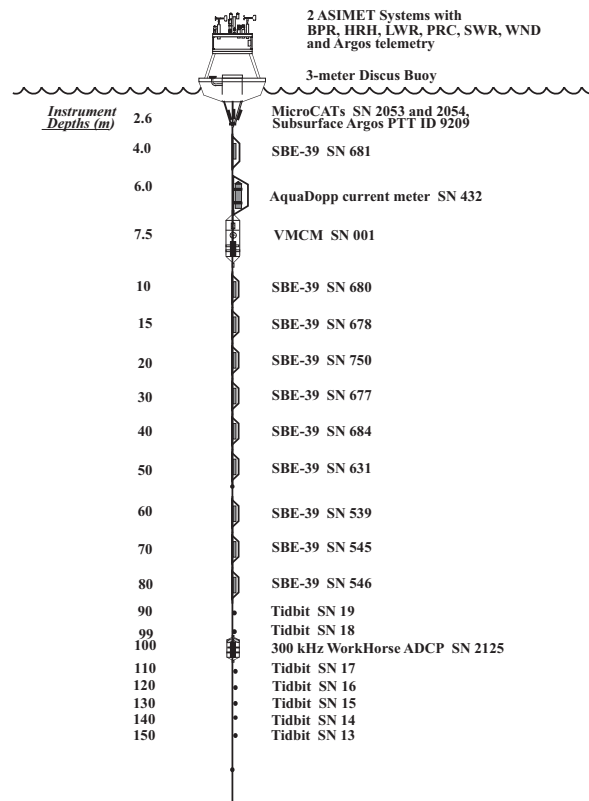
Figure 8: NTAS-2 mooring diagram. Near-surface detail.

Processes Group. The first script unpacks the binary records and generates an ASCII text file containing year, month, day, hour, minute, second, velocity east, velocity north, rotor counts from rotor1 and rotor2, the last compass reading taken during the 1 minute sample period, water temperature, thermistor resistance, tiltx, and tilty. Data are scaled to physical units during this step. In the second Matlab script, which converts the ASCII file to a Matlab data file, the serial date is calculated, and some basic metadata are added. A correction for the magnetic variation is applied.

4.3   ADCP

After instrument recovery and a time check, binary files are downloaded from the instrument to a laptop computer using the manufacturers "WinSC" software. The resulting file is unpacked using the Matlab data conversion utility `upkadcp.m`. This routine originated with E. Terray (WHOI) and was modified for use by the Upper Ocean Processes Group. The routine unpacks the binary ADCP data into eight Matlab structures containing

1. four components of velocity (east, north, up and error),

2. correlation parameter (counts),

3. backscatter intensity parameter (counts),

14
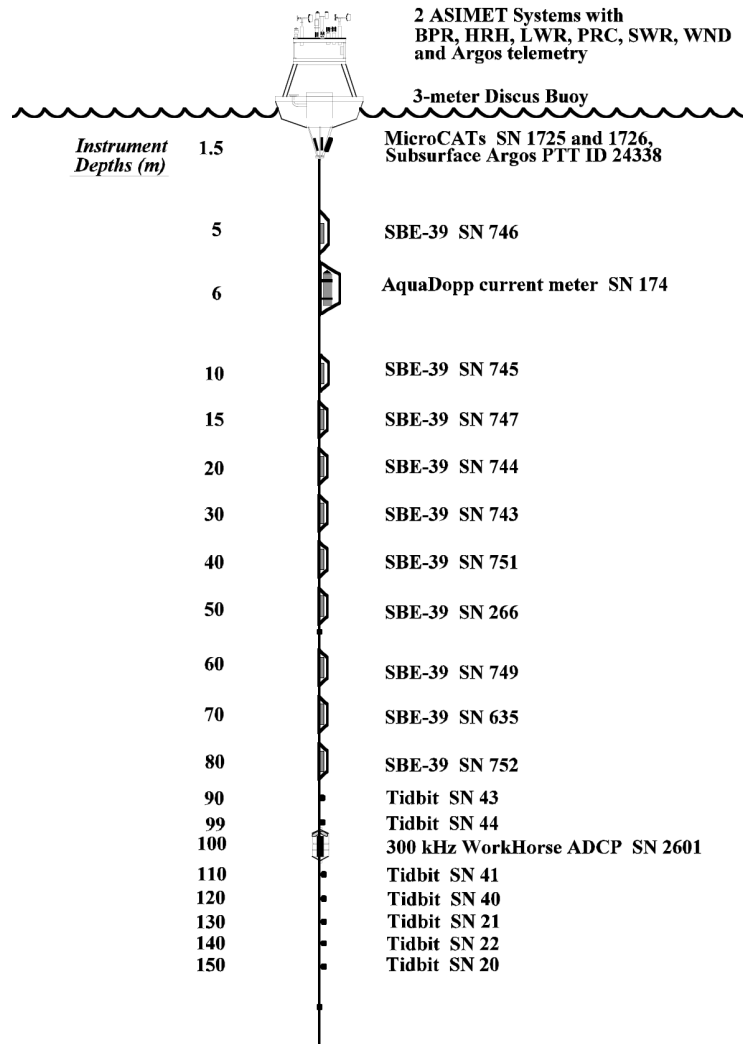
Figure 9: NTAS-3 mooring diagram. Near-surface detail.

4. percent good,

5. environmental data (e.g. time, temperature, heading, pitch, roll),

6. instrument metadata and configuration information,

7. description of the data format, and

8. bin distances from the transducer.

The unpacked data file is processed as described below to create the data evaluated in this report. The instrument metadata and configuration information are used to populate metadata fields in the processed data file.

Unpacked ADCP data are evaluated and processed in Matlab. Unpacked data are evaluated for timing problems (gaps or drift) and adjusted if necessary. Profiles of the mean and standard
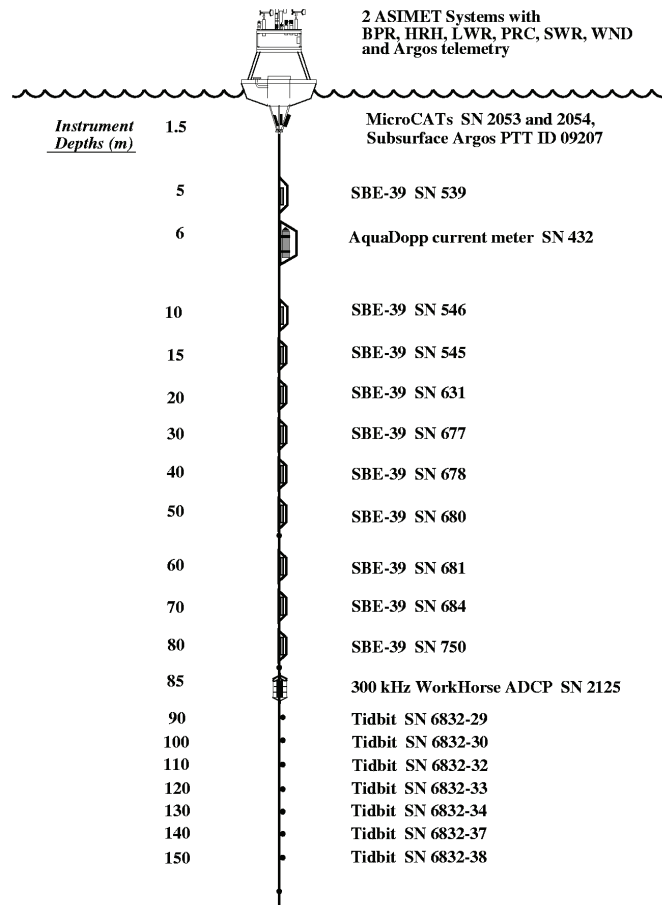
Figure 10: NTAS-4 mooring diagram. Near-surface detail.

deviation of velocity, correlation, intensity and percent good are then evaluated to determine the number of bins with data of sufficient quality to include in further processing. Two principal issues affect data quality for the up-looking ADCPs on NTAS: interference from surface returns and low signal to noise at far range. A combination of quantitative and qualitative criteria is considered in the evaluation.

- Quantitative criteria

    - The mean ADCP correlation parameter should be greater than 60 counts.

    - The mean percent good should be greater than 80%, although values as low as 50% can be tolerated if other criteria are satisfied.

    - The standard deviation of the error velocity should be less than 5 cm·s^{-1}.

- Qualitative criteria

    - The mean intensity should be decreasing with increasing range and neither intensity nor velocity should show evidence of influence from the surface return.

2 ASIMET Systems with
BPR, HRH, LWR, PRC, SWR, WND
and Argos telemetry

MicroCATs SN 1725 and 1726,
on buoy base at 1.5 m depth

DEPTH

5 m   SBE-39 SN 743
6 m   AquaDopp current meter SN 1226

10 m   SBE-39 SN 744

15 m   SBE-39 SN 745

20 m   SBE-39 SN 746

30 m   SBE-39 SN 747

40 m   SBE-39 SN 749

50 m   SBE-39 SN 751

60 m   SBE-39 SN 266

70 m   SBE-39 SN 635

80 m   SBE-39 SN 752

85 m   300 kHz WorkHorse ADCP SN 2601

90 m   Tidbit SN 4924-20
100 m   Tidbit SN 4924-22
110 m   Tidbit SN 6832-35
120 m   Tidbit SN 5827-40
130 m   Tidbit SN 5827-41
140 m   Tidbit SN 5827-43
150 m   Tidbit SN 5827-44

Figure 11: NTAS-5 mooring diagram. Near-surface detail.

- The mean and standard deviation of all four velocity components should vary smoothly with range—"kinks" in the mean profile accompanied by rapid increases in standard deviation are indicative of contamination and/or low signal to noise.

When the number of bins to be included in processing has been determined, a Matlab script is used to compute decimal year day from date and time, assign a subset of data from the unpacked structures to Matlab variables, and truncate the record at the start and end of the deployment. Remaining "bad points" are identified based on an error velocity threshold, and the time series for each bin is interpolated to a "standard" time base. Velocities are converted to units of $\text{cm} \cdot \text{s}^{-1}$, sound speed and magnetic variation corrections are applied and depth bins are assigned based on the mooring log and the distance of each bin from the transducer. Some basic metadata are also assigned at this stage.

5 Data Presentation

5.1 Introduction

The data presentation is briefly described, then each deployment's detail description follows. For each deployment, in addition to the processing outlined in Section 4,

- simple quality control checks on the application of magnetic variation and time base alignment were done, and adjusted where necessary;

- egregious outliers in the velocity data were detected and removed, described in Section 5.1.1.

- The time series of data were plotted.

- A statistical summary of means and variabilities of these time series were tabulated and are presented in an Appendix (Table A1).

- The spectra of the current data were determined and plotted, following the method described in Section 5.1.2. Where several depth bins are sampled by the same instrument (acoustic doppler profilers) the spectra are presented separately and also together in a waterfall plot.

- A table of spectral peaks was extracted from the spectrum for each current meter; and

- a progressive vector plot was prepared for each current meter.

The methods for dealing with outliers and creating spectra are outlined in the following paragraphs.

5.1.1 Outlier Detection

An example of the distribution of the NTAS data before scanning for outliers is shown in Figure 12. It was noted that in comparison to the normal (gaussian) distribution, the NTAS data exhibited long tails. Stripping data further than three standard deviations (3σ) from the mean (as might be reasonable in cleaning strictly normally distributed data) might have eliminated valid geophysical observations. Additionally the shape of the deviations from normal in the near-surface data together with features in the time series suggested that transient phenomena, such as passage of vortices, were being recorded. For this reason, only velocities greater than 5σ from the mean were discarded and replaced by interpolation for the preparation of this report. The number of points discarded for each deployment are listed in Table 5.

5.1.2 Spectral Analysis

The spectra of the data were determined using functions from the Matlab signal processing toolbox [*The Mathworks*, 2008]. The power spectral density estimate was made using the Welch spectral estimator. The Welch method splits the input signal into overlapping segments, applies a windowing filter and a fast Fourier transform (FFT) to determine the spectrum of each segment, and averages the spectra obtained. In this presentation the current meter record was split into segments 1/8 as long as the data record, with 50% overlap and a Hann window applied. The confidence
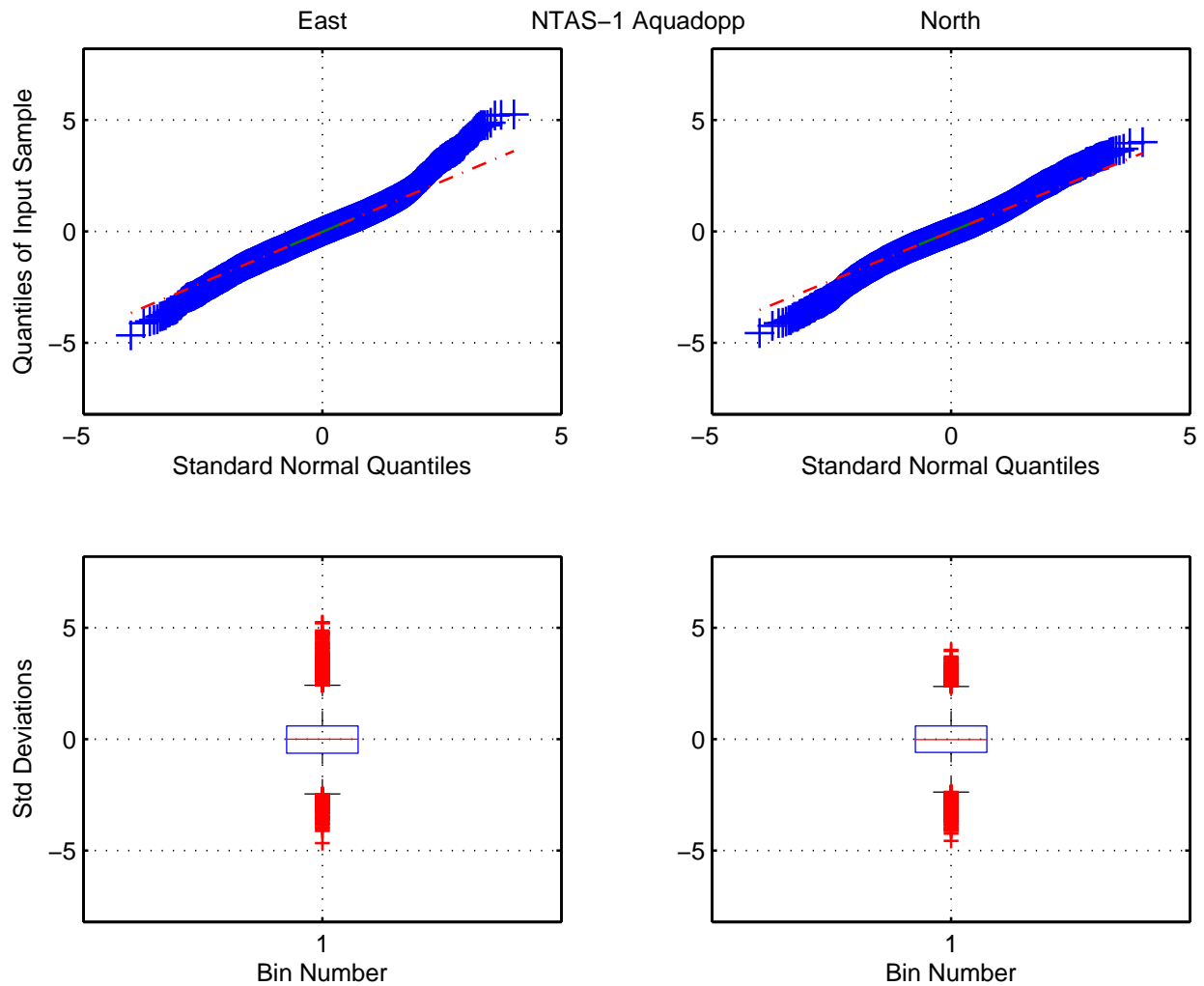
Figure 12: Plot of NTAS-1 Aquadopp velocity data, normalized by subtracting the mean and dividing by the standard deviation of each bin, showing (top) the deviation from the Gaussian distribution and (bottom) the location and variability of (left) East and (right) North current speeds. These plots show the long-tail nature of the current velocity distribution, up to 4 standard deviations from the mean, suggesting that values 4 or 5 standard deviations from the mean should not necessarily be regarded as outliers.

Table 5: The number of outlier points discarded from NTAS velocity data. AQD denotes a Nortek
         Aquadopp; RDI-N—RDI NarrowBand ADCP; RDI-W—RDI Workhorse ADCP; and VMCM—
         Vector Measuring Current Meter.

Deployment	Instrument	Data points discarded		From
		East	North	Total
NTAS-1	AQD	3	0	16342
NTAS-1	RDI-N	6	0	588186
NTAS-2	AQD	0	0	8365
NTAS-2	RDI-W	24	19	150570
NTAS-2	VMCM	0	0	66774
NTAS-3	AQD	95	0	8857
NTAS-3	RDI-W	1	7	159588
NTAS-4	AQD	0	0	6534
NTAS-4	RDI-W	3	3	148384
NTAS-5	AQD	0	0	8488
NTAS-5	RDI-W	0	2	135808

level was set to 90%. Once the spectrum was obtained, the frequency and power spectral density
were transformed by taking the base-10 logarithm of each. The best fit regression line to the trans-
formed spectrum was determined and subtracted to detrend the spectrum, allowing the spectral
peak heights to be measured.

The background level of instrumental noise was determined by assuming that this level could be
estimated from the highest frequencies. The spectrum was split into 16 segments and the segments
compared using the Wilcoxon rank sum test [*Wilcoxon*, 1945; *The Mathworks*, 2008: `ranksum`].
Those segments at high frequencies found to have the same median according to the statistical test
were then grouped and the background level determined as the median of these grouped values.

To investigate the influence of the movement of the buoy on the current data, the velocity of
the surface movement of the buoy was calculated from the Argos position and time stamp and
the rotary spectrum was calculated. The data buoy position can only be determined to within
∼1000 m using the Argos system [*Galbraith and Allsup*, 2005]. The Argos position is sampled
∼2–4 hourly (Fig. 13) and telemetered approximately every six hours [N. Galbraith, WHOI, pers.
comm.]. Consequently, this velocity record was noisy, with errors inherently larger than can be
expected for direct water velocity measurements, requiring careful attention in discarding outliers.

The approach was to:

1. convert position in terms of latitude and longitude to distances from the median position of
   the buoy;

2. calculate differences in time (δt) and displacement ($\delta \mathbf{x}$);

3. calculate velocity $\mathbf{v} = \delta \mathbf{x}/\delta t$.

4. Outliers in current speed ($|\mathbf{v}|$) were then discarded, with outliers determined as values lying
   further from the upper and lower quartiles than 1.5 times the interquartile range.
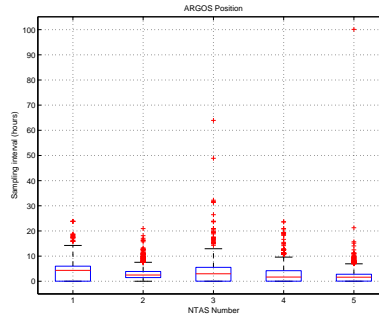
Figure 13: Boxplots of the time between observations of the buoy position using ARGOS satellite

5. The remaining velocity data were interpolated onto a regular timebase with intervals equal
    to the median of the position time differences ($\Delta t = \widetilde{\delta t}$)

6. the spectrum of the regular velocity series was determined in the same manner as for the
    velocity spectra above (not shown),

7. in addition the rotary spectra of the position were determined from the autospectra, cross
    spectra, and quadrature spectra of the scalar components calculated using FFT,

    The result for NTAS-1 is shown in Figure 14, and is somewhat representative of the rest
    of the deployments. In essence, the buoy motion is restricted by the diameter of the watch
    circle and the low frequency response is much less than that of the current meter. At inertial
    frequencies the buoy motion is more influential, yet still a few orders of magnitude less than
    the currents. At the higher frequencies the buoy motion is of the same order of magnitude
    as the currents and could have a strong influence on, e.g., the tidal response in the current
    record. The details will be discussed for each cruise below.

In the following sections the data from the NTAS deployments are presented.
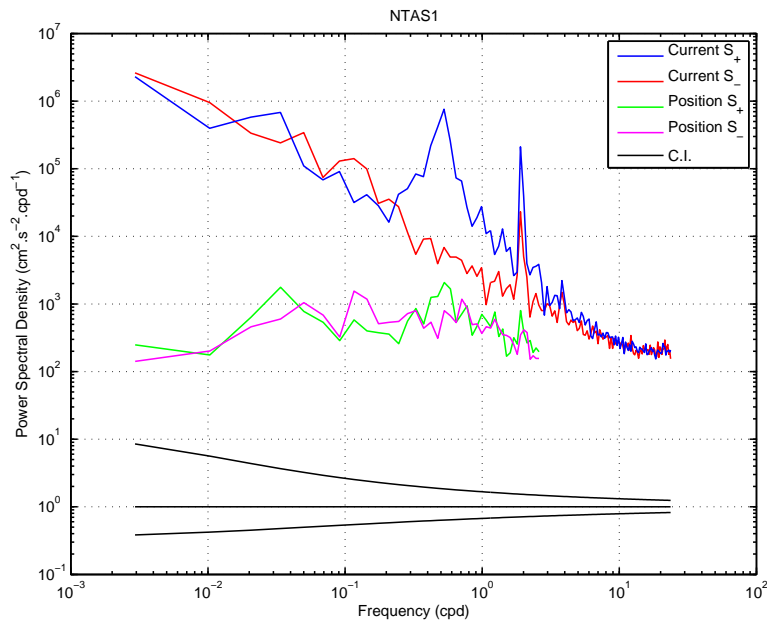
Figure 14: Showing the rotary spectra of velocities determined from the near-surface current meter (Aquadopp at 8 m) and the Argos buoy position from NTAS-1.

5.2 NTAS-1 Velocity Data

Rotary spectra for estimating the influence of the buoy motion on velocity data are shown in Figure 14.

5.2.1 Aquadopp

The time series of the speeds measured with the Aquadopp current meter is shown in Figure 15. The current velocities are shown integrated in a progressive vector diagram in Figure 16. The spectrum is shown in Figure 17. The spectral peaks are tabulated in Table 6.

5.2.2 RDI ADCP

RDI NarrowBand ADCP data were collected on NTAS-1. Time series of the current speed data are shown (Fig. 18).

The spectra for all RDI NarrowBand ADCP bins are shown as a waterfall plot in Figure 19. Tables of the spectral peaks obtained from the RDI Workhorse bins are shown in Tables 7 and 8. Only the deepest (90 m) and shallowest (22 m) bins are tabulated. Progressive vector diagrams for all bins of the NarrowBand ADCP data are shown in Figure 20.

Figure 15: Unfiltered current speed time series measured by NTAS-1 Aquadopp. The abscissa is marked in days since the beginning of the year or deployment of NTAS-1 (2001). (a) Northward speeds in cm·s^{-1}. (b) Eastward speeds in cm·s^{-1}. (c) Magnitude in cm·s^{-1}. (d) Direction in degrees clockwise from North.
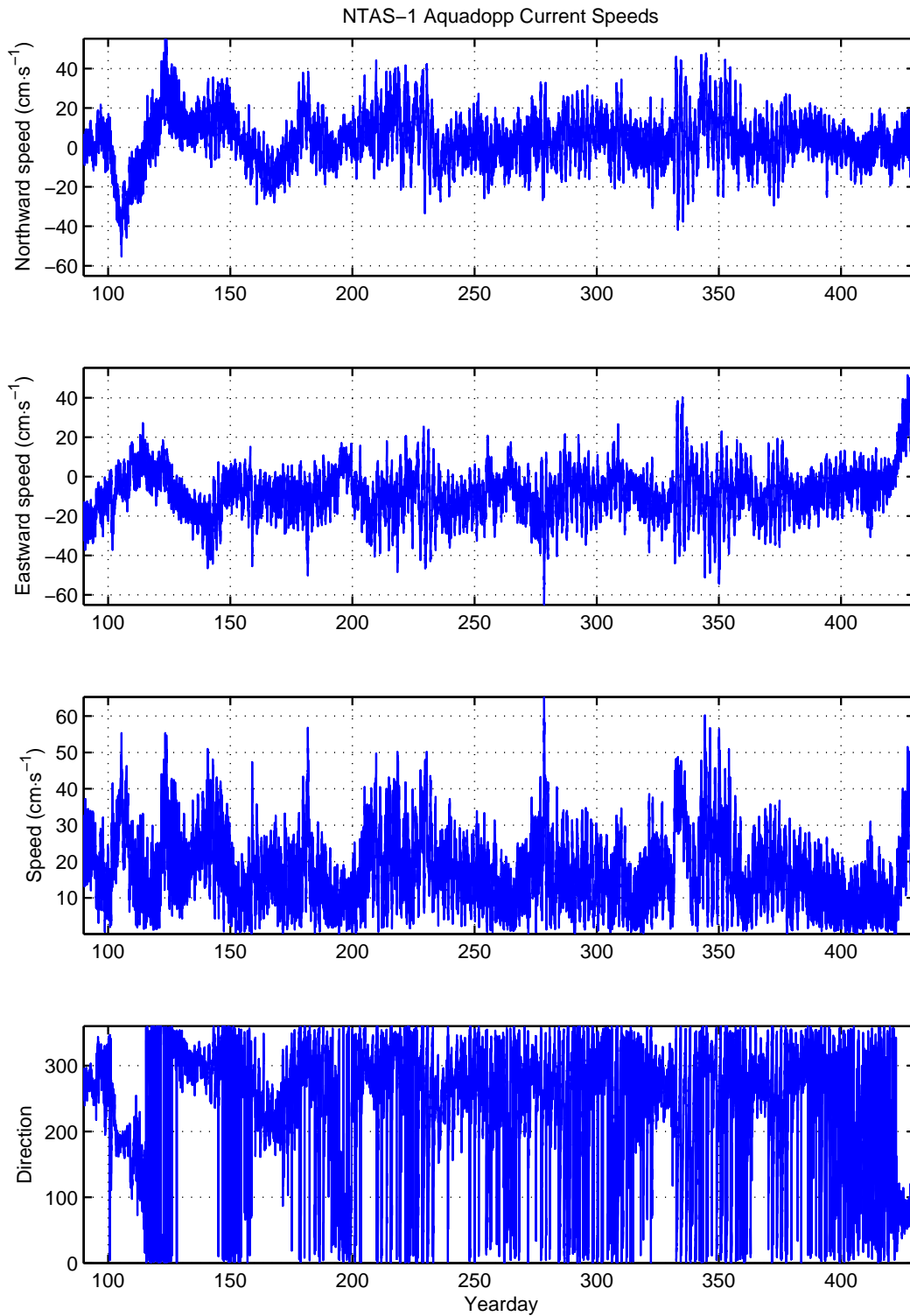
Table 6: Spectral peak heights for NTAS-1 Aquadopp. Peaks are ordered relative to the baseline.

Top 15 Peak Frequencies (NTAS-1 Aquadopp 7.8 m)

f (cpd)	T (day)	T (hr)	PeakHgt $(\text{cm}^2 \cdot \text{s}^{-2})$
1.94531	0.51406	12.33735	114.695
0.49219	2.03175	48.76190	180.231
0.02344	42.66667	1024.00000	4348.405
1.00781	0.99225	23.81395	31.451
1.40625	0.71111	17.06667	20.847
1.31250	0.76190	18.28571	12.316
3.84375	0.26016	6.24390	3.601
21.77344	0.04593	1.10226	0.418
23.48437	0.04258	1.02196	0.372
2.41406	0.41424	9.94175	4.111
1.21875	0.82051	19.69231	8.415
22.10156	0.04525	1.08590	0.359
22.54687	0.04435	1.06445	0.351
22.92187	0.04363	1.04703	0.342
22.47656	0.04449	1.06778	0.341

Table 7: Spectral peak heights for NTAS-1 RDI NarrowBand, 90 m bin. Peaks are ordered relative to the baseline.

Top 15 Peak Frequencies (NTAS-1 NarrowBand 90 m)

f (cpd)	T (day)	T (hr)	PeakHgt $(\text{cm}^2 \cdot \text{s}^{-2})$
1.94531	0.51406	12.33735	65.618
0.02344	42.66667	1024.00000	2744.690
0.53906	1.85507	44.52174	82.059
1.40625	0.71111	17.06667	19.147
2.43750	0.41026	9.84615	7.449
4.03125	0.24806	5.95349	2.349
3.86719	0.25859	6.20606	2.350
47.74219	0.02095	0.50270	0.175
38.85938	0.02573	0.61761	0.201
47.97656	0.02084	0.50024	0.148
47.46094	0.02107	0.50568	0.147
4.28906	0.23315	5.59563	1.716
2.67188	0.37427	8.98246	2.739
47.88281	0.02088	0.50122	0.141
37.75781	0.02648	0.63563	0.179
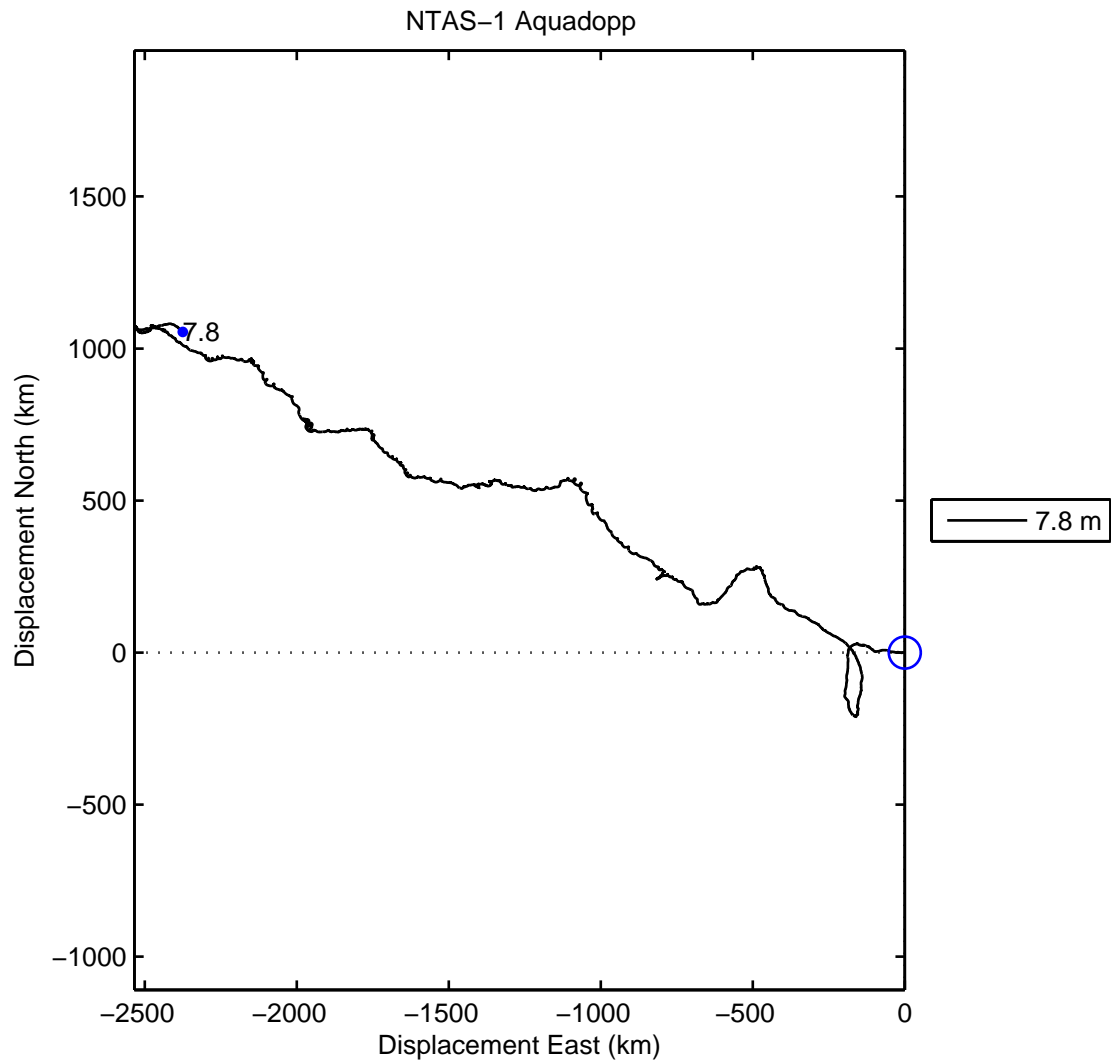
Figure 16: Progressive vector diagram of the NTAS-1 Aquadopp current meter.
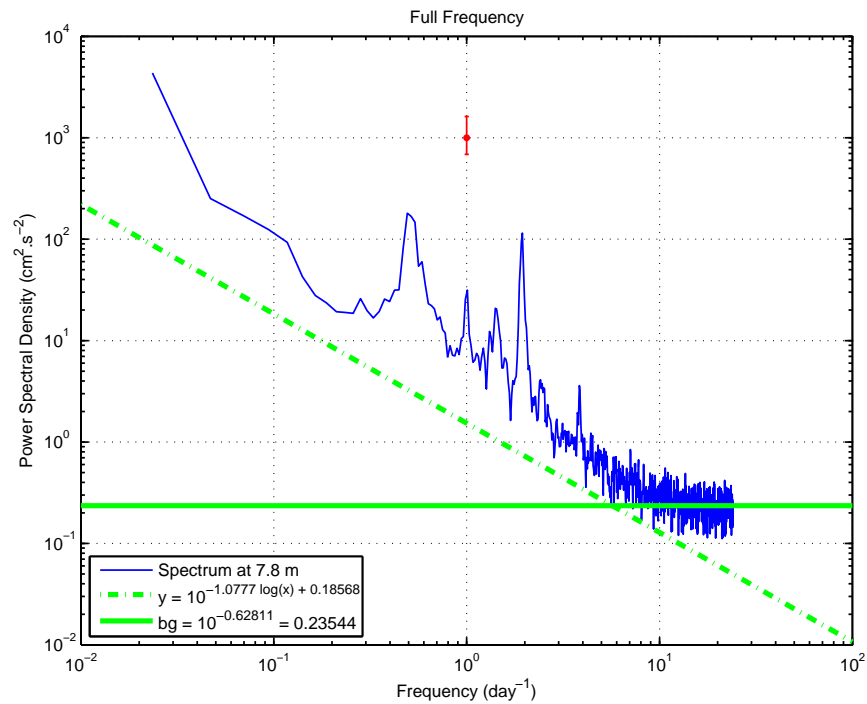
Figure 17: Spectrum of NTAS-1 Aquadopp current speed. Symbol at top center indicates confidence interval for the spectrum. Dashed line has the slope of the least-squares regression line passing through the data, but has been shifted down to pass through the minimum spectral density. The solid line indicates the level of instrumental noise, determined from the leveling off of the tail of the high frequency spectrum. The equation in the legend describes the best fit regression line through the spectral data.
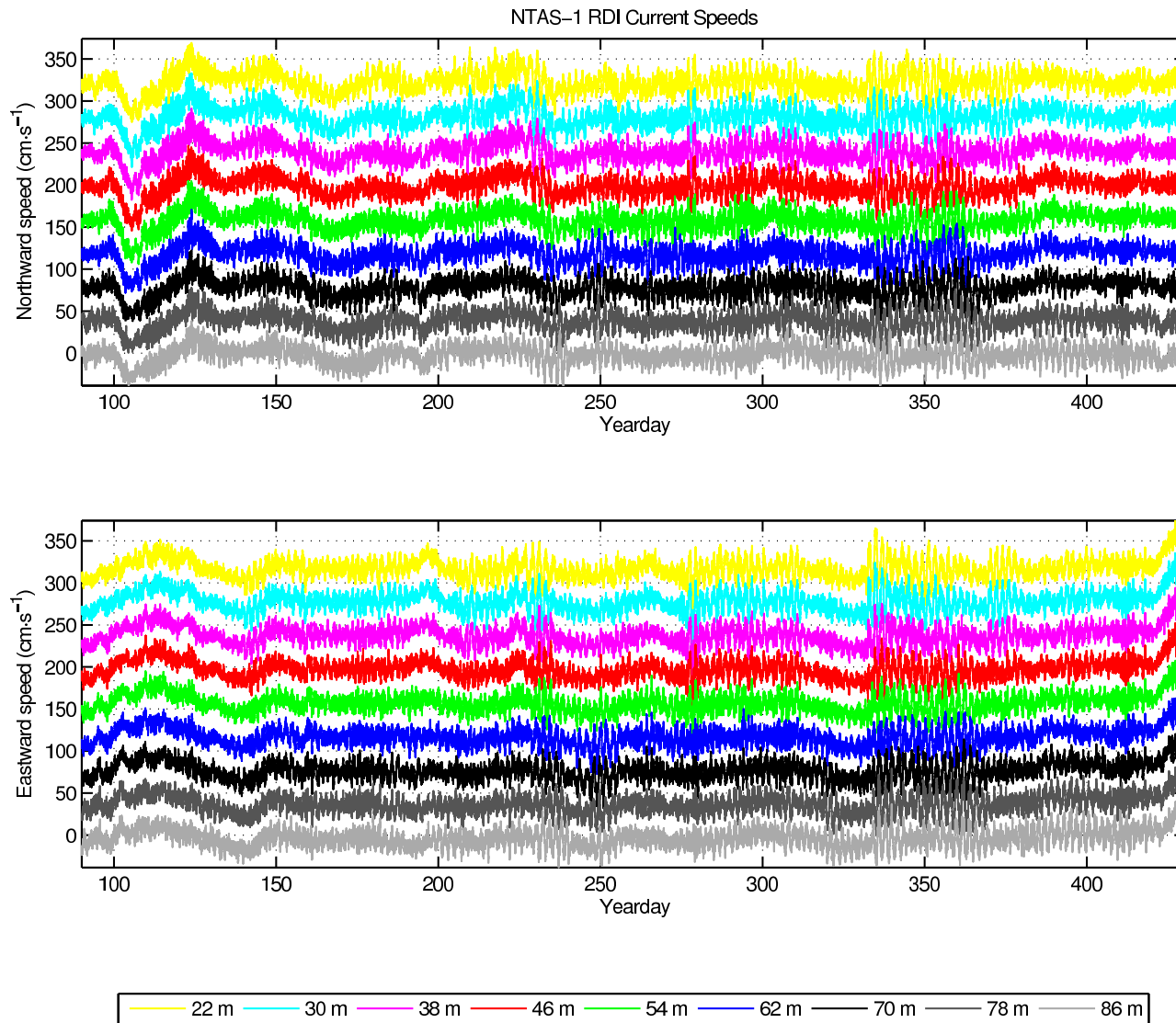
Figure 18: (a) Waterfall plots of the current speed time series from the NTAS-1 RDI NarrowBand. Northerly (top) and easterly (bottom) current speeds for the ADCP bins. Series are offset by 40 cm·s^{-1}. In each plot the axis values are correct for the lowest series. Each subsequent series is offset upwards. In each plot the series are from every second 4 m bin, i.e., the [86, 78, 70, 62, 54, 46, 38, 30, 22] m bins (reading upwards from the deepest trace in each case).
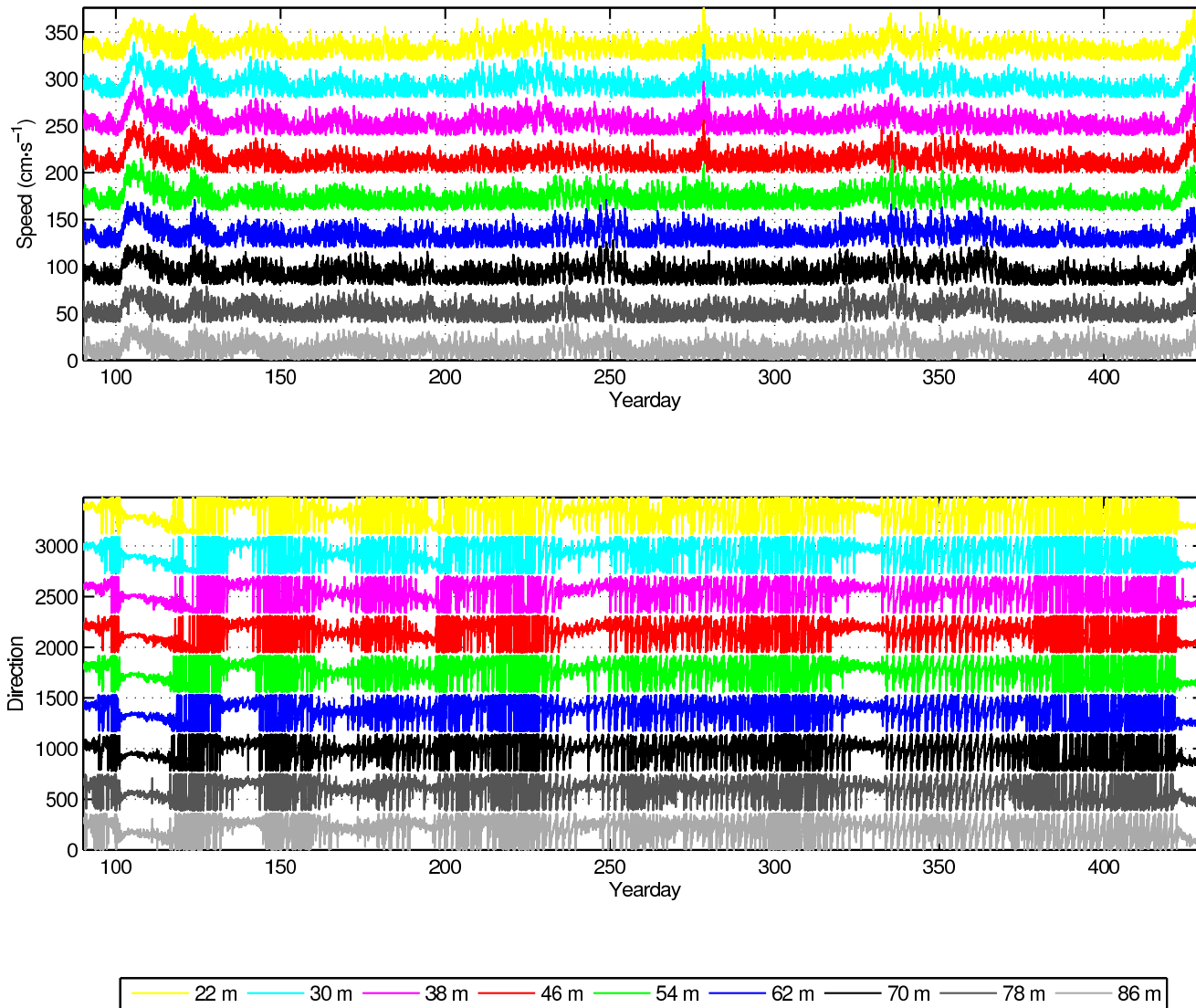
Figure 18: (b) Waterfall plots of the currents time series from the NTAS-1 RDI NarrowBand. Current magnitude (top) and direction (bottom). The magnitude is offset by 40 cm·s^{-1}. Each direction plot is offset by 390 degrees from the one below. In each plot the axis values are correct for the lowest series. Each subsequent series is offset upwards. In each plot the series are from every second 4 m bin, i.e., the [86, 78, 70, 62, 54, 46, 38, 30, 22] m bins (reading from the lowest trace in each case).
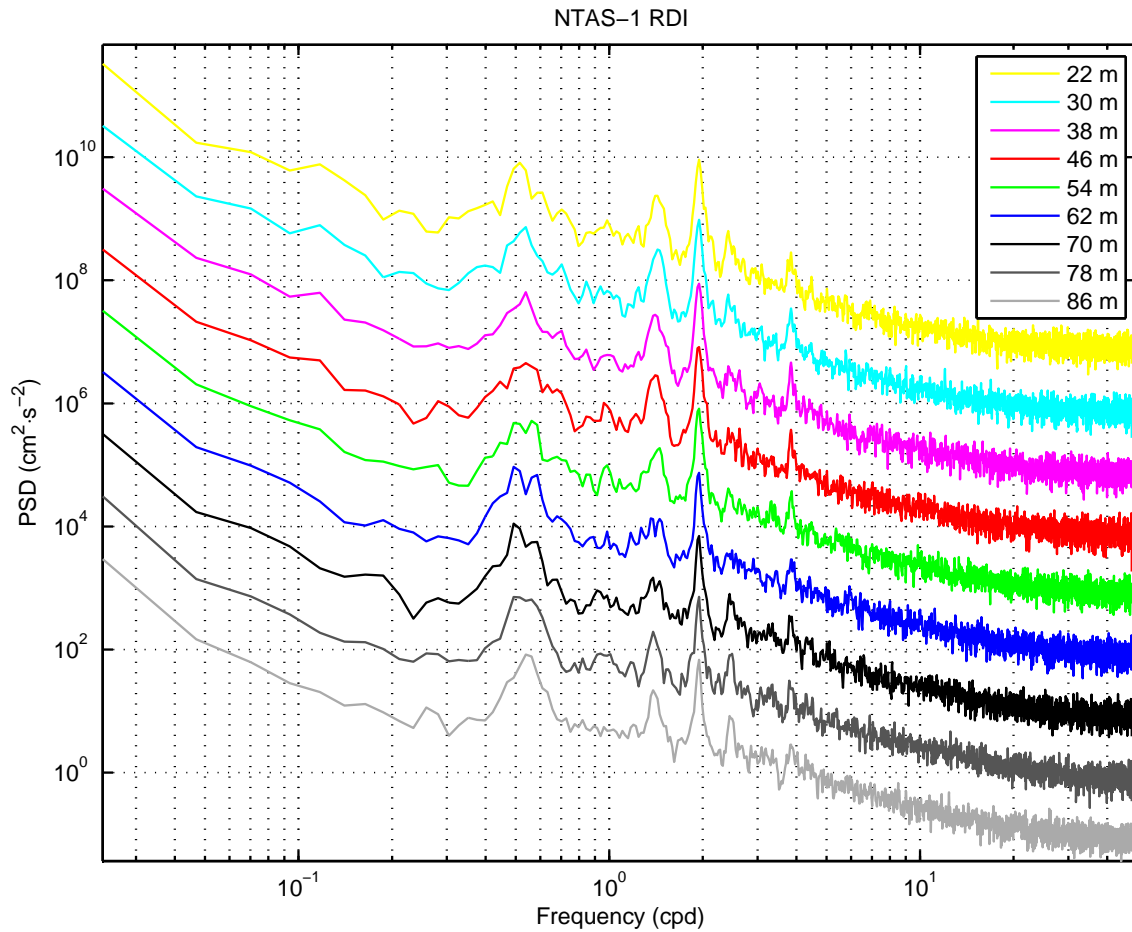
Figure 19: NTAS-1 RDI NarrowBand spectra from 86 to 22 meters (spectra for every second 4 m bin are shown from bottom to top, each spectrum offset by $10\times$ the previous spectrum).

Table 8: Spectral peak heights for NTAS-1 RDI NarrowBand, 22 m bin. Peaks are ordered relative to the baseline.

| Top 15 Peak Frequencies (NTAS-1 NarrowBand 22 m)			
f (cpd)	T (day)	T (hr)	PeakHgt ($cm^2 \cdot s^{-2}$)
1.94531	0.51406	12.33735	91.099
0.02344	42.66667	1024.00000	3287.050
0.51563	1.93939	46.54545	81.293
1.42969	0.69945	16.78689	23.611
2.41406	0.41424	9.94175	6.354
0.70313	1.42222	34.13333	14.105
0.98438	1.01587	24.38095	9.404
1.24219	0.80503	19.32075	7.600
3.84375	0.26016	6.24390	2.832
3.75000	0.26667	6.40000	2.138
1.14844	0.87075	20.89796	5.698
2.69531	0.37101	8.90435	2.237
3.96094	0.25247	6.05917	1.500
3.09375	0.32323	7.75758	1.815
46.42969	0.02154	0.51691	0.158

Figure 20: Superimposed progressive vector diagram of currents from the NTAS-1 RDI NarrowBand ADCP. Vectors start at ○ at the origin $(0,0)$ and end at the ●. Every second 4 m bin from 22 to 86 m is plotted as listed in the legend on the figure.
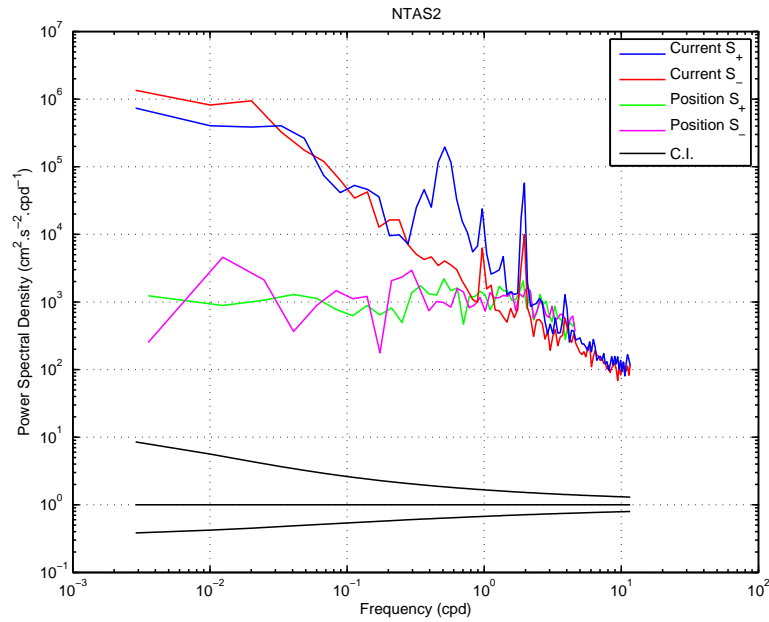
Figure 21: Showing the rotary spectra of velocities determined from the near-surface current meter (Aquadopp at 6 m) and the Argos buoy position from NTAS-2.
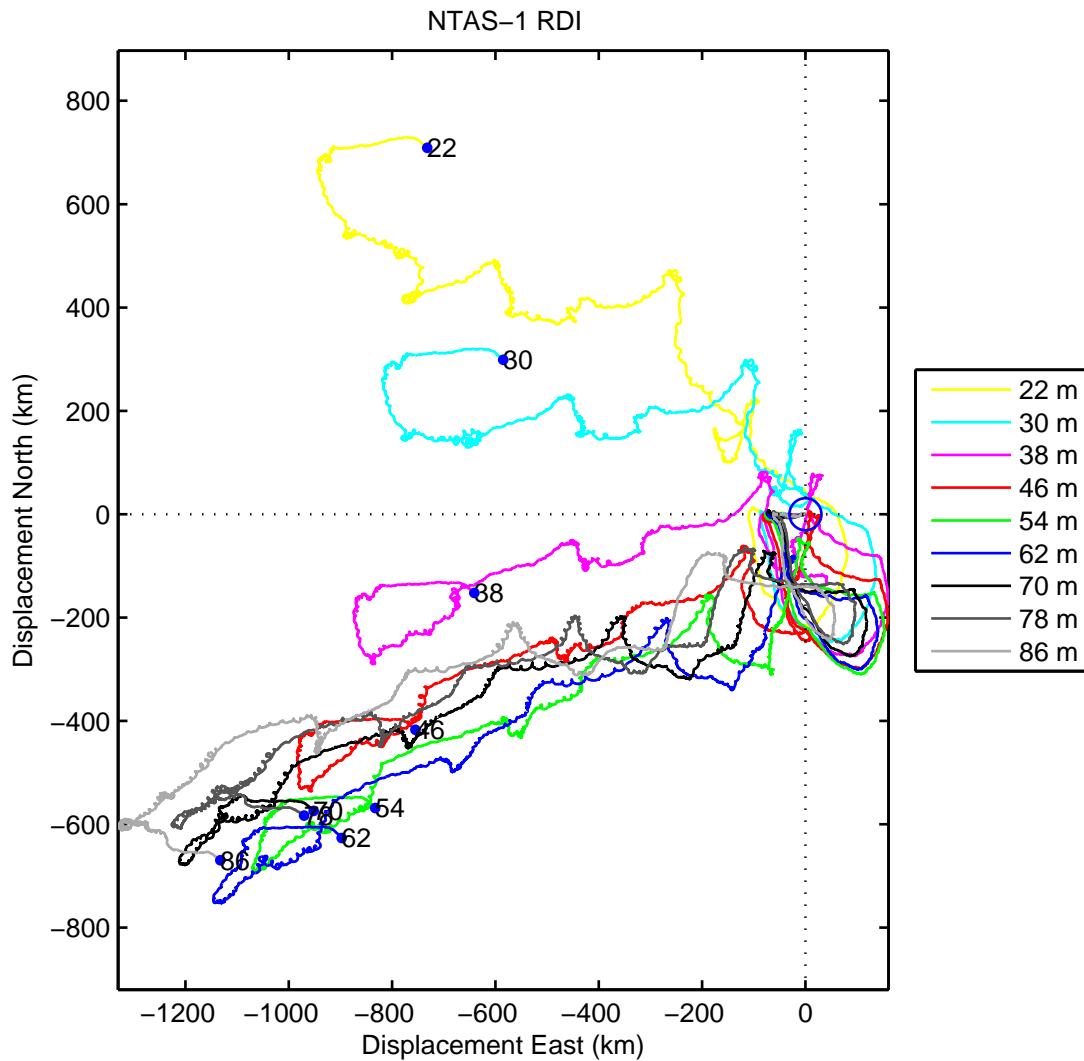
5.3   NTAS-2 Velocity Data

Rotary spectra estimating the influence of the buoy motion on velocity data are shown in Figure 21.

5.3.1   Aquadopp

The time series of the speeds measured with the Aquadopp current meter is shown in Figure 22. The current velocities are shown integrated in a progressive vector diagram in Figure 23. The spectrum is shown in Figure 24. The spectral peaks are tabulated in Table 9.

5.3.2   RDI Workhorse

A time series of the current speed data from the RDI workhorse ADCP is shown in Figure 25. The spectra for all RDI Workhorse ADCP bins are shown as a waterfall plot in Figure 26 Tables of the spectral peaks obtained from the RDI Workhorse bins are shown in Tables 10 and 11. Only the deepest (90 m) and shallowest (46 m) bins are tabulated. Progressive vector diagrams for all bins of the Workhorse data are shown in Figure 27.

5.3.3   Vector Measuring Current Meter

During initial processing of the VMCM on NTAS-2, a magnetic variation of $-15.55°$ was applied, instead of the required $-17.5°$. This was corrected during the analysis.

The time series of speeds measured with the VMCM current meter is shown in Figure 28. The current velocities are shown integrated in a progressive vector diagram in Figure 29. The spectrum is shown in Figure 30. The spectral peaks are tabulated in Table 12.

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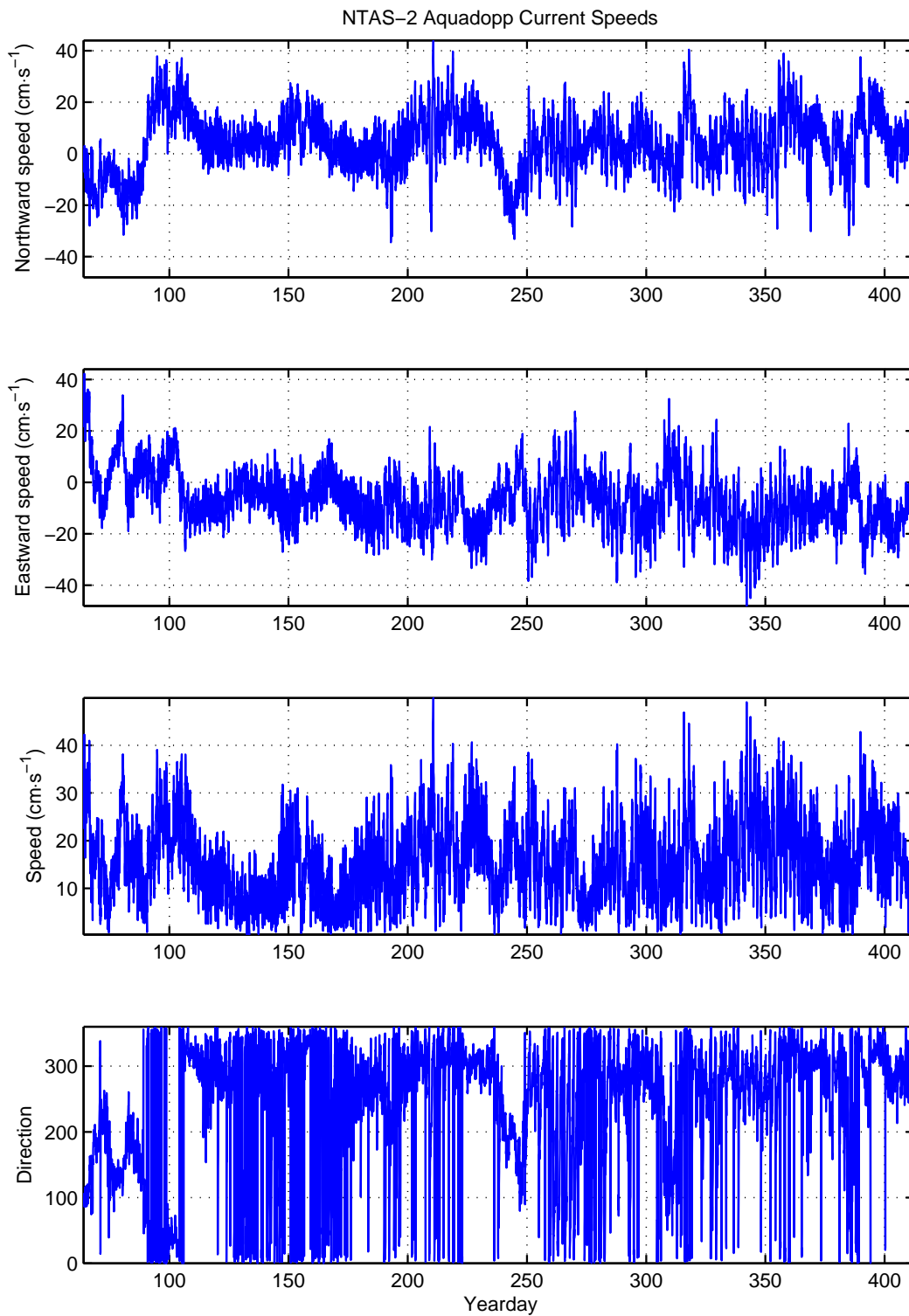Figure 22: Unfiltered currents from NTAS-2 Aquadopp. (a) Northward current speeds. (b) Eastward current speeds. (c) Magnitude. (d) Direction.

Table 9: Spectral peak heights for NTAS-2 Aquadopp. Peaks are ordered relative to the baseline.

Top 15 Peak Frequencies (NTAS-2 Aquadopp 6 m)

f (cpd)	T (day)	T (hr)	PeakHgt ($cm^2 \cdot s^{-2}$)
1.93359	0.51717	12.41212	105.072
0.51562	1.93939	46.54545	134.692
1.00781	0.99225	23.81395	50.375
0.01172	85.33333	2048.00000	10558.943
0.59766	1.67320	40.15686	43.403
1.40625	0.71111	17.06667	11.879
2.43750	0.41026	9.84615	3.909
1.48828	0.67192	16.12598	7.033
1.12500	0.88889	21.33333	9.915
11.47266	0.08716	2.09193	0.419
9.86719	0.10135	2.43230	0.499
8.90625	0.11228	2.69474	0.556
3.86719	0.25859	6.20606	1.663
11.13281	0.08982	2.15579	0.399
0.94922	1.05350	25.28395	10.826

Table 10: Spectral peak heights for NTAS-2 RDI Workhorse, 90 m bin. Peaks are ordered relative to the baseline.

Top 15 Peak Frequencies (NTAS-2 Workhorse 90 m)

f (cpd)	T (day)	T (hr)	PeakHgt ($cm^2 \cdot s^{-2}$)
0.01172	85.33333	2048.00000	6638.381
1.94531	0.51406	12.33735	41.315
0.52734	1.89630	45.51111	67.912
1.39453	0.71709	17.21008	12.900
11.91797	0.08391	2.01377	1.405
2.46094	0.40635	9.75238	5.933
2.08594	0.47940	11.50562	6.580
2.37891	0.42036	10.08867	5.750
3.82031	0.26176	6.28221	3.574
11.21484	0.08917	2.14002	1.263
3.86719	0.25859	6.20606	3.349
8.53125	0.11722	2.81319	1.543
1.33594	0.74854	17.96491	8.341
0.75000	1.33333	32.00000	13.579
1.48828	0.67192	16.12598	7.154

Table 11: Spectral peak heights for NTAS-2 RDI Workhorse, 46 m bin. Peaks are ordered relative to the baseline.

Top 15 Peak Frequencies (NTAS-2 Workhorse 46 m)

f (cpd)	T (day)	T (hr)	PeakHgt ($cm^2 \cdot s^{-2}$)
0.01172	85.33333	2048.00000	7375.793
1.94531	0.51406	12.33735	62.631
0.53906	1.85507	44.52174	33.399
1.41797	0.70523	16.92562	10.966
0.48047	2.08130	49.95122	28.110
1.34766	0.74203	17.80870	10.235
11.94141	0.08374	2.00981	1.501
11.76562	0.08499	2.03984	1.519
10.60547	0.09429	2.26298	1.463
1.00781	0.99225	23.81395	11.410
1.47656	0.67725	16.25397	8.130
3.91406	0.25549	6.13174	3.390
9.03516	0.11068	2.65629	1.529
10.18359	0.09820	2.35673	1.358
0.69141	1.44633	34.71186	14.109

Table 12: Spectral peak heights from the VMCM on NTAS-2. Peaks are ordered relative to the baseline.

Top 15 Peak Frequencies (NTAS-2 VMCM 7.5 m)

f (cpd)	T (day)	T (hr)	PeakHgt ($cm^2 \cdot s^{-2}$)
1.93232	0.51751	12.42029	82.018
0.51529	1.94067	46.57610	105.563
1.00715	0.99290	23.82963	34.988
1.40532	0.71158	17.07790	12.167
0.01171	85.38951	2049.34827	7489.546
2.11970	0.47177	11.32237	4.044
1.48730	0.67236	16.13660	6.358
2.49445	0.40089	9.62135	2.774
2.42419	0.41251	9.90023	2.778
0.94859	1.05419	25.30060	9.215
4.00518	0.24968	5.99225	1.249
1.20624	0.82902	19.89659	6.406
1.12426	0.88947	21.34738	6.928
3.86464	0.25876	6.21015	1.235
2.93947	0.34020	8.16473	1.610
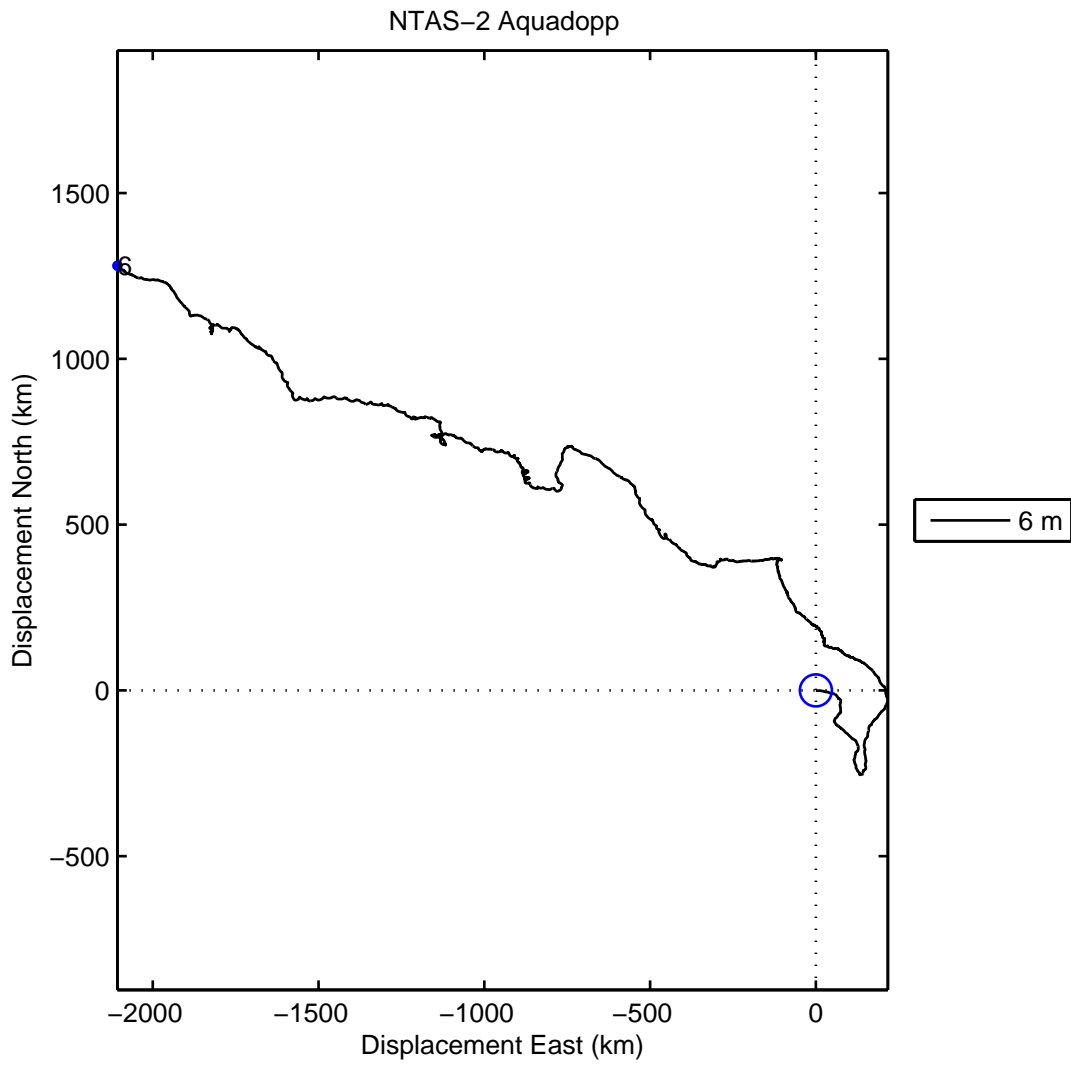
Figure 23: Progressive vector diagram of currents from the NTAS-2 Aquadopp.
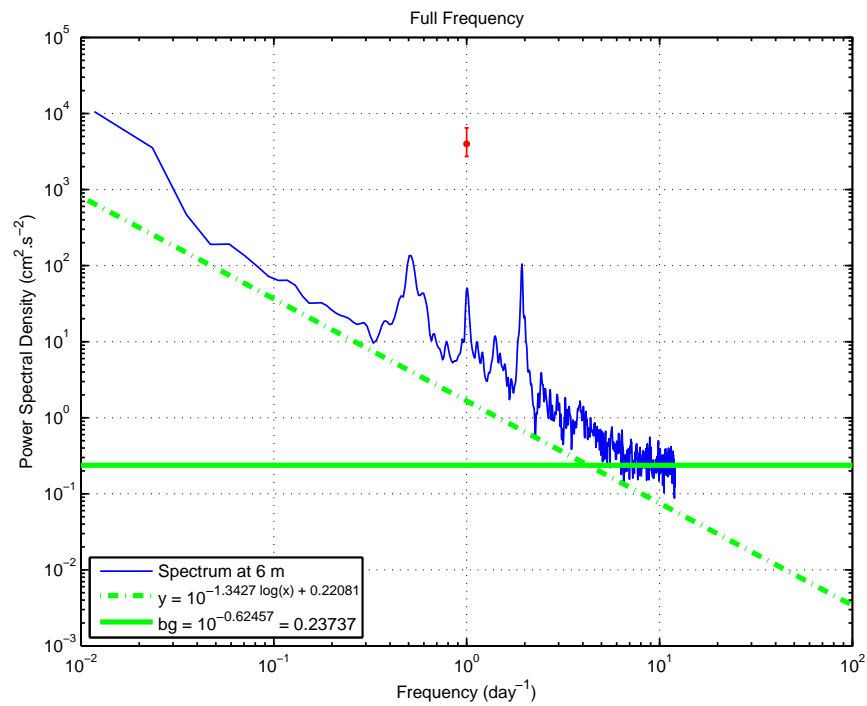
Figure 24: Spectrum of NTAS-2 Aquadopp current speed. Symbol at top center indicates confidence interval for the spectrum. Dashed line has the slope of the least-squares regression line passing through the data, but has been shifted down to pass through the minimum spectral density. The solid line indicates the level of instrumental noise, determined from the leveling off of the tail of the high frequency spectrum.
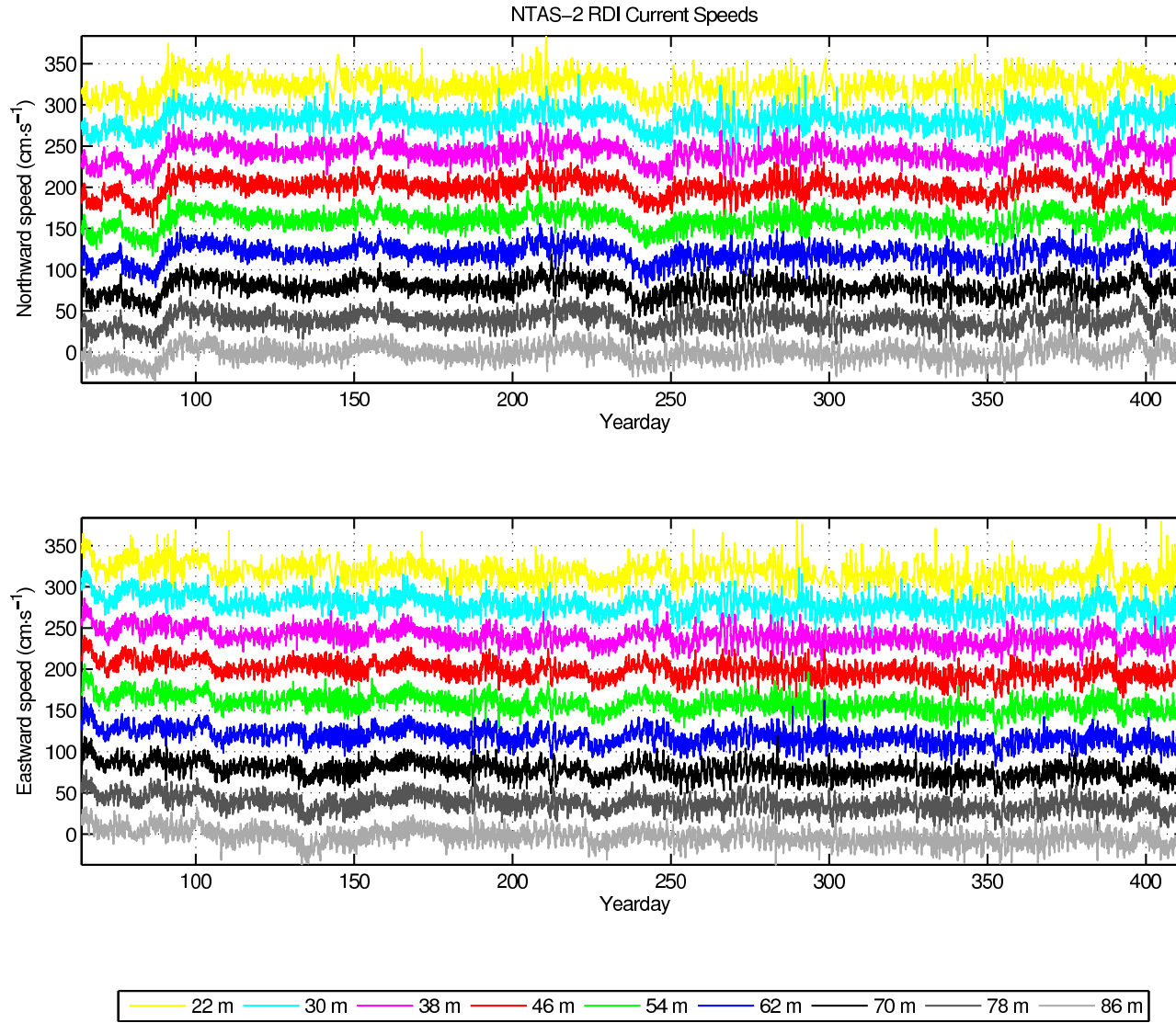
Figure 25: (a) Waterfall plots of the current speed time series from the NTAS-2 RDI Workhorse ADCP. Northerly (top) and easterly (bottom) current speeds for the ADCP bins. Series are offset by 40 cm·s^{-1}. In each plot the axis values are correct for the lowest series. Each subsequent series is offset upwards. In each plot the series are from every second 4 m bin, i.e., the [86, 78, 70, 62, 54, 50, 46, 38, 30, 22] m bins (reading upwards from the deepest trace in each case).
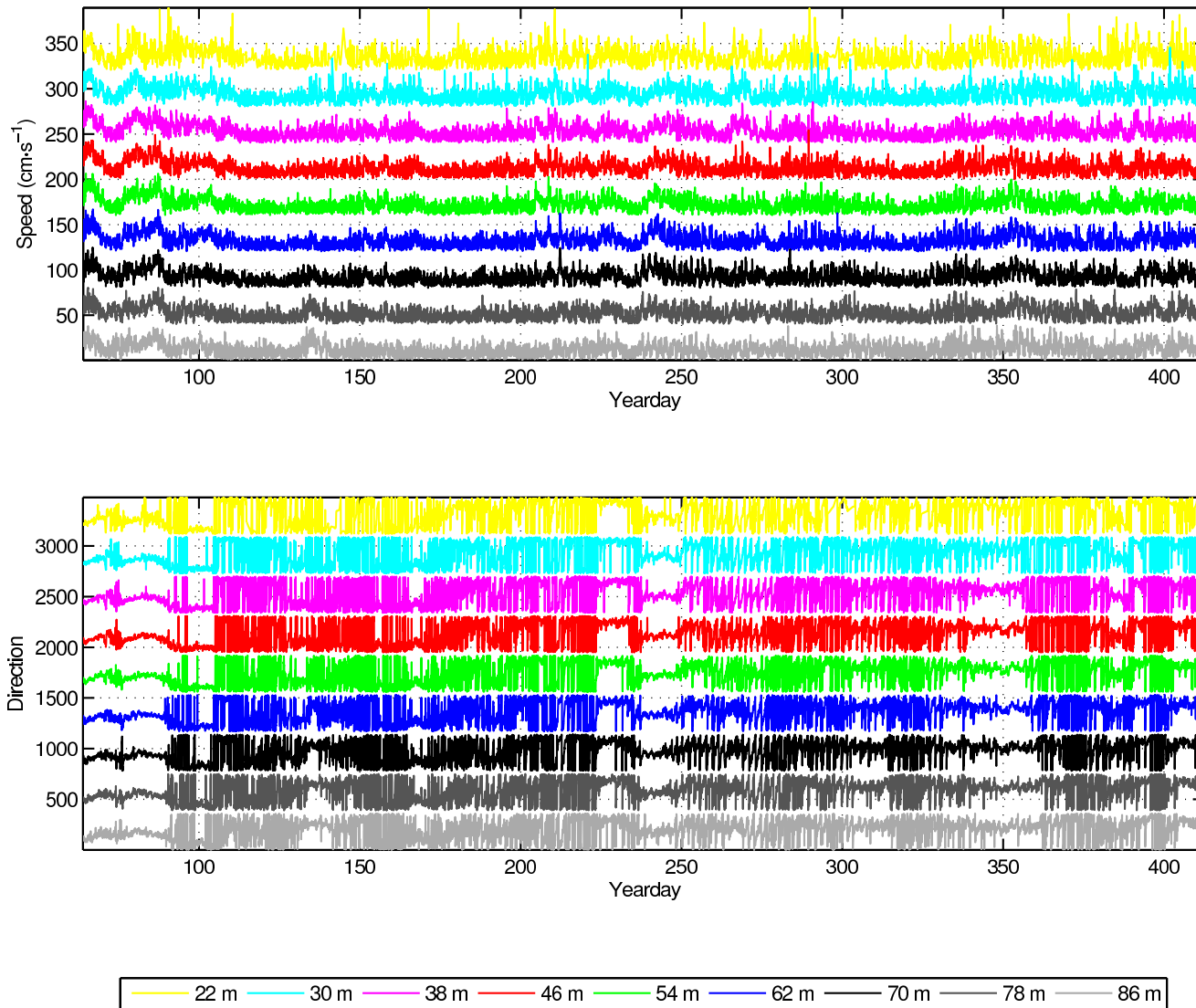
Figure 25: (b) Waterfall plots of the currents time series from the NTAS-2 RDI Workhorse. Current magnitude (top) and direction (bottom). The magnitude is offset by 40 cm·s^{-1}. Each direction plot is offset by 390 degrees from the one below. In each plot the axis values are correct for the lowest series. Each subsequent series is offset upwards. In each plot the series are from every second 4 m bin, i.e., the [86, 78, 70, 62, 54, 50, 46, 38, 30, 22] m bins (reading from the lowest trace in each case).
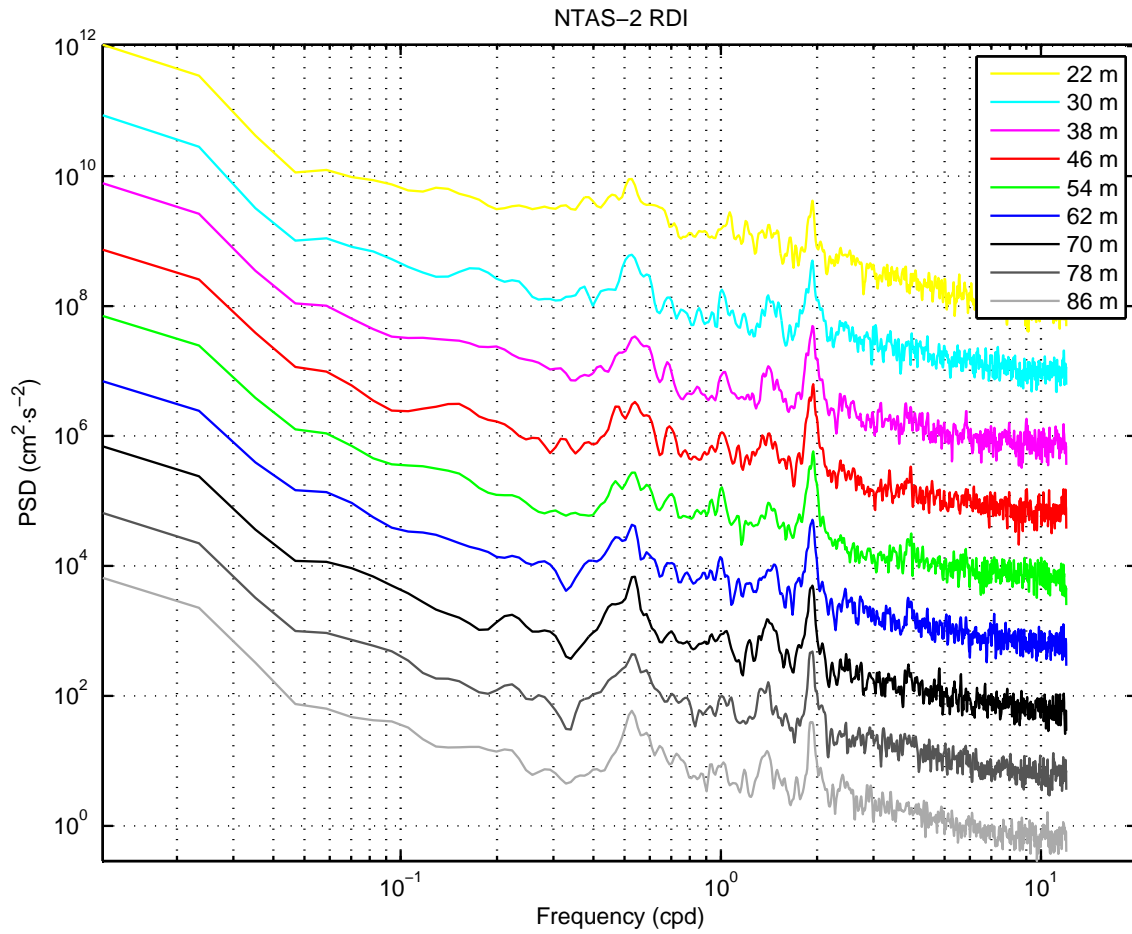
Figure 26: NTAS-2 RDI Workhorse spectra from 86 to 22 meters (spectra for every second 4 m bin are shown from bottom to top, each spectrum offset by $10\times$ the previous spectrum).
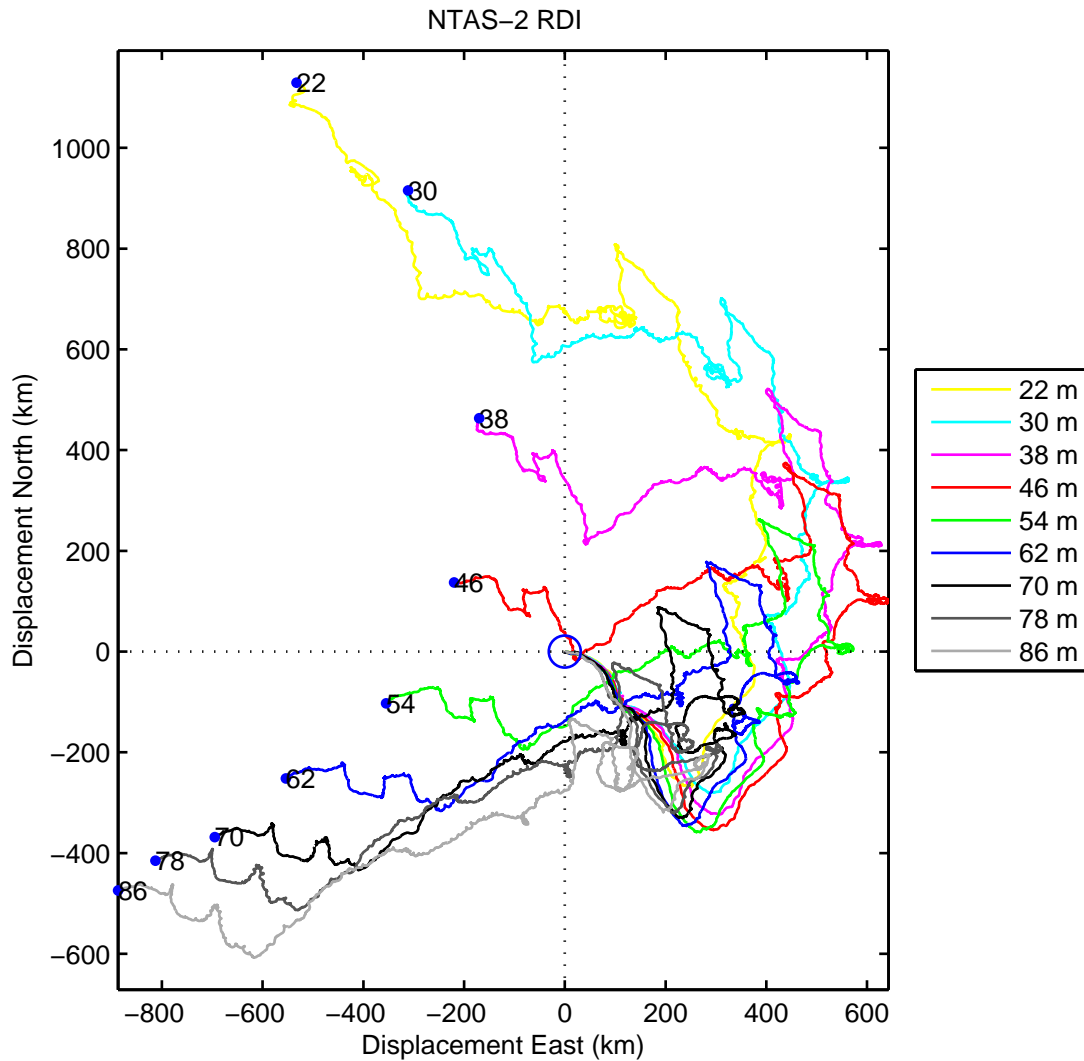
Figure 27: Superimposed progressive vector diagram of currents from the NTAS-2 RDI Workhorse. Vectors start at ○ at the origin (0,0) and end at the ●. Every second 4 m bin from 22 to 86 m is plotted as listed in the legend on the figure.
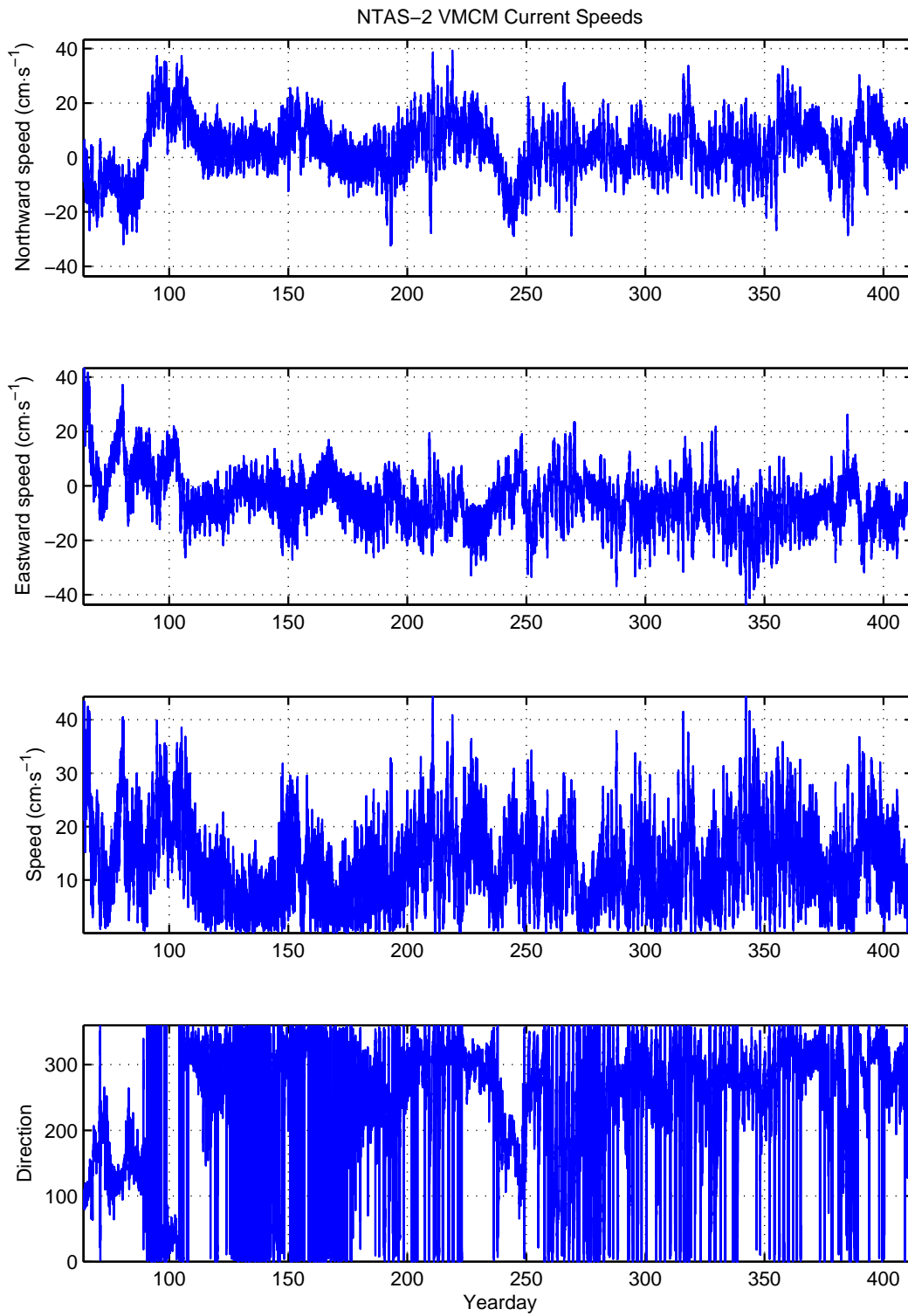
Figure 28: Currents from VMCM NTAS-2. (a) Northward. (b) Eastward. (c) Magnitude. (d) Direction.

NTAS−2 VMCM
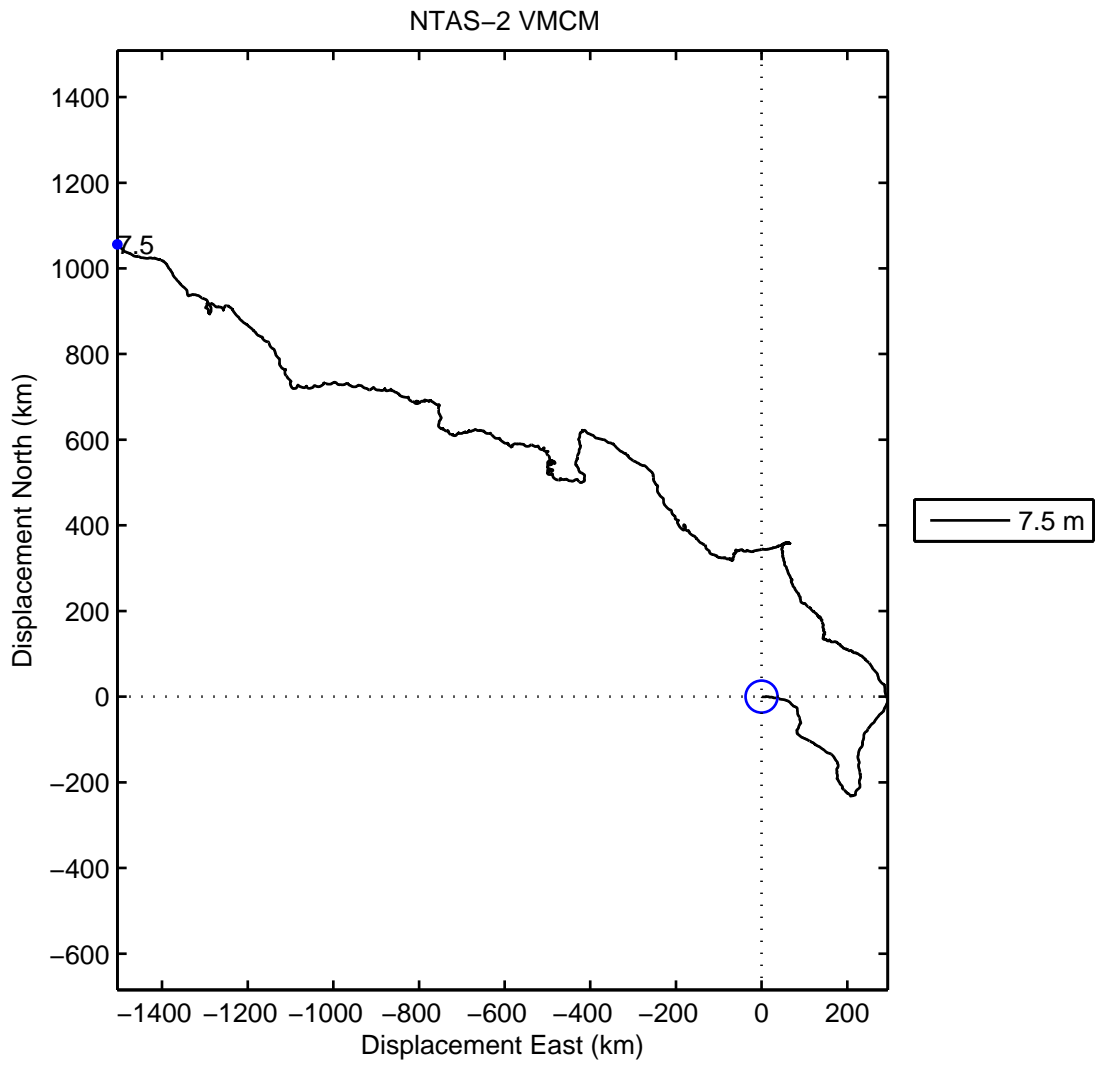
Figure 29: Progressive vector diagram from the VMCM NTAS-2.
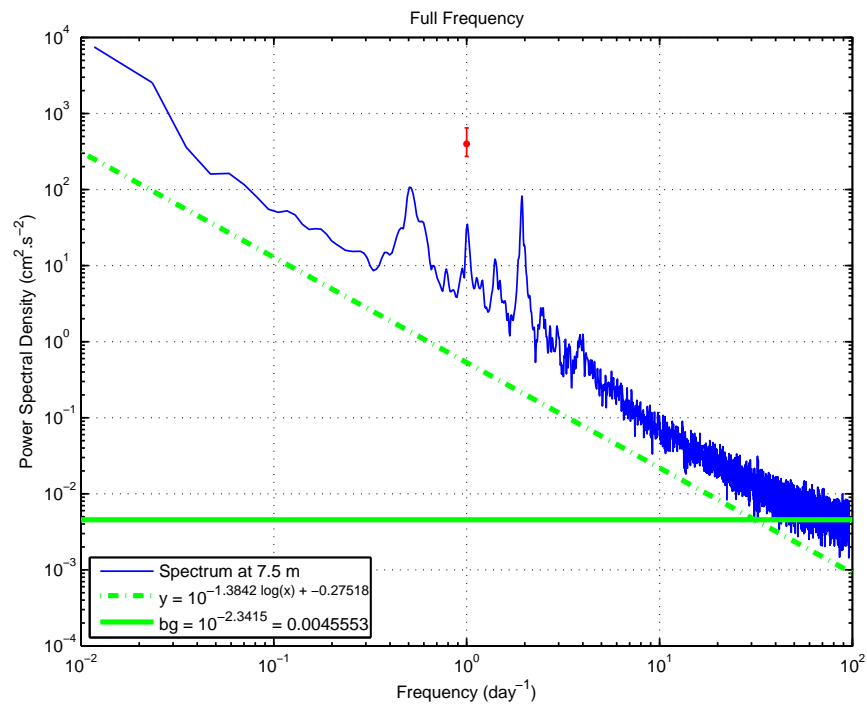
Figure 30: Spectrum from the vector measuring current meter deployed on NTAS-2. Symbol at top center indicates confidence interval for the spectrum. Dashed line has the slope of the least-squares regression line passing through the data, but has been shifted down to pass through the minimum spectral density. The solid line indicates the level of instrumental noise, determined from the leveling off of the tail of the high frequency spectrum.
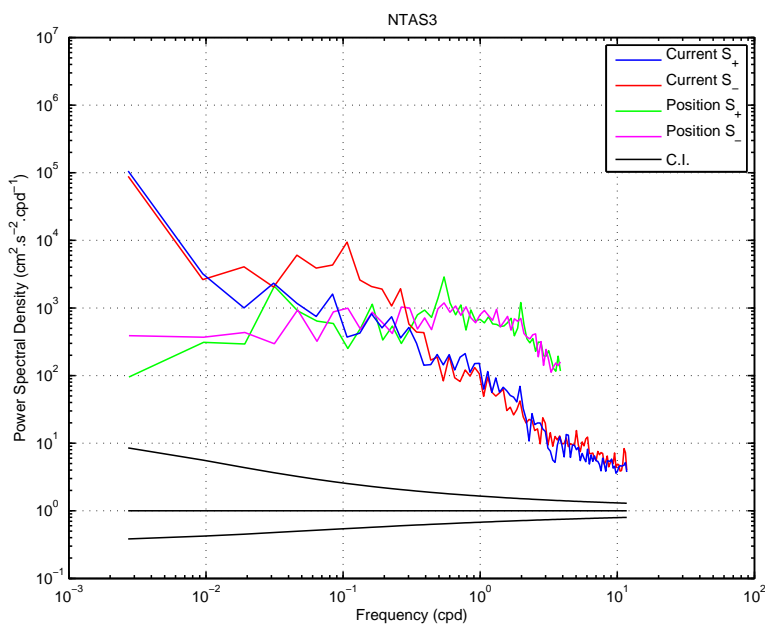
Figure 31: Showing the rotary spectra of velocities determined from the near-surface current meter (Aquadopp at 6 m) and the Argos buoy position from NTAS-3.

5.4 NTAS-3 Velocity Data

The NTAS-3 buoy went adrift on 16 February 2004 due to a mooring component failure. The last position within the watch circle was at 18:10Z on 15 February 2004, after which the buoy showed a persistent drift to the NW at about 0.25 kt. The buoy, with surface meteorological and upper subsurface instruments, was located and recovered on 19 Feburary 2004, beginning at 16:49Z. The position of recovery was $14°53.7'$N, $51°22.817'$W, about 21.2 n.m. from the anchor position. For the purposes of this report and due to the proximity of the buoy when recovered to its nominal anchor position, the three days of data were not discarded from the analysis.

Rotary spectra for estimating the influence of the buoy motion on velocity data are shown in Figure 31.

5.4.1 Aquadopp

The time series of the speeds measured with the Aquadopp current meter on NTAS-3 is shown in Figure 32. The current velocities are shown integrated in a progressive vector diagram in Figure 33. The spectrum is shown in Figure 34. The spectral peaks are tabulated in Table 13. It is apparent from these data that the Aquadopp instrument deployed on NTAS-3 failed and returned erroneous data. This is especially evident when the data are plotted alongside the RDI data (not shown).

5.4.2 RDI Workhorse

A time series of the current speed data from the RDI workhorse ADCP is shown in Figure 35. The spectra for all RDI Workhorse ADCP bins are shown as a waterfall plot in Figure 36. Tables of
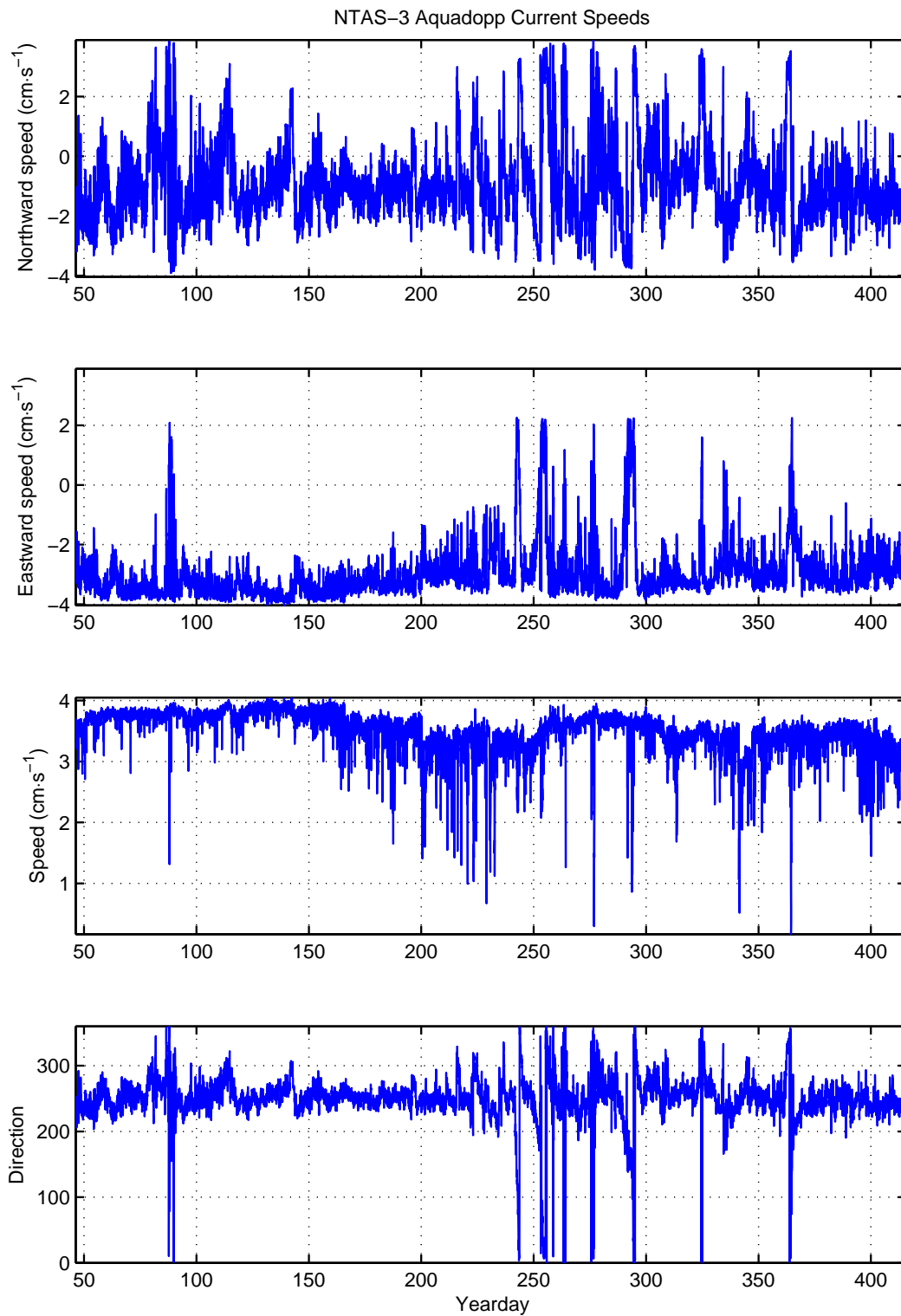
Figure 32: Unfiltered currents from NTAS-3 Aquadopp. (a) Northward current speeds. (b) Eastward current speeds. (c) Magnitude. (d) Direction.
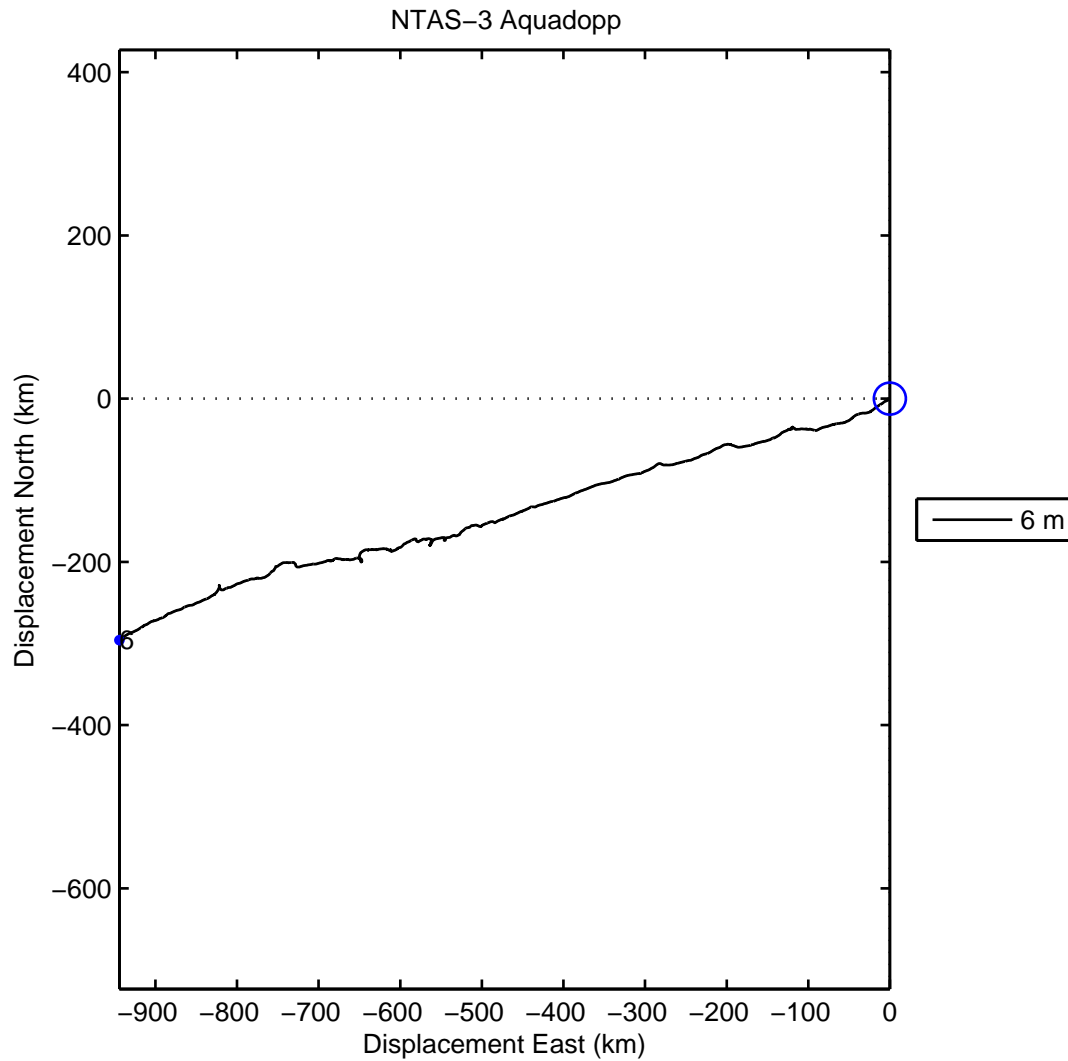
Figure 33: Progressive vector diagram of currents from the NTAS-3 Aquadopp.

the spectral peaks obtained from the RDI Workhorse bins are shown in Tables 14 and 15. Only the deepest (90 m) and shallowest (26 m) bins are tabulated. Progressive vector diagrams for all bins of the Workhorse data are shown in Figure 37.

Table 13: Spectral peak heights for NTAS-3 Aquadopp. Peaks are ordered relative to the baseline.

f (cpd)	T (day)	T (hr)	PeakHgt ($cm^2 \cdot s^{-2}$)
Top 15 Peak Frequencies (NTAS-3 Aquadopp 6 m)			
0.01172	85.33333	2048.00000	512.470
0.99609	1.00392	24.09412	0.116
1.06641	0.93773	22.50549	0.042
1.96875	0.50794	12.19048	0.022
0.75000	1.33333	32.00000	0.049
1.88672	0.53002	12.72050	0.017
10.85156	0.09215	2.21166	0.003
11.88281	0.08416	2.01972	0.003
9.64453	0.10369	2.48846	0.003
1.82813	0.54701	13.12821	0.016
11.15625	0.08964	2.15126	0.003
9.16406	0.10912	2.61893	0.003
0.87891	1.13778	27.30667	0.032
11.00391	0.09088	2.18104	0.002
3.57422	0.27978	6.71475	0.008
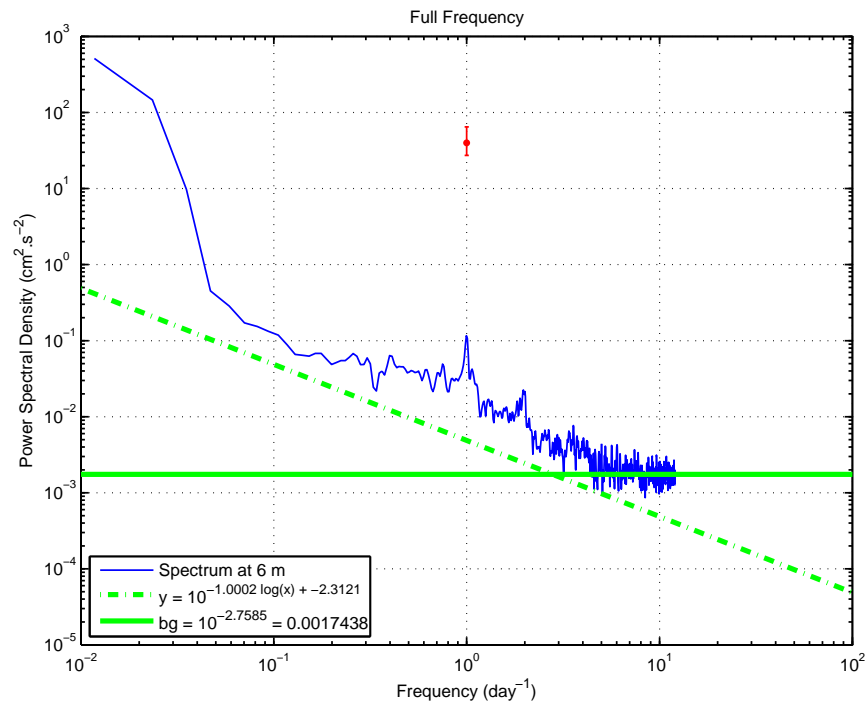
Figure 34: Spectrum of NTAS-3 Aquadopp current speed. Symbol at top center indicates confidence interval for the spectrum. Dashed line has the slope of the least-squares regression line passing through the data, but has been shifted down to pass through the minimum spectral density. The solid line indicates the level of instrumental noise, determined from the leveling off of the tail of the high frequency spectrum.
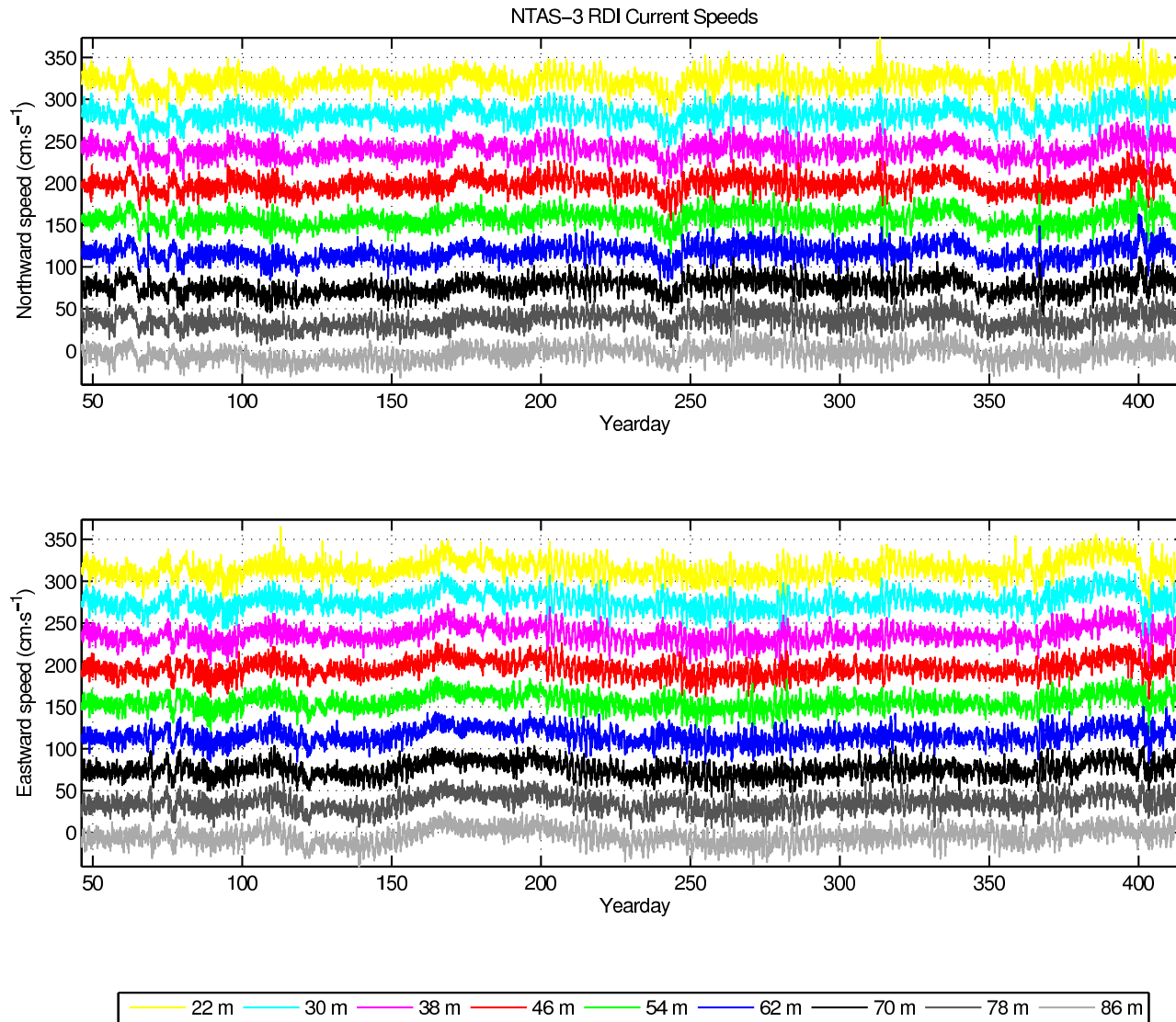
Figure 35: (a) Waterfall plots of the current speed time series from the NTAS-3 RDI Workhorse ADCP. Northerly (top) and easterly (bottom) current speeds for the ADCP bins. Series are offset by 40 cm·s^{-1}. In each plot the axis values are correct for the lowest series. Each subsequent series is offset upwards. In each plot the series are from every second 4 m bin, i.e., the [86, 78, 70, 62, 54, 46, 38, 30, 22] m bins (reading upwards from the deepest trace in each case).
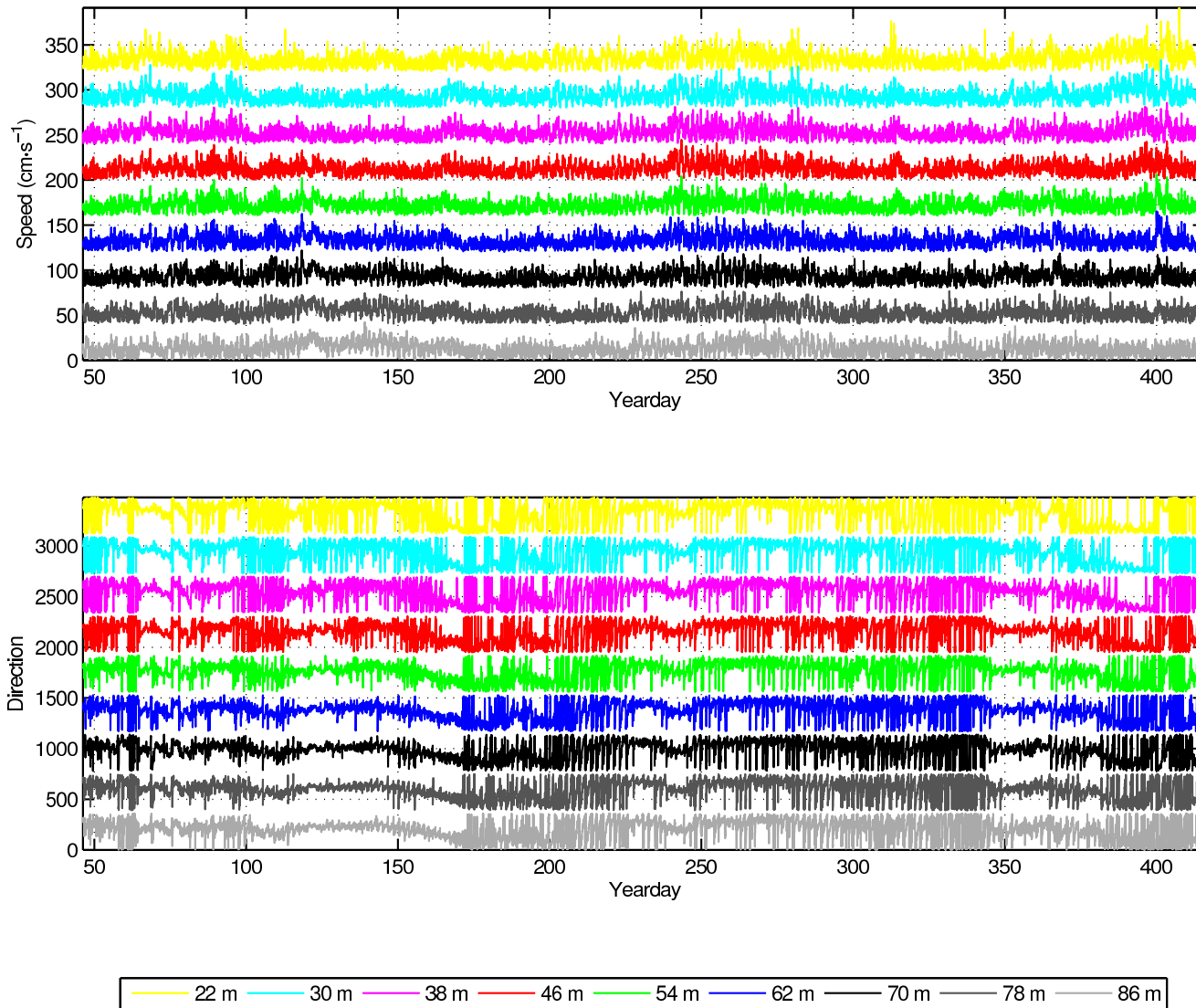
Figure 35: (b) Waterfall plots of the currents time series from the NTAS-3 RDI Workhorse. Current magnitude (top) and direction (bottom). The magnitude is offset by 40 cm·s^{-1}. Each direction plot is offset by 390 degrees from the one below. In each plot the axis values are correct for the lowest series. Each subsequent series is offset upwards. In each plot the series are from every second 4 m bin, i.e., the [86, 78, 70, 62, 54, 46, 38, 30, 22] m bins (reading from the lowest trace in each case).

Table 14: Spectral peak heights for NTAS-3 RDI Workhorse, 90 m bin. Peaks are ordered relative to the baseline.

| Top 15 Peak Frequencies (NTAS-3 Workhorse 90 m)			
f (cpd)	T (day)	T (hr)	PeakHgt ($cm^2 \cdot s^{-2}$)
0.01172	85.33333	2048.00000	7495.426
1.93359	0.51717	12.41212	31.387
0.51562	1.93939	46.54545	83.177
0.60937	1.64103	39.38462	38.174
1.40625	0.71111	17.06667	15.114
0.67969	1.47126	35.31034	27.533
3.41016	0.29324	7.03780	4.138
1.80469	0.55411	13.29870	7.405
3.80859	0.26256	6.30154	3.547
10.14844	0.09854	2.36490	1.257
1.32422	0.75516	18.12389	8.909
2.54297	0.39324	9.43779	4.684
2.49609	0.40063	9.61502	4.748
2.58984	0.38612	9.26697	4.411
0.86719	1.15315	27.67568	12.656

Table 15: Spectral peak heights for NTAS-3 RDI Workhorse, 26 m bin. Peaks are ordered relative to the baseline.

Top 15 Peak Frequencies (NTAS-3 Workhorse 26 m)			
f (cpd)	T (day)	T (hr)	PeakHgt ($cm^2 \cdot s^{-2}$)
0.01172	85.33333	2048.00000	8601.201
1.93359	0.51717	12.41212	66.268
0.53906	1.85507	44.52174	77.266
1.39453	0.71709	17.21008	18.582
2.07422	0.48211	11.57062	9.771
2.53125	0.39506	9.48148	5.700
11.15625	0.08964	2.15126	1.369
1.48828	0.67192	16.12598	9.160
0.72656	1.37634	33.03226	17.736
3.87891	0.25780	6.18731	3.521
0.94922	1.05350	25.28395	13.073
1.78125	0.56140	13.47368	7.173
10.03125	0.09969	2.39252	1.352
11.95312	0.08366	2.00784	1.100
2.42578	0.41224	9.89372	4.823
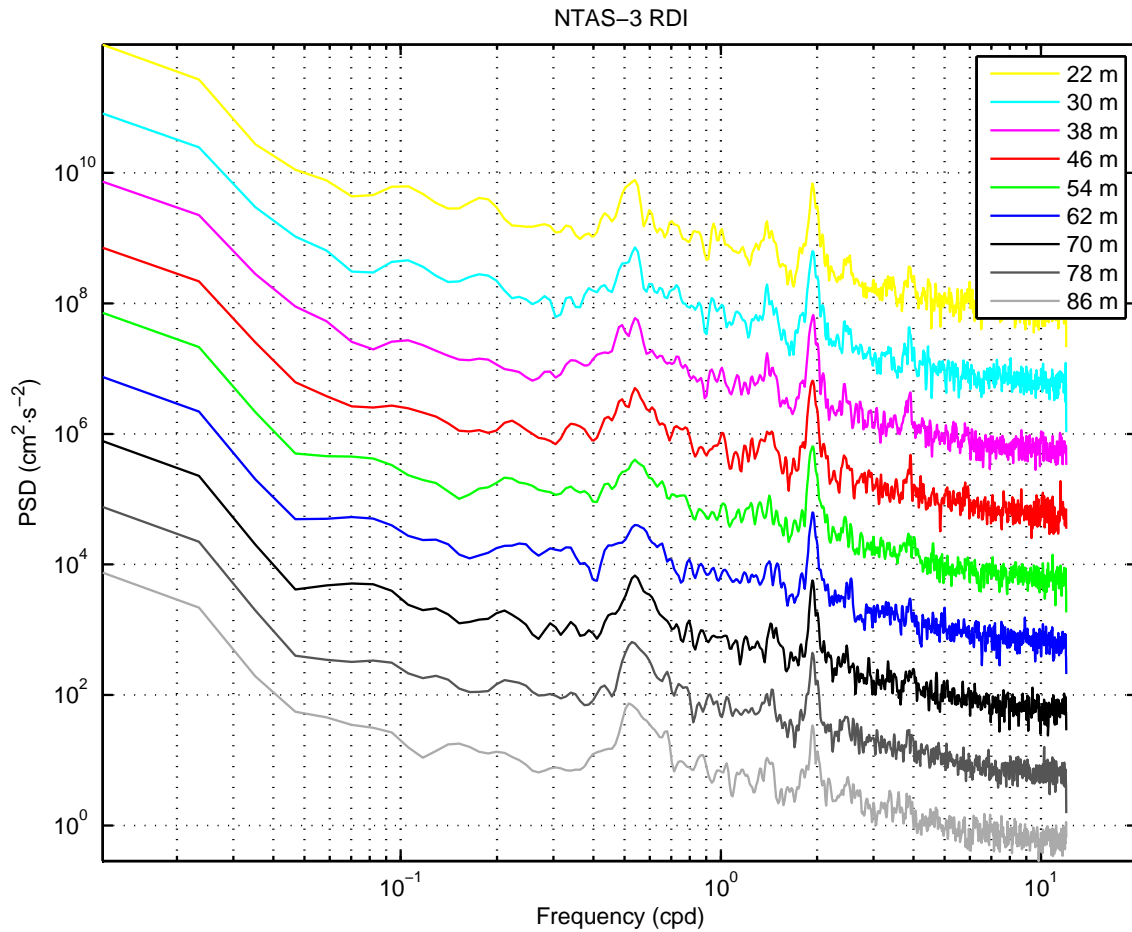
Figure 36: NTAS-3 RDI Workhorse spectra from 86 to 22 meters (spectra for every second 4 m bin are shown from bottom to top, each spectrum offset by $10\times$ the previous spectrum).
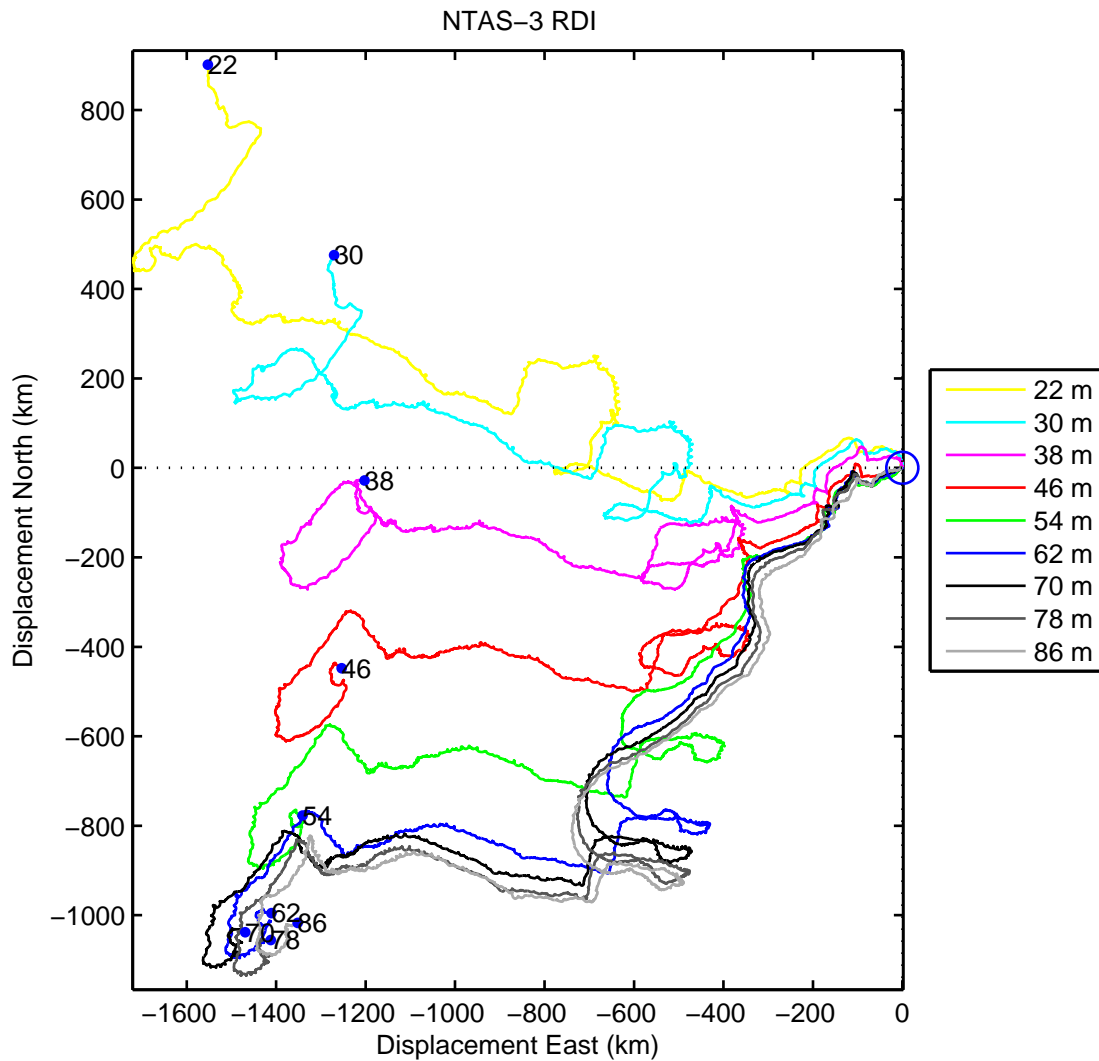
Figure 37: Superimposed progressive vector diagram of currents from the NTAS-3 RDI Workhorse. Vectors start at ∘ at the origin $(0,0)$ and end at the •. Every second 4 m bin from 22 to 86 m is plotted as listed in the legend on the figure.
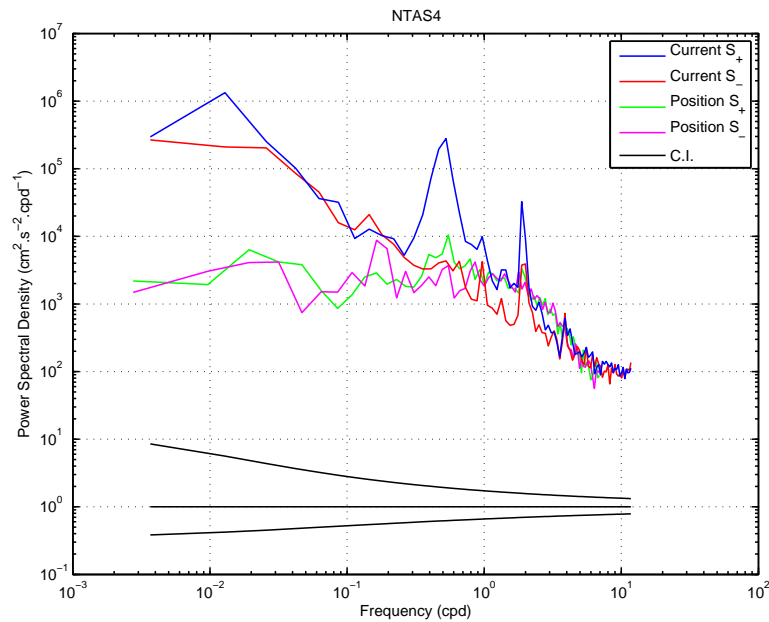
Figure 38: The rotary spectra of velocities determined from the near-surface current meter (Aquadopp at 6 m) and the Argos buoy position from NTAS-4.

5.5 NTAS-4 Velocity Data

Rotary spectra for estimating the influence of the buoy motion on velocity data are shown in Figure 38.

5.5.1 Aquadopp

The time series of the speeds measured with the Aquadopp current meter is shown in Figure 39. The current velocities are shown integrated in a progressive vector diagram in Figure 40. The spectrum is shown in Figure 41. The spectral peaks are tabulated in Table 16.

5.5.2 RDI Workhorse ADCP

A time series of the current speed data from the RDI workhorse ADCP is shown in Figure 42. The spectra for all RDI Workhorse ADCP bins are shown as a waterfall plot in Figure 43. Tables of the spectral peaks obtained from the RDI Workhorse bins are shown in Tables 17 and 18. Only the deepest (78 m) and shallowest (22 m) bins are tabulated. Progressive vector diagrams for all bins of the Workhorse data are shown in Figure 44.

NTAS−4 Aquadopp Current Speeds

Figure 39: Unfiltered currents from NTAS-4 Aquadopp. (a) Northward current speeds. (b) Eastward current speeds. (c) Magnitude. (d) Direction.

Table 16: Spectral peak heights for NTAS-4 Aquadopp. Peaks are ordered relative to the baseline.

Top 15 Peak Frequencies (NTAS-4 Aquadopp 6 m)

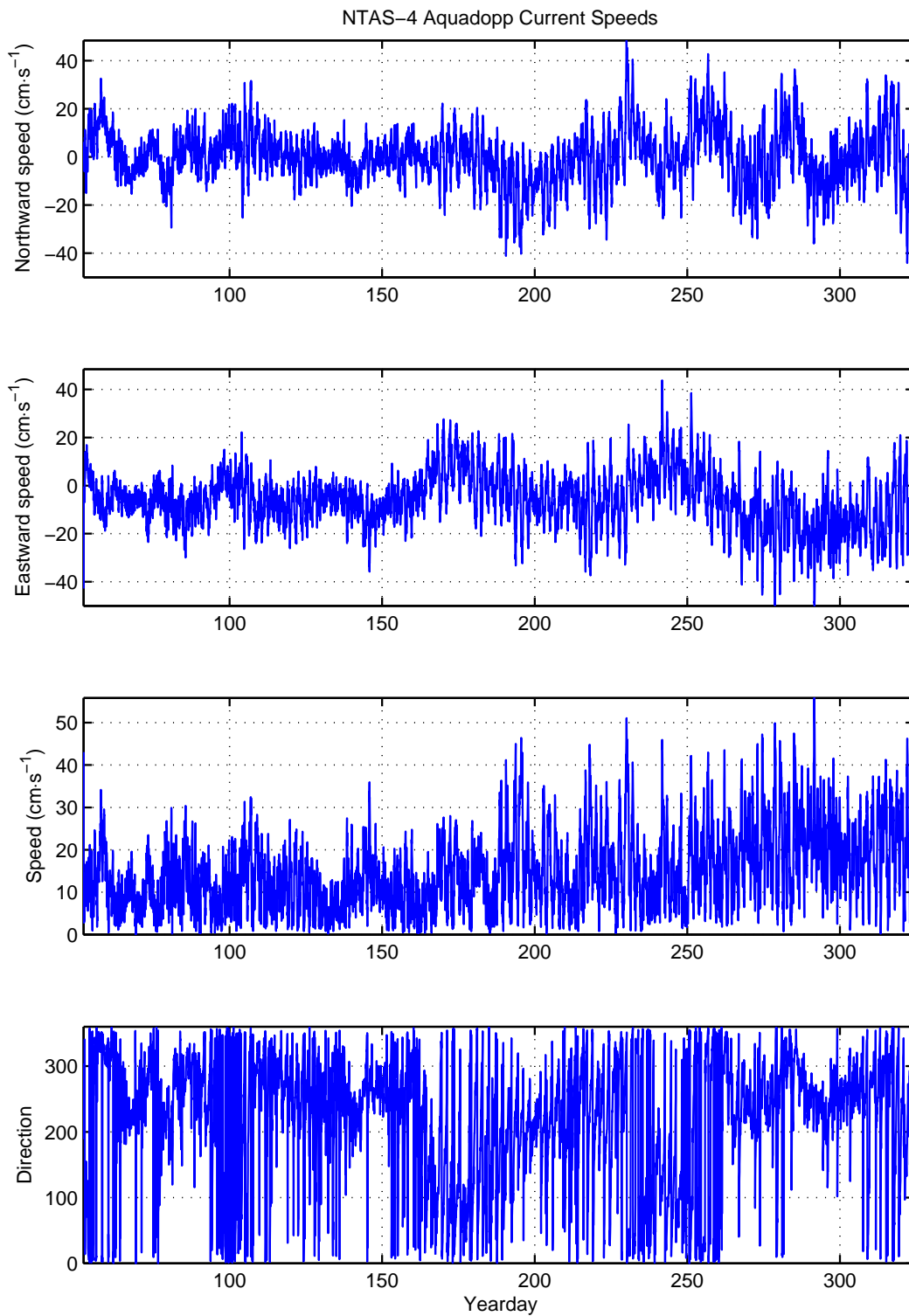| f (cpd)	T (day)	T (hr)	PeakHgt ($cm^2 \cdot s^{-2}$)
1.92188	0.52033	12.48780	71.999
0.53906	1.85507	44.52174	165.286
1.00781	0.99225	23.81395	27.944
1.47656	0.67725	16.25397	12.231
2.53125	0.39506	9.48148	4.667
10.40625	0.09610	2.30631	0.420
11.67188	0.08568	2.05622	0.344
3.82031	0.26176	6.28221	2.018
8.55469	0.11689	2.80548	0.549
11.43750	0.08743	2.09836	0.342
1.38281	0.72316	17.35593	10.160
11.01563	0.09078	2.17872	0.356
11.32031	0.08834	2.12008	0.339
10.75781	0.09296	2.23094	0.355
10.87500	0.09195	2.20690	0.346

Table 17: Spectral peak heights for NTAS-4 RDI Workhorse, 78 m bin. Peaks are ordered relative to the baseline.

Top 15 Peak Frequencies (NTAS-4 Workhorse 78 m)

f (cpd)	T (day)	T (hr)	PeakHgt ($cm^2 \cdot s^{-2}$)
0.01172	85.33333	2048.00000	5244.393
1.93359	0.51717	12.41212	30.560
0.52734	1.89630	45.51111	60.366
1.41797	0.70523	16.92562	13.633
2.00391	0.49903	11.97661	9.721
2.49609	0.40063	9.61502	6.942
0.67969	1.47126	35.31034	23.011
0.99609	1.00392	24.09412	13.200
2.44922	0.40829	9.79904	5.438
0.73828	1.35450	32.50794	15.350
1.08984	0.91756	22.02151	9.256
11.61328	0.08611	2.06660	1.003
3.87891	0.25780	6.18731	2.605
11.68359	0.08559	2.05416	0.899
1.76953	0.56512	13.56291	5.068
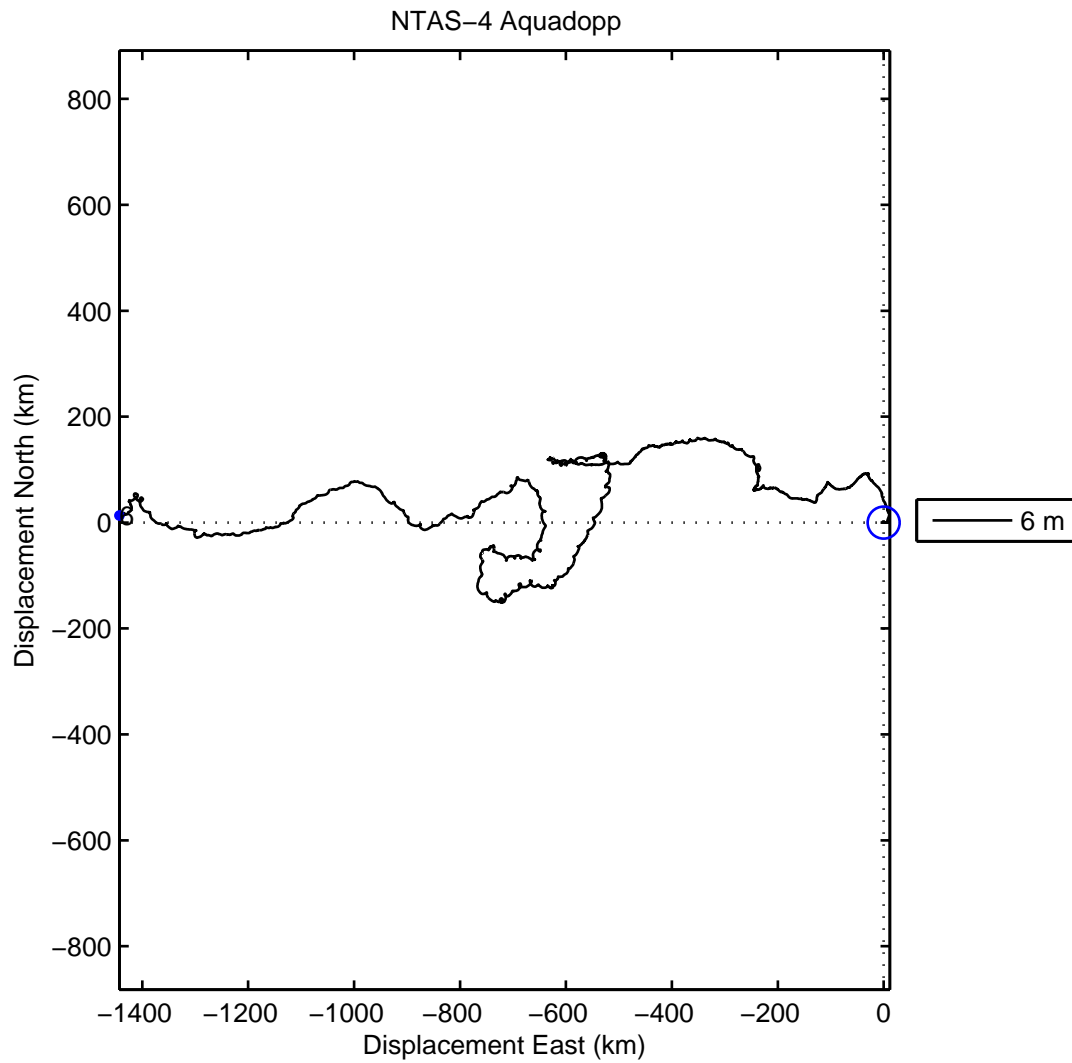
NTAS−4 Aquadopp

Figure 40: Progressive vector diagram of currents from the NTAS-4 Aquadopp.
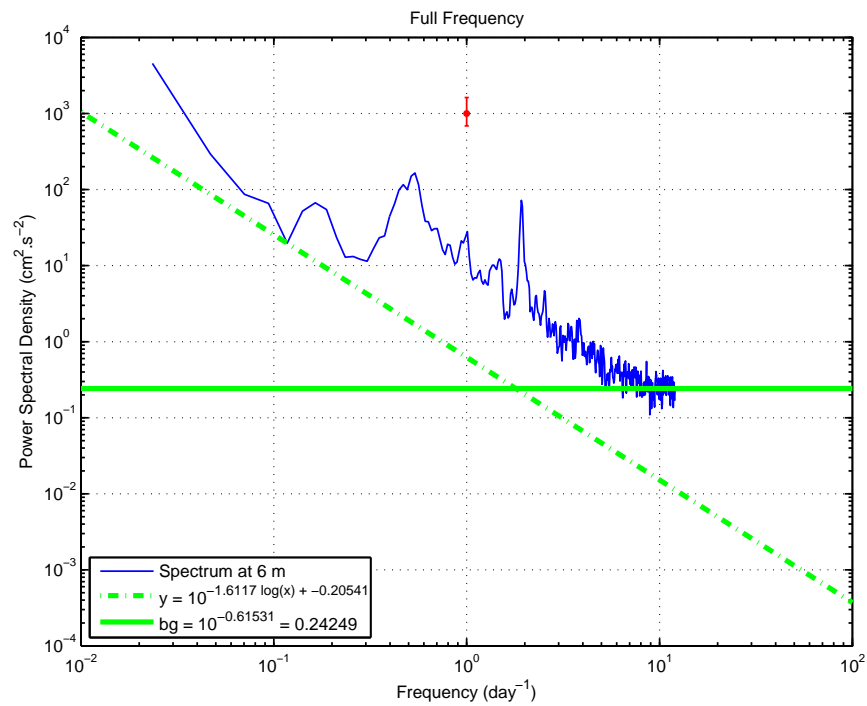
Figure 41: Spectrum of NTAS-4 Aquadopp current speed. Symbol at top center indicates confidence interval for the spectrum. Dashed line has the slope of the least-squares regression line passing through the data, but has been shifted down to pass through the minimum spectral density. The solid line indicates the level of instrumental noise, determined from the leveling off of the tail of the high frequency spectrum.
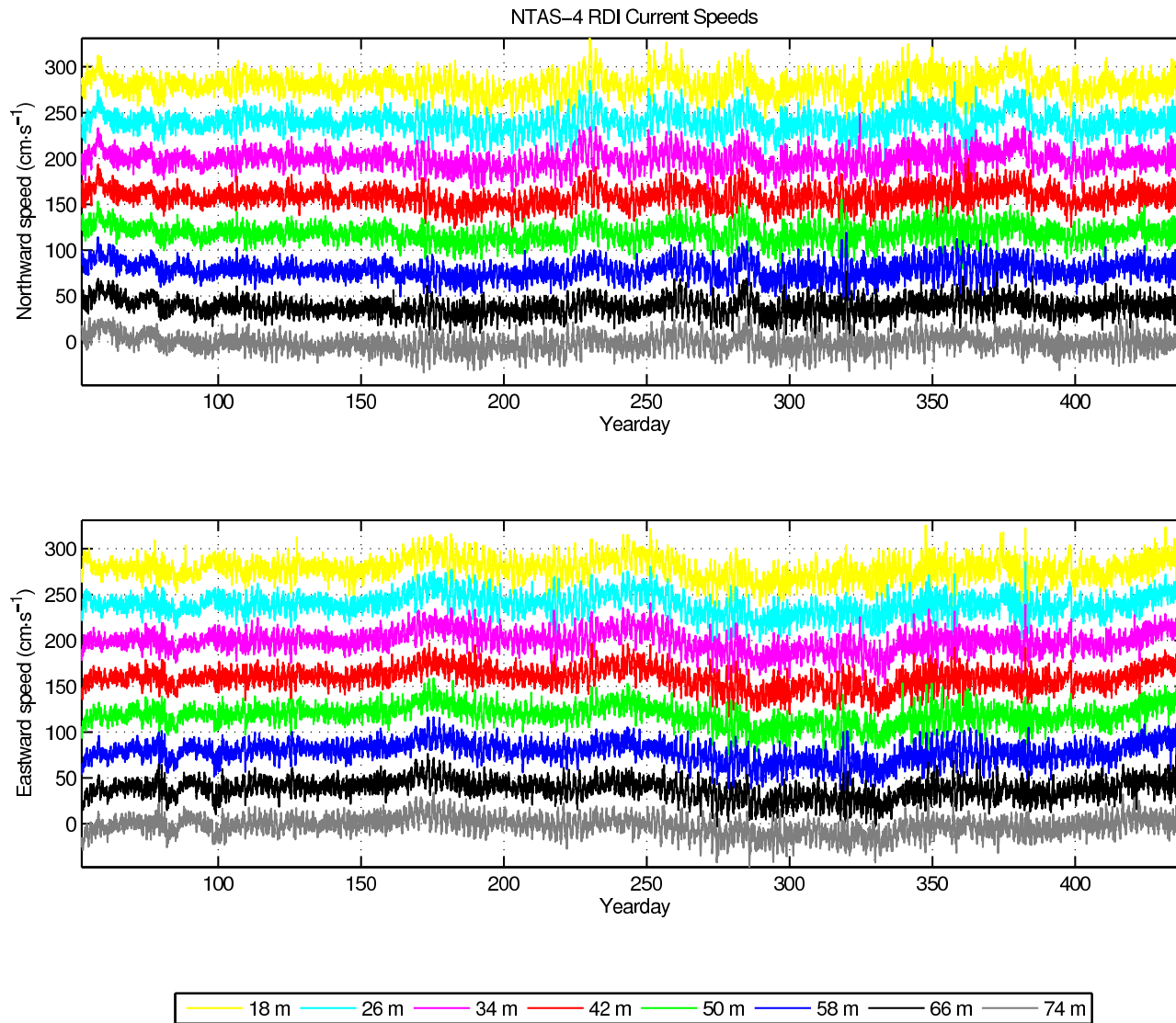
Figure 42: (a) Waterfall plots of the current speed time series from the NTAS-4 RDI Workhorse. Northerly (top) and easterly (bottom) current speeds for the ADCP bins. Series are offset by 40 cm·s^{-1}. In each plot the axis values are correct for the lowest series. Each subsequent series is offset upwards. In each plot the series are from the [74, 66, 58, 50, 42, 34, 26, 18] m bins (every second data bin reading upwards from the lowest trace in each case).
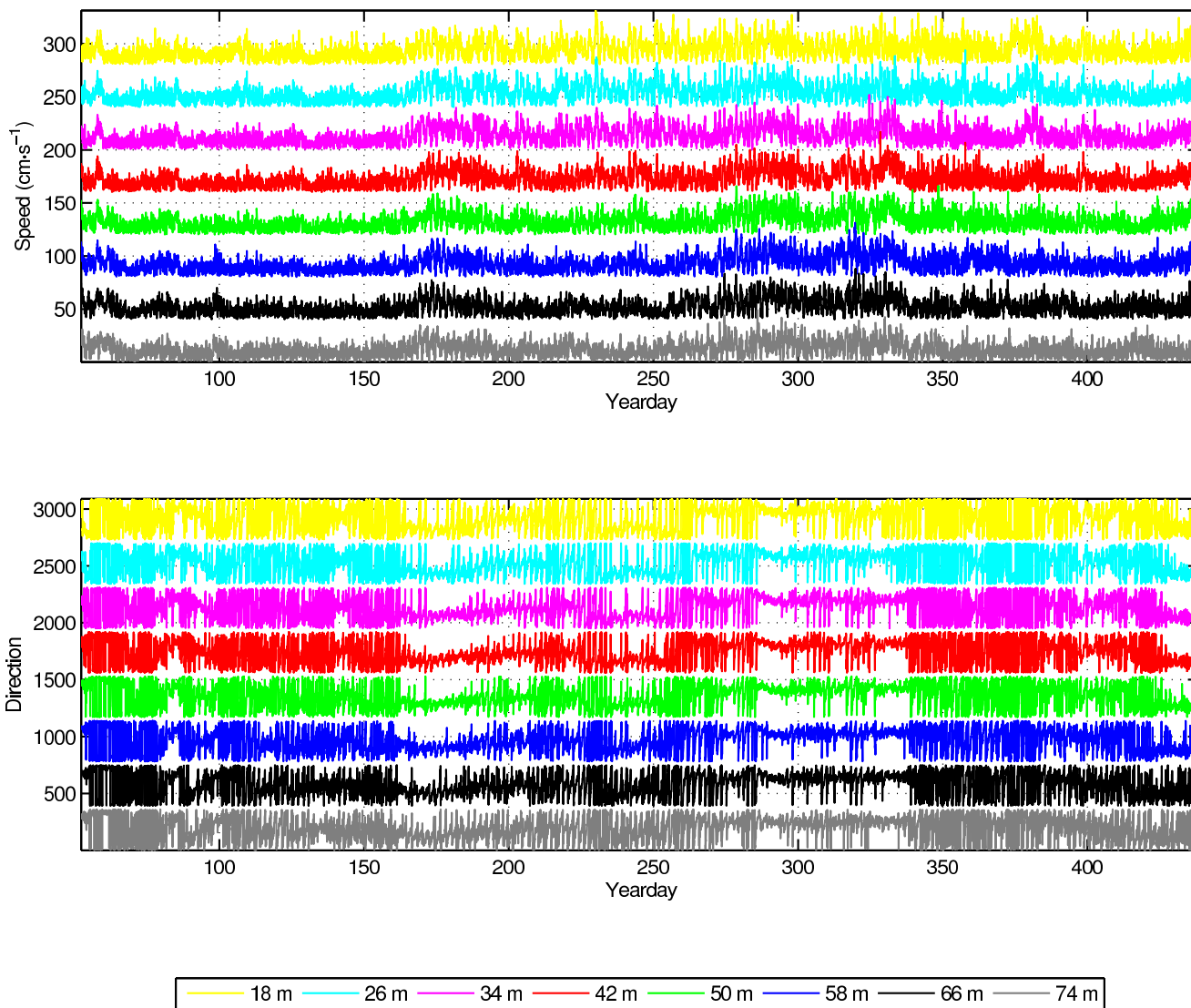
Figure 42: (b) Waterfall plots of the currents time series from the NTAS-4 RDI Workhorse. Current magnitude (top) and direction (bottom). The magnitude is offset by 40 cm·s^{-1}. Each direction plot is offset by 390 degrees from the one below. In each plot the axis values are correct for the lowest series. Each subsequent series is offset upwards. In each plot the series are from the [74, 66, 58, 50, 42, 34, 26, 18] m bins (every second data bin reading upwards from the lowest trace in each case).
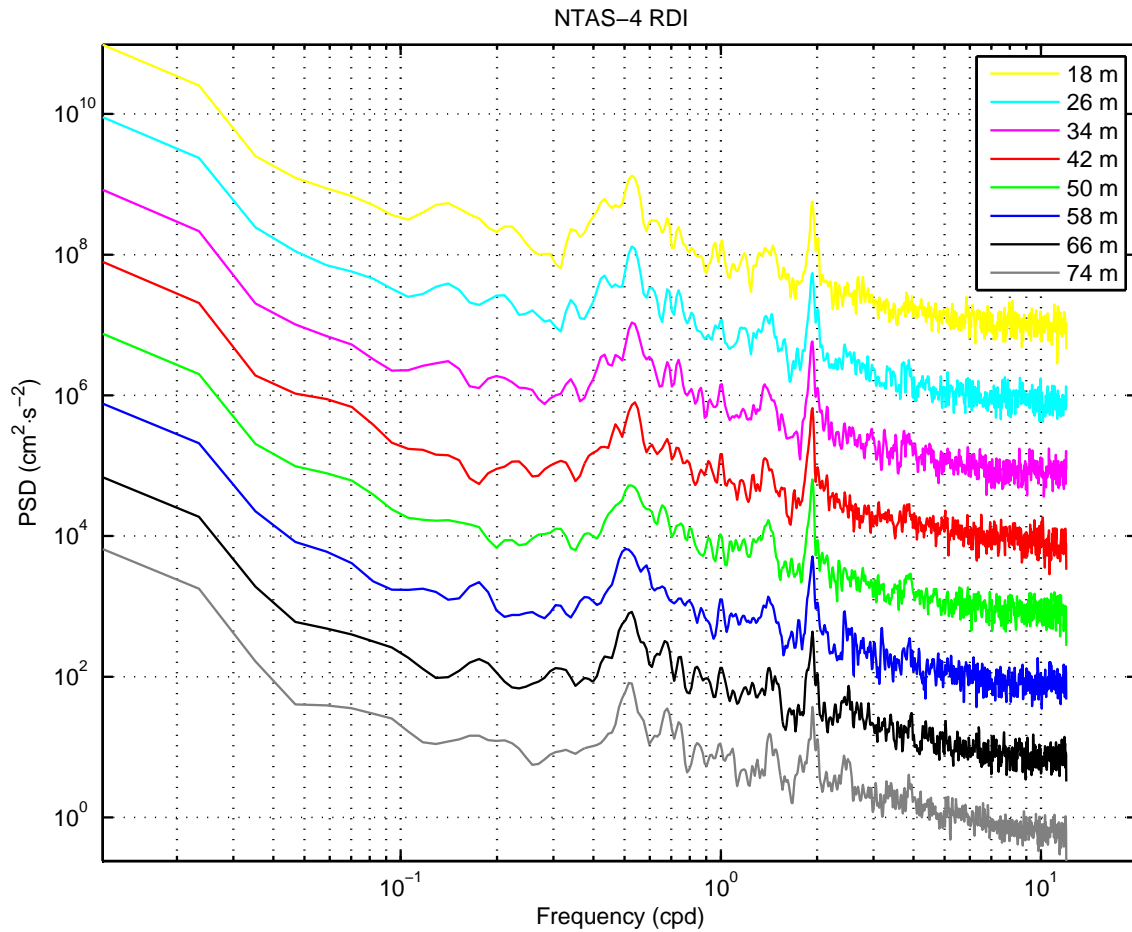
Figure 43: NTAS-4 RDI Workhorse spectra from 18 to 74 meters (every second 4 m bin is plotted from bottom (74 m) to top (18 m), each spectrum offset upwards by $10\times$ the previous spectrum).

Table 18: Spectral peak heights for NTAS-4 RDI Workhorse, 22 m bin. Peaks are ordered relative to the
baseline.

Top 15 Peak Frequencies (NTAS-4 Workhorse 22 m)			
f (cpd)	T (day)	T (hr)	PeakHgt ($cm^2 \cdot s^{-2}$)
0.01172	85.33333	2048.00000	9305.085
1.93359	0.51717	12.41212	55.888
0.52734	1.89630	45.51111	130.495
2.01562	0.49612	11.90698	17.400
0.43359	2.30631	55.35135	55.712
0.67969	1.47126	35.31034	34.543
0.62109	1.61006	38.64151	33.710
0.73828	1.35450	32.50794	27.132
1.38281	0.72316	17.35593	12.777
1.44141	0.69377	16.65041	12.208
9.98437	0.10016	2.40376	1.996
11.55469	0.08654	2.07708	1.498
7.89844	0.12661	3.03858	2.093
1.00781	0.99225	23.81395	13.667
11.12109	0.08992	2.15806	1.416
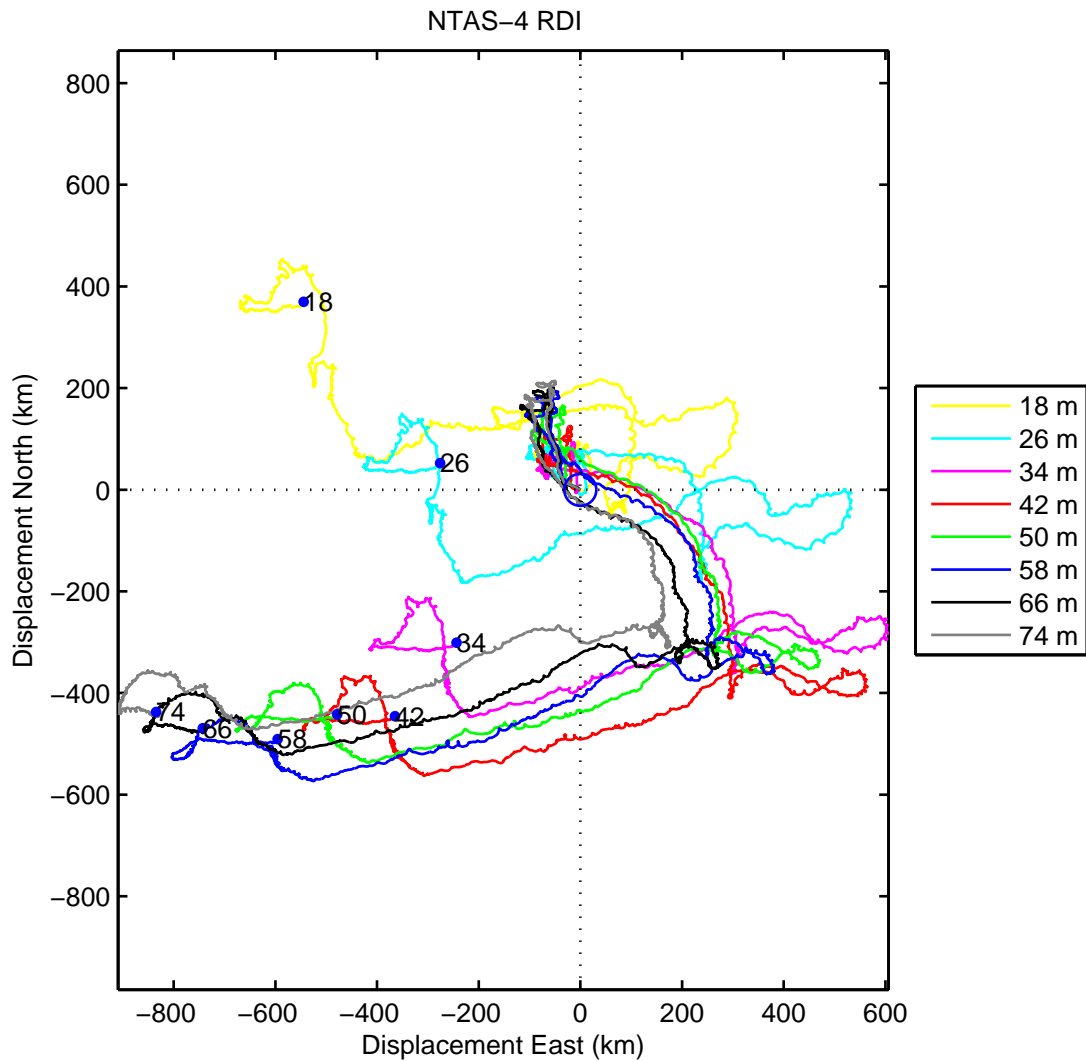
Figure 44: Superimposed progressive vector diagram of currents from the NTAS-4 RDI Workhorse. Vectors start at ○ at the origin (0,0) and end at the ●. Every second 4 m bin from 18 to 74 m is plotted as listed in the legend on the figure.
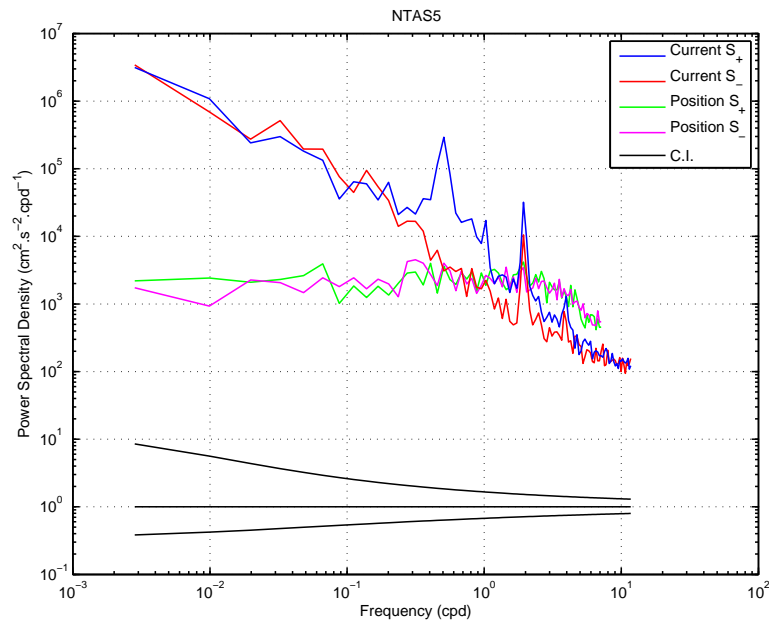
Figure 45: Showing the rotary spectra of velocities determined from the near-surface current meter (Aquadopp at 6 m) and the Argos buoy position from NTAS-5.

5.6   NTAS-5 Velocity Data

Rotary spectra for estimating the influence of the buoy motion on velocity data are shown in Figure 45.

5.6.1   Aquadopp

The time series of the speeds measured with the Aquadopp current meter on NTAS-5 is shown in Figure 46. The current velocities are shown integrated in a progressive vector diagram in Figure 47. The spectrum is shown in Figure 48. The spectral peaks are tabulated in Table 19.

5.6.2   RDI Workhorse ADCP

A time series of the current speed data from the RDI workhorse ADCP is shown in Figure 49. The spectra for all RDI Workhorse ADCP bins are shown as a waterfall plot in Figure 50. Tables of the spectral peaks obtained from the RDI Workhorse bins are shown in Tables 20 and 21. Only the deepest (78 m) and shallowest (14 m) bins are tabulated. Progressive vector diagrams for all bins of the Workhorse data are shown in Figure 51.

Figure 46: Unfiltered currents from NTAS-5 Aquadopp. (a) Northward current speeds. (b) Eastward current speeds. (c) Magnitude. (d) Direction.

Table 19: Spectral peak heights for NTAS-5 Aquadopp. Peaks are ordered relative to the baseline.

Top 15 Peak Frequencies (NTAS-5 Aquadopp 6 m)

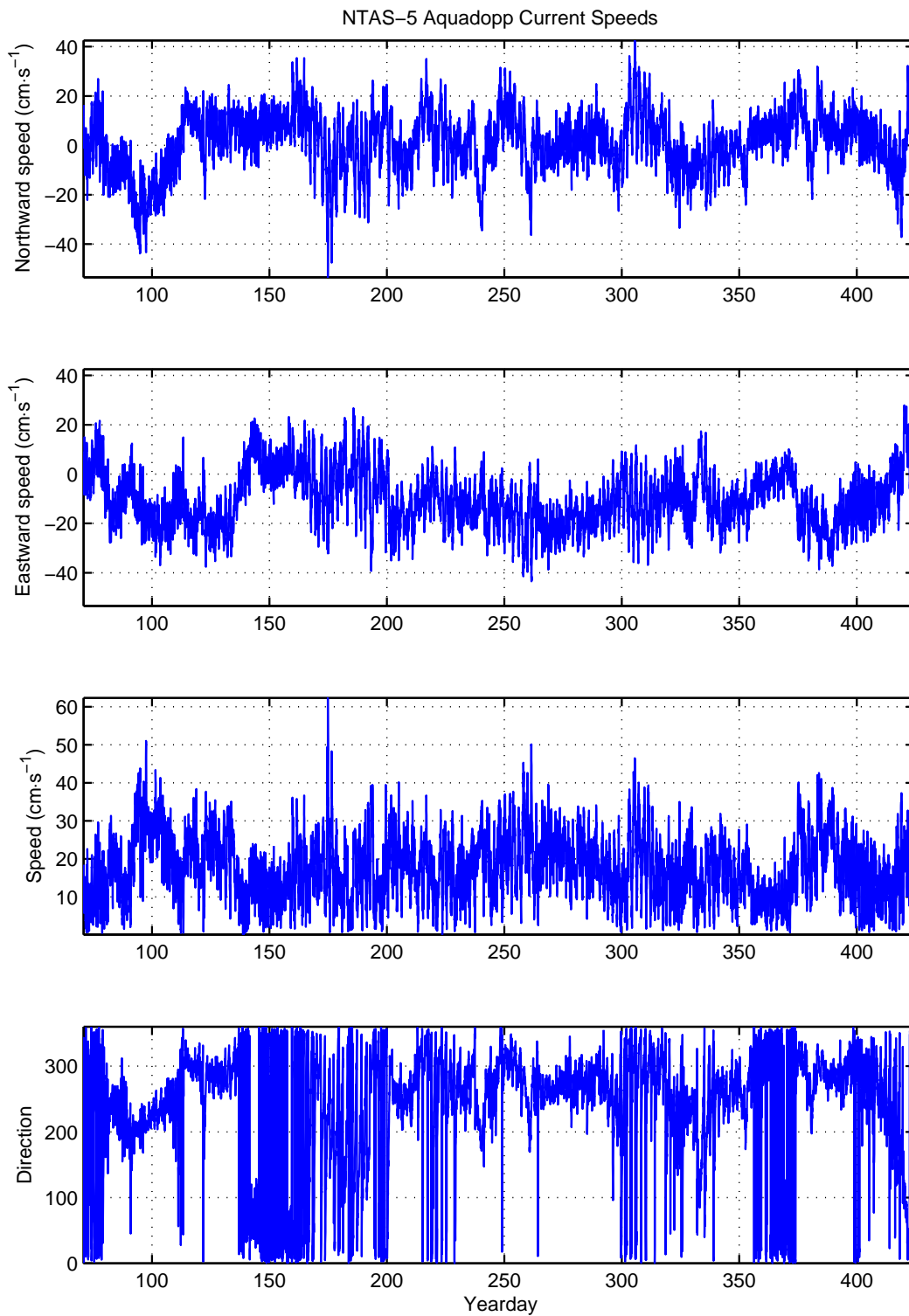| f (cpd)	T (day)	T (hr)	PeakHgt ($cm^2 \cdot s^{-2}$)
1.93359	0.51717	12.41212	51.162
0.51562	1.93939	46.54545	147.272
1.00781	0.99225	23.81395	41.579
0.01172	85.33333	2048.00000	13573.005
3.91406	0.25549	6.13174	2.851
3.83203	0.26096	6.26300	2.804
11.01562	0.09078	2.17872	0.667
11.98828	0.08341	2.00196	0.555
2.44922	0.40829	9.79904	4.279
0.80859	1.23671	29.68116	17.792
11.69531	0.08550	2.05210	0.488
11.25000	0.08889	2.13333	0.509
0.70312	1.42222	34.13333	20.063
10.33594	0.09675	2.32200	0.541
10.20703	0.09797	2.35132	0.538

Table 20: Spectral peak heights for NTAS-5 RDI Workhorse, 78 m bin. Peaks are ordered relative to the baseline.

Top 15 Peak Frequencies (NTAS-5 Workhorse 78 m)

f (cpd)	T (day)	T (hr)	PeakHgt ($cm^2 \cdot s^{-2}$)
0.01172	85.33333	2048.00000	7226.505
1.93359	0.51717	12.41212	49.958
0.50391	1.98450	47.62791	85.313
2.00391	0.49903	11.97661	15.321
0.59766	1.67320	40.15686	38.851
1.40625	0.71111	17.06667	16.824
2.43750	0.41026	9.84615	9.249
2.51953	0.39690	9.52558	6.212
3.84375	0.26016	6.24390	3.607
1.82812	0.54701	13.12821	6.680
10.62891	0.09408	2.25799	1.344
5.66016	0.17667	4.24017	2.214
11.84766	0.08440	2.02572	1.120
8.73047	0.11454	2.74899	1.460
3.31641	0.30153	7.23675	3.372
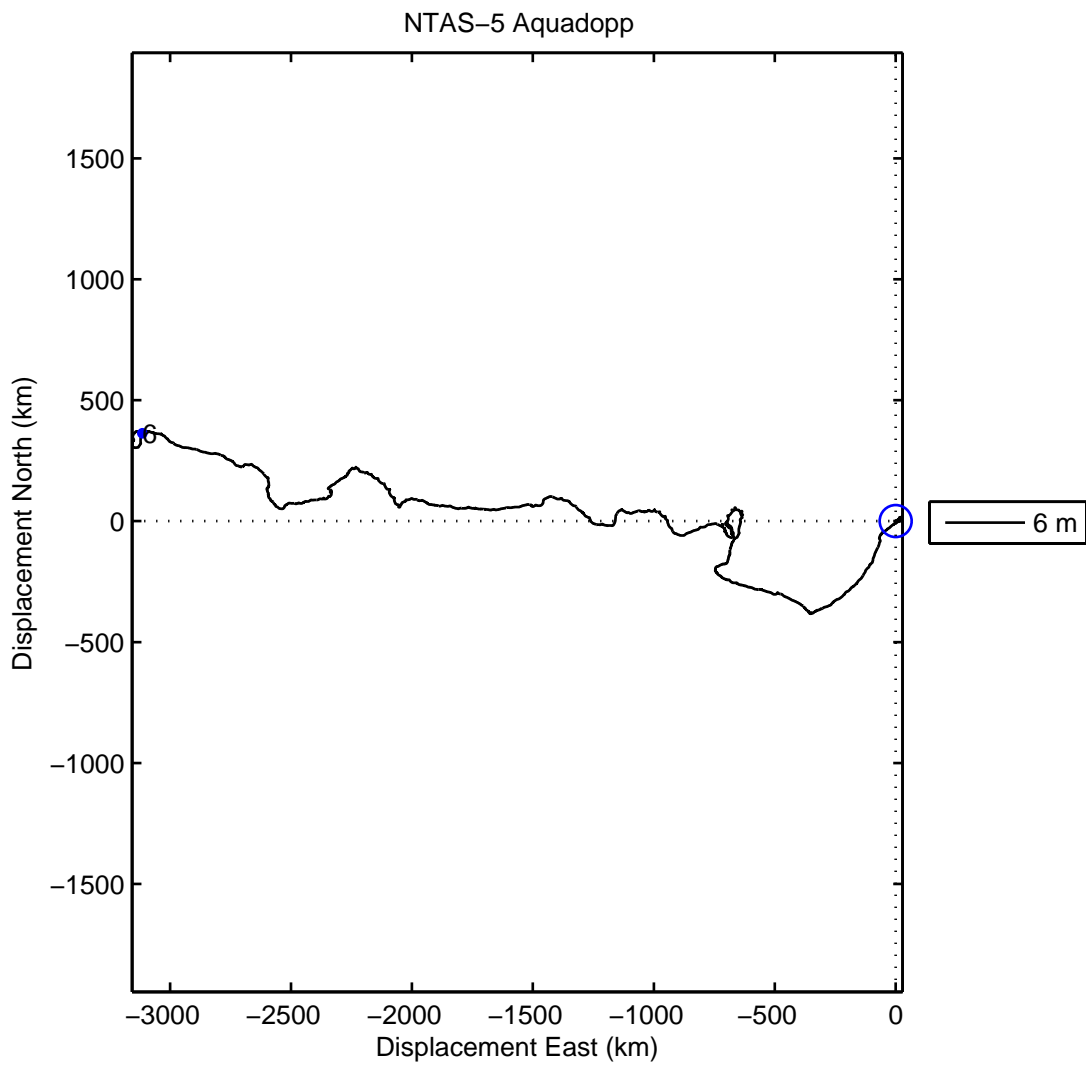
Figure 47: Progressive vector diagram of currents from the NTAS-5 Aquadopp.
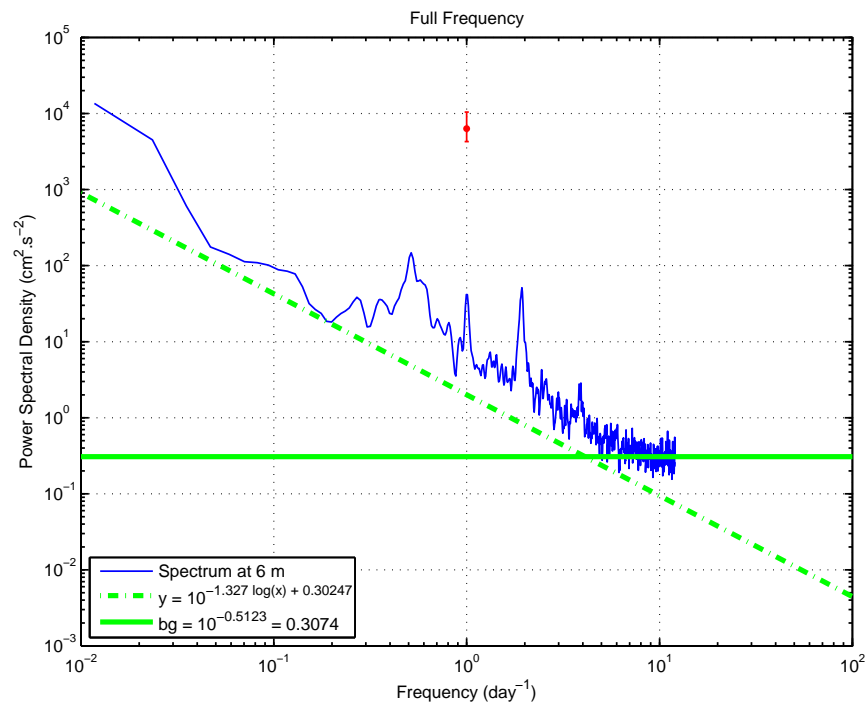
Figure 48: Spectrum of NTAS-5 Aquadopp current speed. Symbol at top center indicates confidence interval for the spectrum. Dashed line has the slope of the least-squares regression line passing through the data, but has been shifted down to pass through the minimum spectral density. The solid line indicates the level of instrumental noise, determined from the leveling off of the tail of the high frequency spectrum.
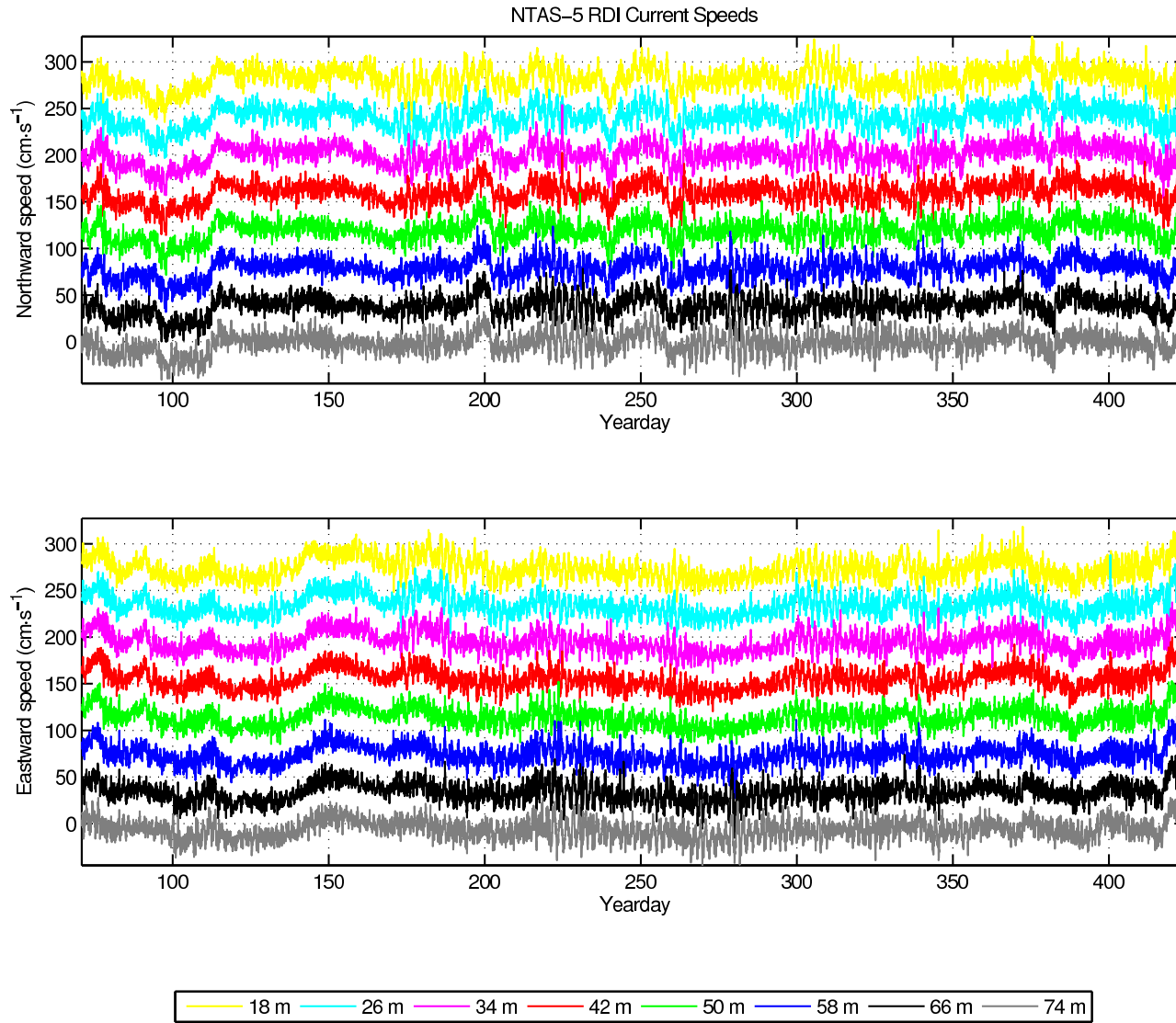
Figure 49: (a) Waterfall plots of the current speed time series from the NTAS-5 RDI Workhorse. Northerly (top) and easterly (bottom) current speeds for the ADCP bins. Series are offset by 40 cm·s^{-1}. In each plot the axis values are correct for the lowest series. Each subsequent series is offset upwards. In each plot the series are from the [74, 66, 58, 50, 42, 34, 26, 18] m bins (every second data bin reading upwards from the lowest trace in each case).
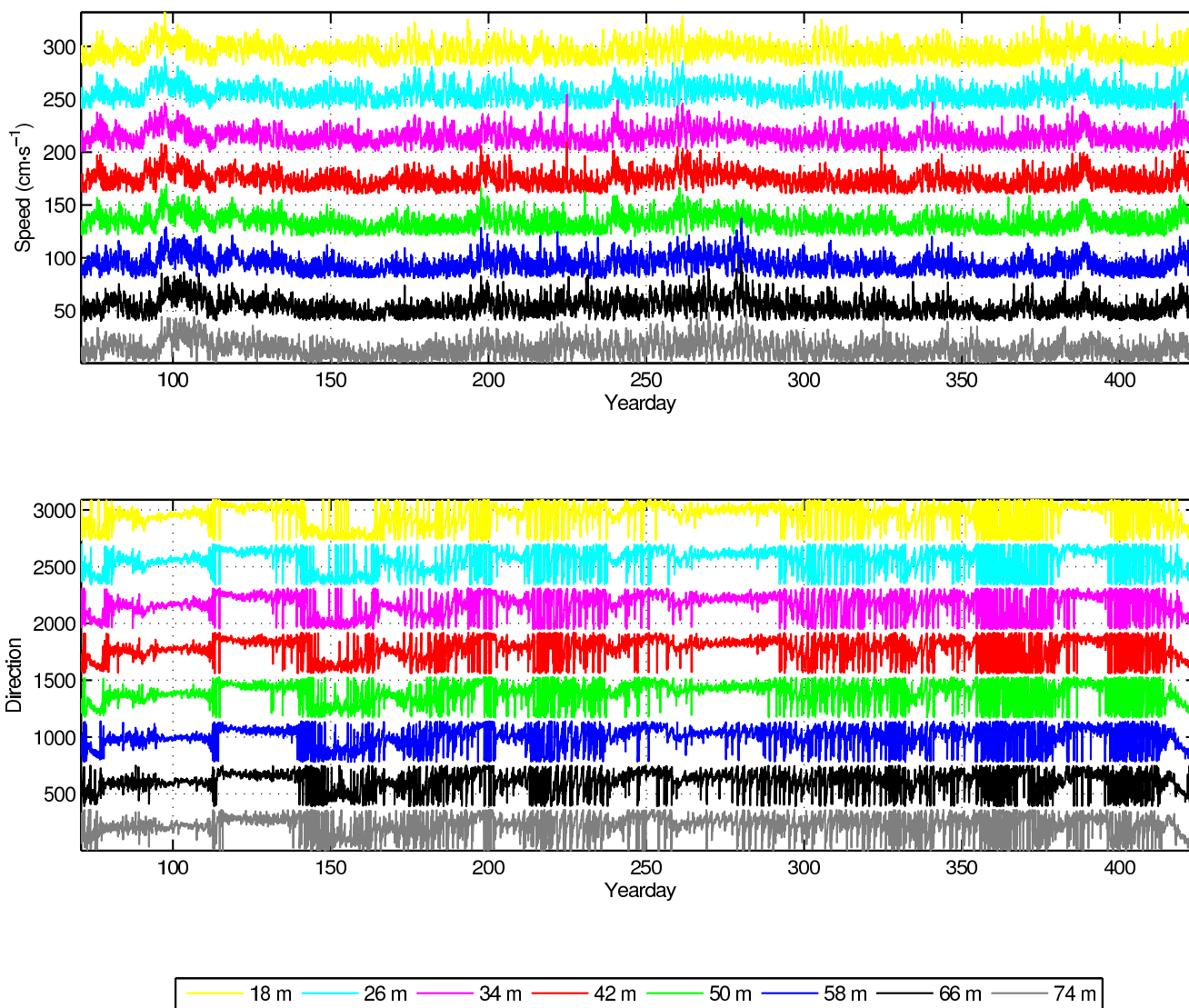
Figure 49: (b) Waterfall plots of the currents time series from the NTAS-5 RDI Workhorse. Current magnitude (top) and direction (bottom). The magnitude is offset by 40 cm·s⁻¹. Each direction plot is offset by 390 degrees from the one below. In each plot the axis values are correct for the lowest series. Each subsequent series is offset upwards. In each plot the series are from the [74, 66, 58, 50, 42, 34, 26, 18] m bins (every second data bin reading from the lowest trace in each case).
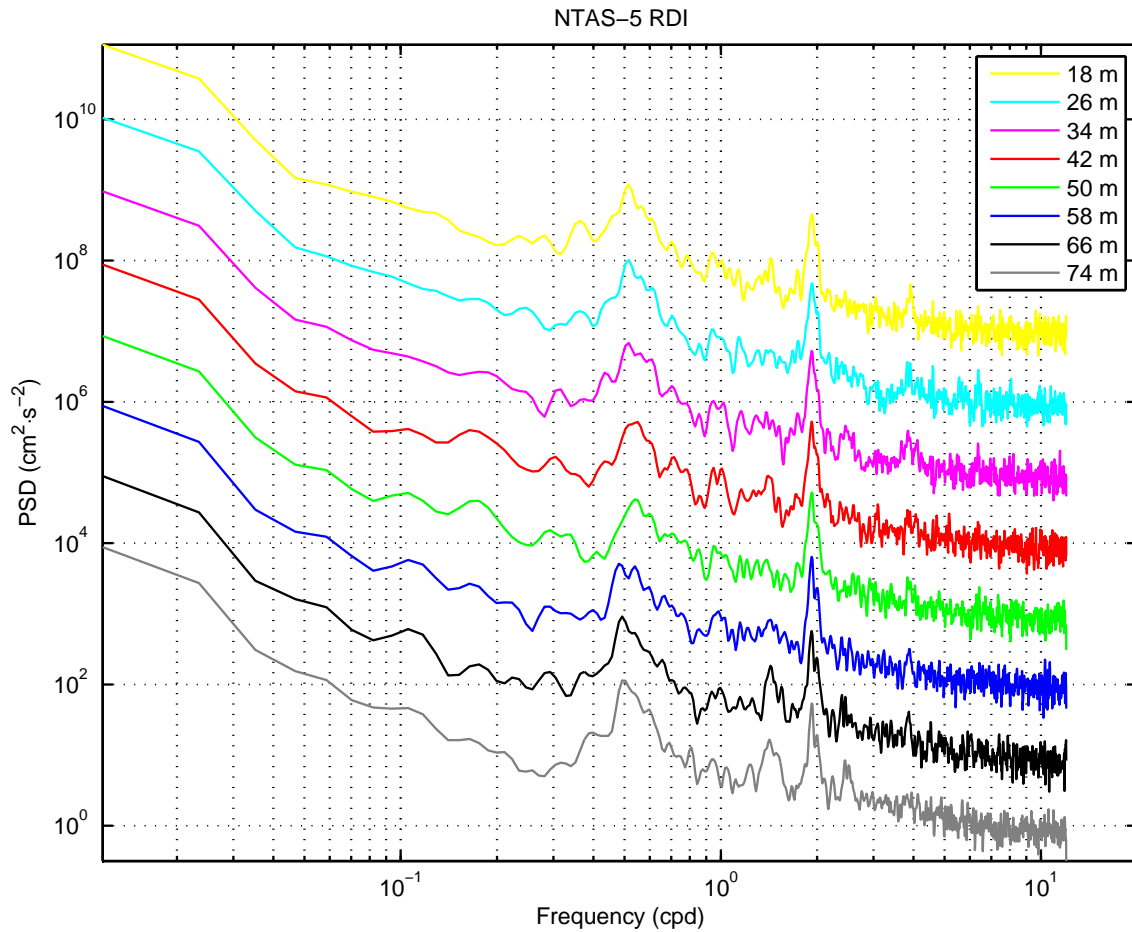
Figure 50: NTAS-5 RDI Workhorse spectra from 18 to 74 meters (every second 4 m bin is plotted from bottom (74 m) to top (18 m), each spectrum offset upwards by 10× the previous spectrum).

Table 21: Spectral peak heights for NTAS-5 RDI Workhorse, 14 m bin. Peaks are ordered relative to the baseline.

Top 15 Peak Frequencies (NTAS-5 Workhorse 14 m)			
f (cpd)	T (day)	T (hr)	PeakHgt ($cm^2.s^{-2}$)
0.01172	85.33333	2048.00000	12132.681
1.93359	0.51717	12.41212	42.187
0.51562	1.93939	46.54545	116.825
2.00391	0.49903	11.97661	17.622
10.30078	0.09708	2.32992	2.420
0.99609	1.00392	24.09412	16.988
9.60937	0.10407	2.49756	2.248
0.36328	2.75269	66.06452	35.420
11.58984	0.08628	2.07078	1.844
11.98828	0.08341	2.00196	1.781
11.84766	0.08440	2.02572	1.778
9.97266	0.10027	2.40658	1.903
10.98047	0.09107	2.18570	1.752
9.73828	0.10269	2.46450	1.853
0.93750	1.06667	25.60000	13.346
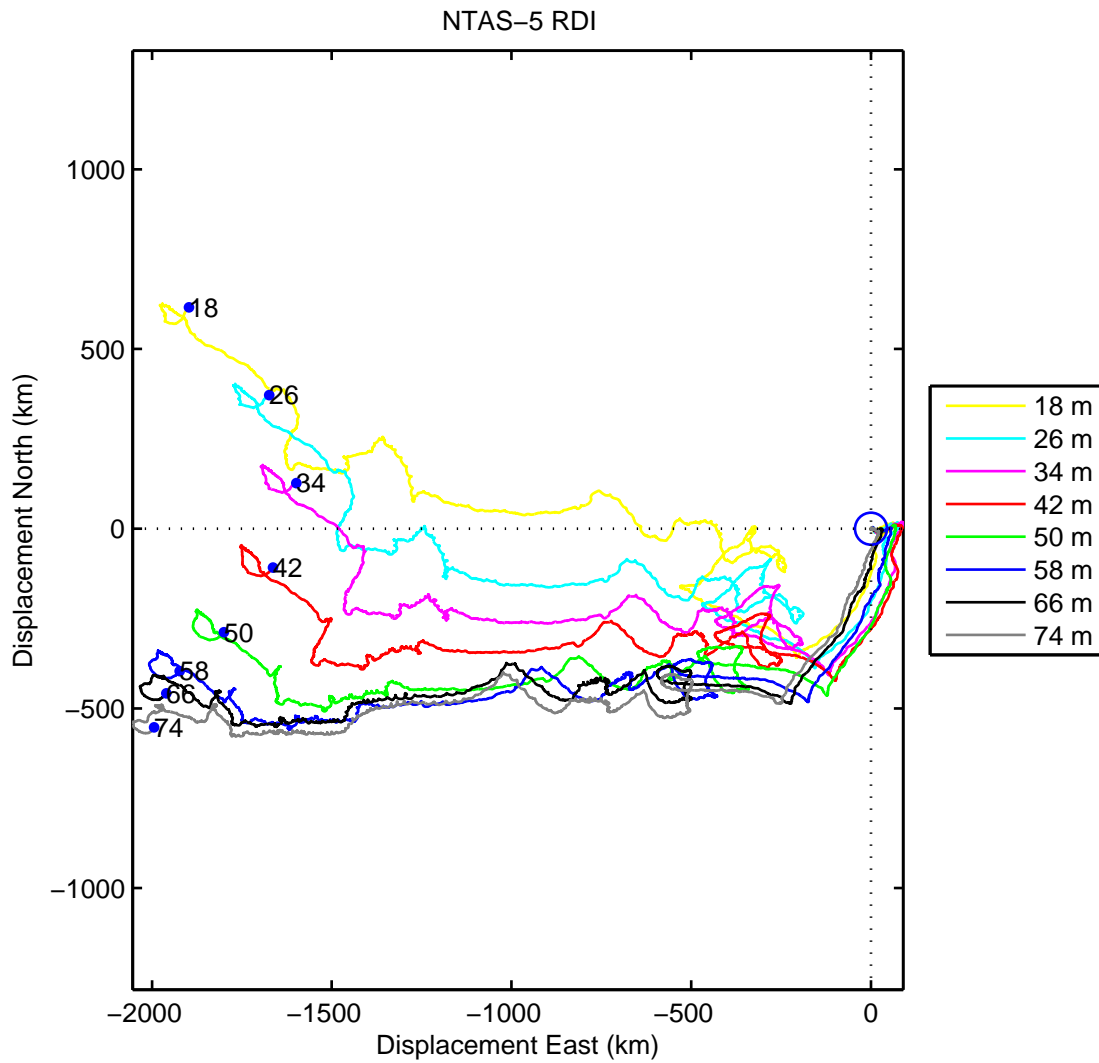
Figure 51: Superimposed progressive vector diagram of currents from the NTAS-5 RDI Workhorse. Vectors start at ∘ at the origin (0,0) and end at the ●. Every second 4 m bin is plotted from 18 to 74 m, as indicated in the legend on the figure.

6   Comparisons of Data

After quality assessment and removal of worst offending outliers (e.g., the entire record of the Aquadopp current meter on NTAS-3 was removed), the velocity data collected were distributed as shown in Figure 52.

Where multiple current meter data are available, these are plotted together so that a comparison is made between the data sets.
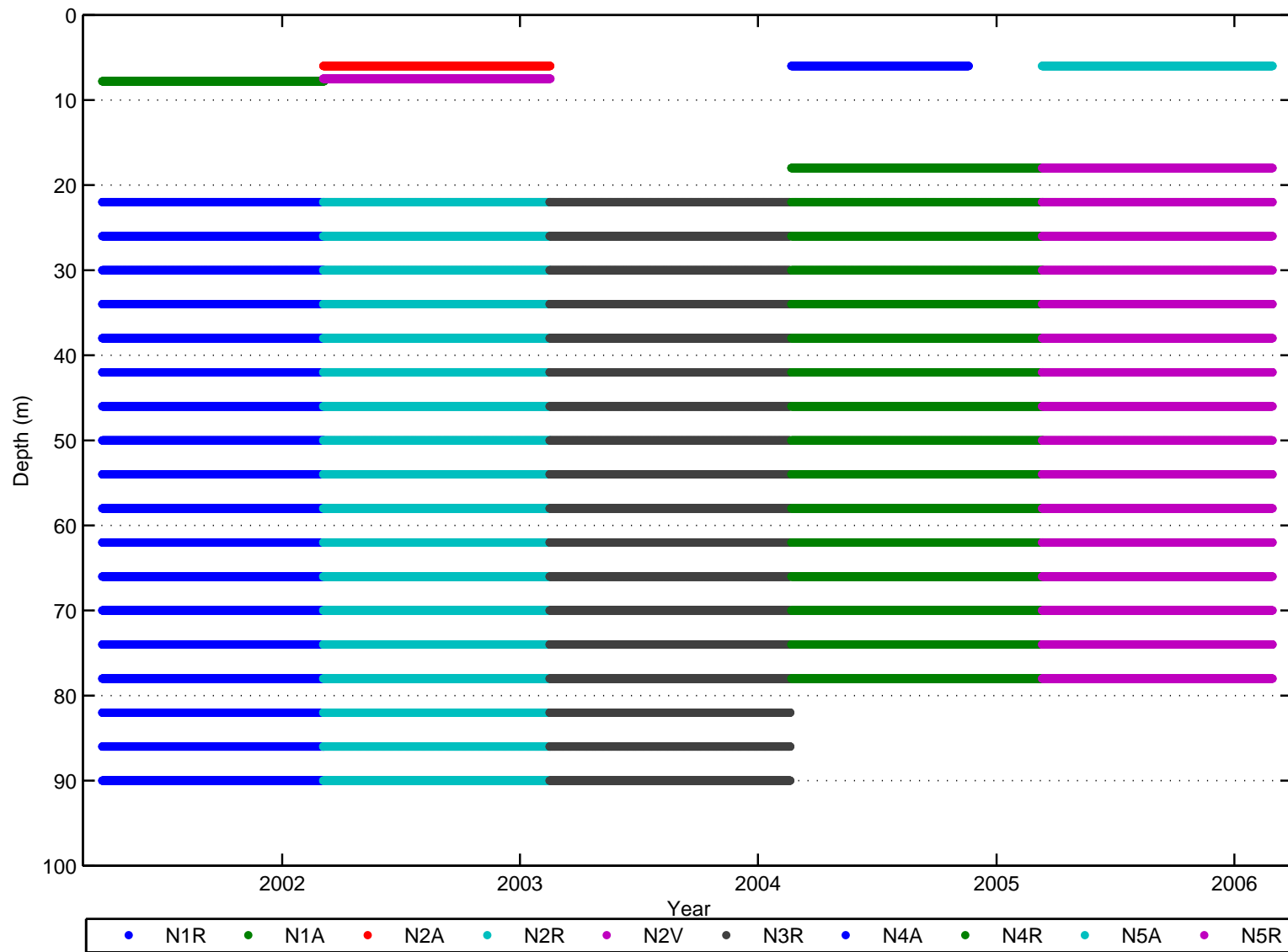
Figure 52: Data return for NTAS-1 to -5 current meters. Labels in the legend are in the form NTAS number and current meter type, e.g., N1A refers to the NTAS-1 Aquadopp. Type designators are A—Aquadopp, R—RDI Workhorse, and V—vector measuring current meter. Labels in the time axis refer to 00:00Z on January 1 of the year indicated.

Figure 53: Vertical profile of all velocity data on NTAS-1. The data are shown as horizontal box-and-whisker plots. A + identifies the median value; a thick line covers the interquartile range; a thin line extends between the outlier limits; and the dots indicate the maximum and minimum values. Cyan and blue lines indicate one and three standard deviations from the mean respectively. (a) Northerly current speeds. (b) Easterly current speeds.

6.1 Intra-Deployment Comparisons

6.1.1 Comparison of Current Meters on NTAS-1

Vertical profiles of velocity from the NTAS-1 current meters are shown in Figure 53. Progressive vectors of all velocity data on NTAS-1 are shown in Figure 54. The spectrum for the Aquadopp and a selection of the spectra from the RDI NarrowBand depth bins appear in Figure 55.

6.1.2 Comparison of Current Meters on NTAS-2

Vertical profiles of velocity from the NTAS-2 current meters are shown in Figure 56. Progressive vectors of these velocity data are shown in Figure 57. Spectra for the Aquadopp and VMCM current meters and a selection of the spectra from the RDI Workhorse depth bins are shown in

Figure 54: Progressive vectors of all velocity data on NTAS-1. The RDI data are plotted in blue, and the Aquadopp is plotted in a thicker line. The final point of each series is labelled with the nominal depth of the sensor or bin.
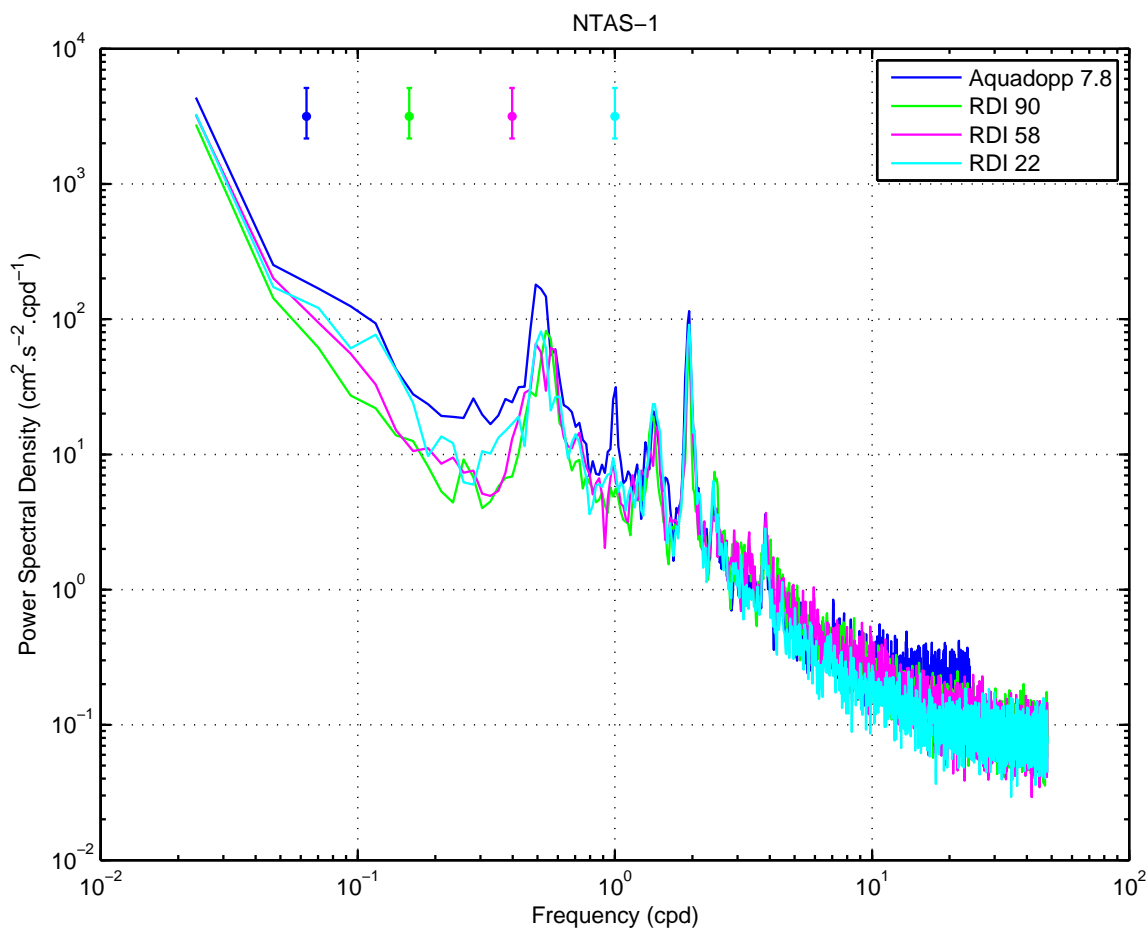
Figure 55: Spectra for the NTAS-1 current meters: Aquadopp and a selection of the RDI spectra (deepest bin, middle bin, and shallowest bin).

Figure 58.

6.1.3   Comparison of Current Meters on NTAS-3

Vertical profiles of velocity from the NTAS-3 current meters are shown in Figure 59. Data from the Aquadopp at 6 m depth indicated that the sensor failed and are omitted.

   Progressive vectors of the velocity data on NTAS-3 are shown in Figure 60.

   Spectra for the Aquadopp and a selection of the spectra from the RDI Workhorse depth bins are shown in Figure 61.

6.1.4   Comparison of Current Meters on NTAS-4

Vertical profiles of velocity from the NTAS-4 current meters are shown in Figure 62. Progressive vectors of all velocity data on NTAS-4 are shown in Figure 63. The spectrum for the Aquadopp and a selection of the spectra from the RDI WorkHorse depth bins appear in Figure 64.
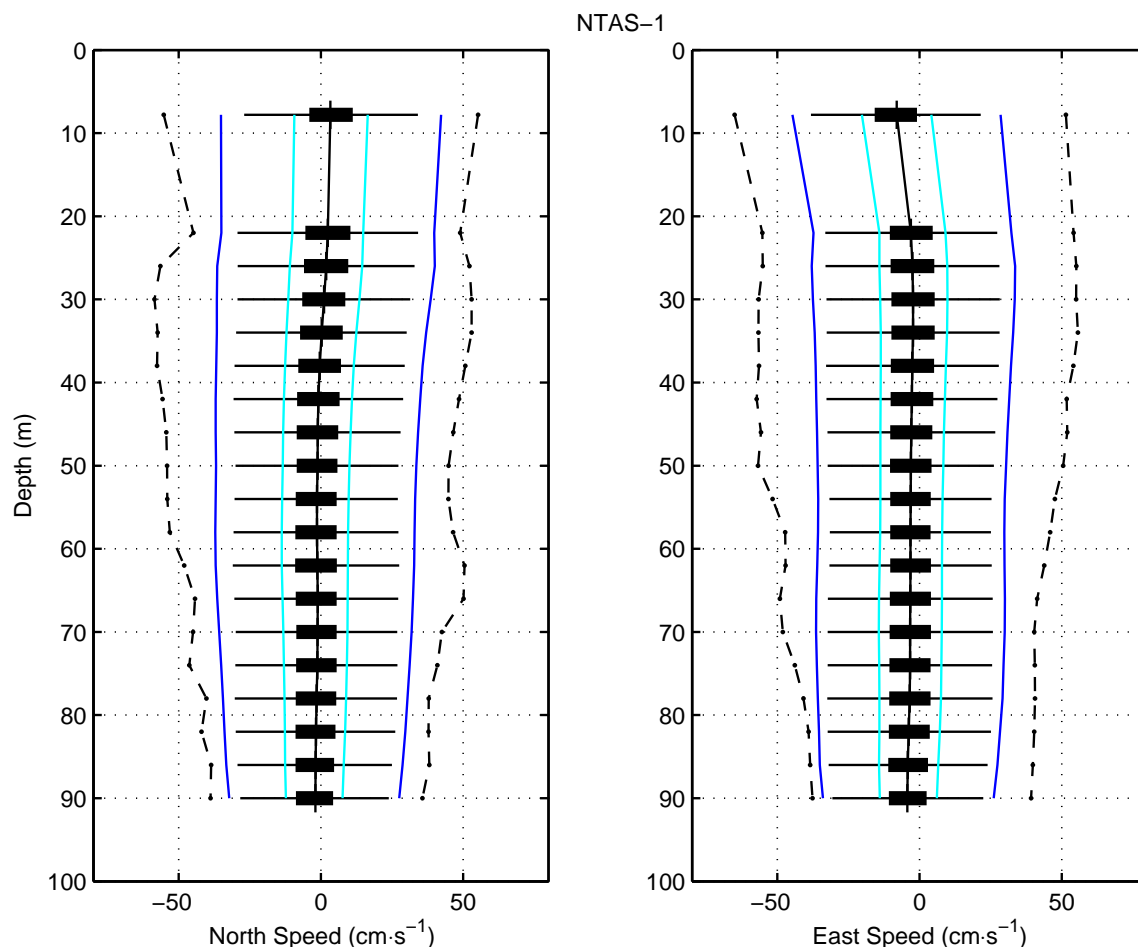
Figure 56: Vertical profile of all velocity data on NTAS-2. The data are shown as horizontal box-and-whisker plots. A + and the solid line identifies the median value; a thick line denotes the interquartile range; a thin line extends between the outlier limits at each depth; and the dashed line between dots indicates the maximum and minimum values. Cyan and blue lines indicate one and three standard deviations from the mean respectively. (a) Northerly current speeds. (b) Easterly current speeds.
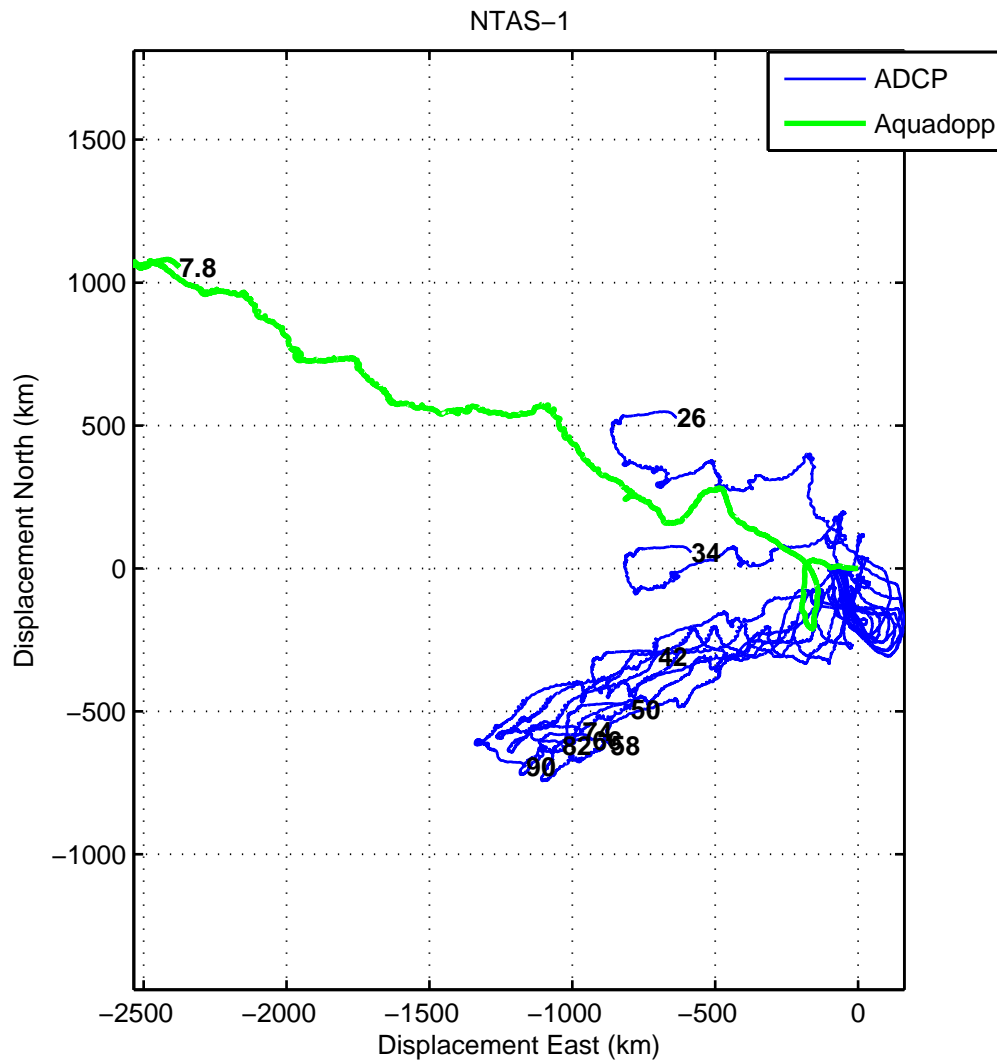
Figure 57: Progressive vectors of all velocity data on NTAS-2. The RDI data are plotted in blue, and the VMCM and Aquadopp are plotted in a thicker line. The final point of each series is labelled with the nominal depth of the sensor or bin.
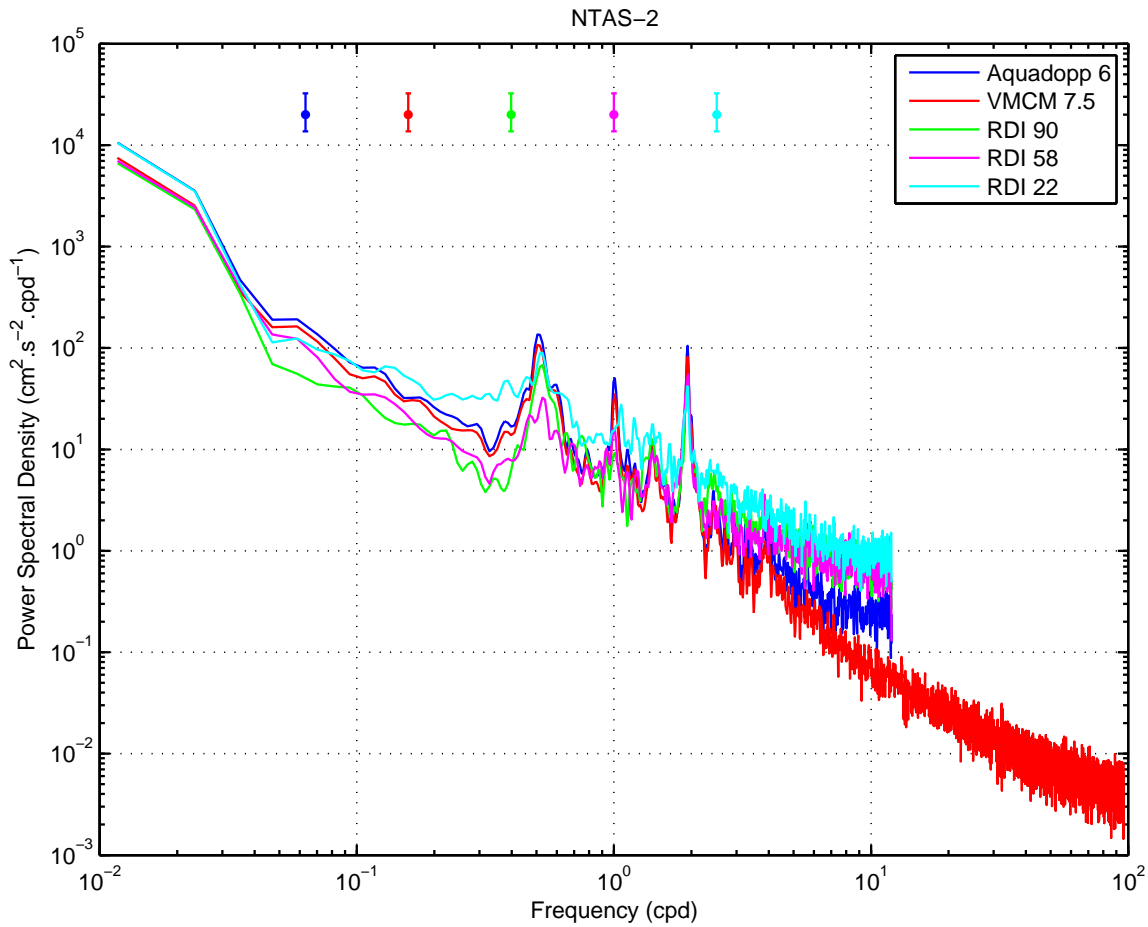
Figure 58: Spectra for the NTAS-2 current meters: VMCM, Aquadopp and a selection of the RDI spectra (deepest bin, middle bin, and shallowest bin).

6.1.5   Comparison of Current Meters on NTAS-5

Vertical profiles of velocity from the NTAS-5 current meters are shown in Figure 65 Progressive vectors of all velocity data on NTAS-5 are shown in Figure 66. The spectrum for the Aquadopp and a selection of the spectra from the RDI WorkHorse depth bins appear in Figure 67.
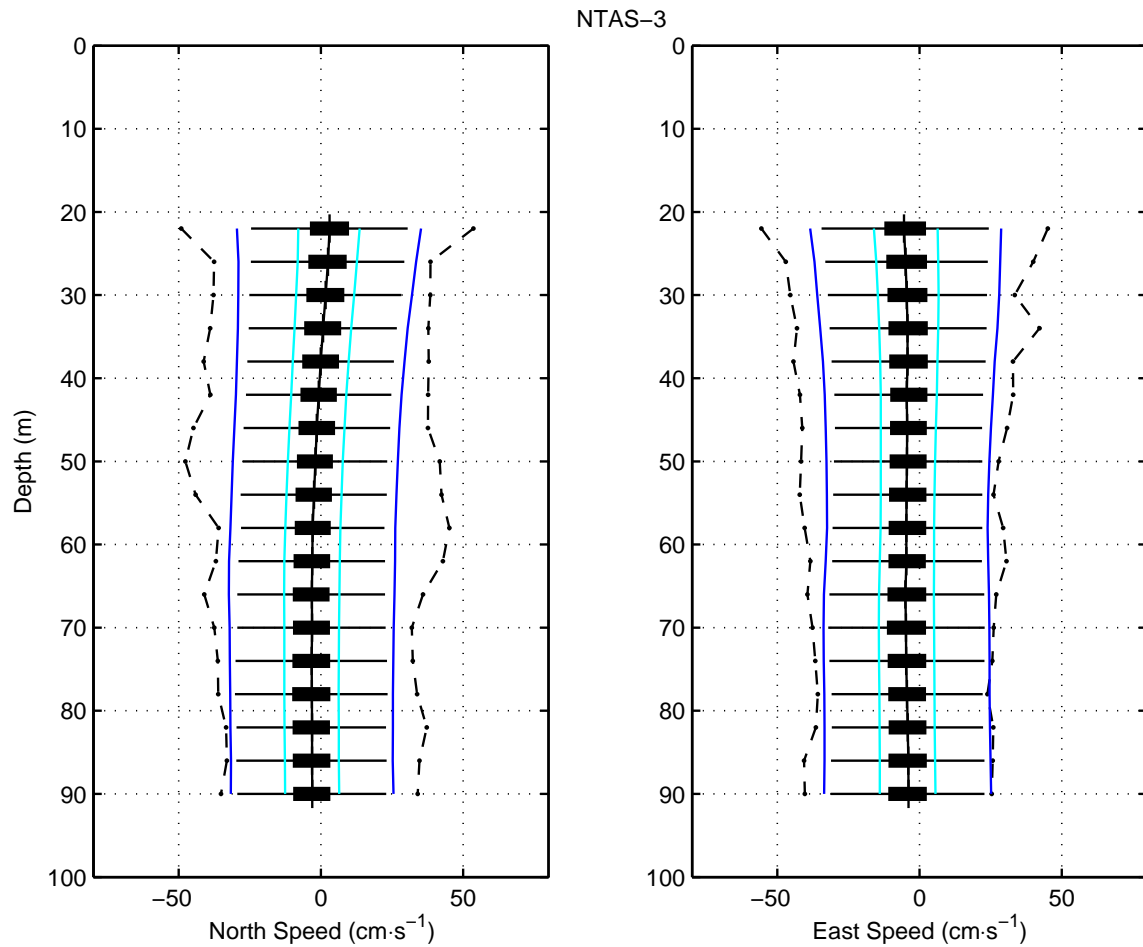
Figure 59: Vertical profile of RDI velocity data on NTAS-3. Aquadopp data were considered bad and are omitted (see Section 5.4.1). The data are shown as horizontal box-and-whisker plots. A + and the solid line identifies the median value; a thick line denotes the interquartile range; a thin line extends between the outlier limits at each depth; and the dashed line between dots indicates the maximum and minimum values. Cyan and blue lines indicate one and three standard deviations from the mean respectively. (a) Northerly current speeds. (b) Easterly current speeds.
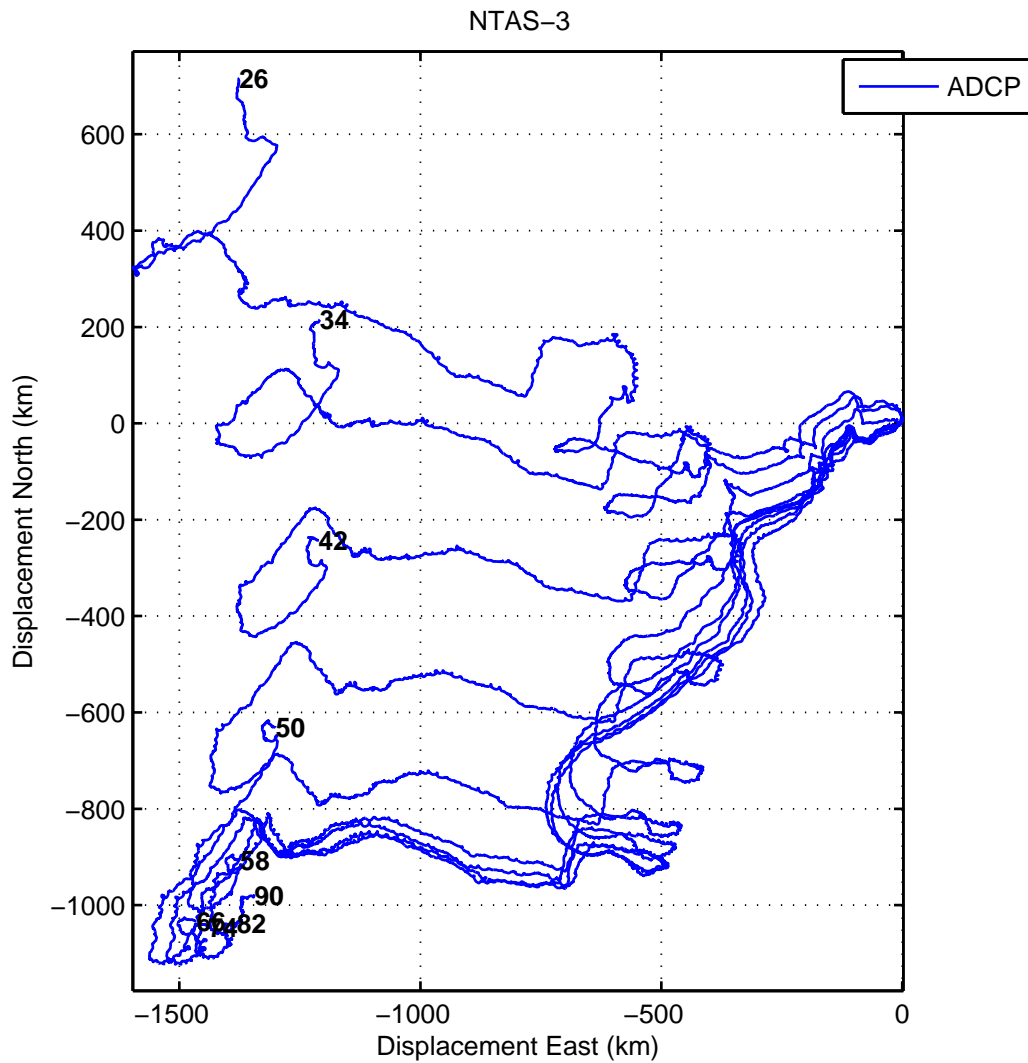
Figure 60: Progressive vectors of all velocity data on NTAS-3. The RDI bin data are plotted. The final point of each series is labelled with the nominal depth of the sensor or bin.
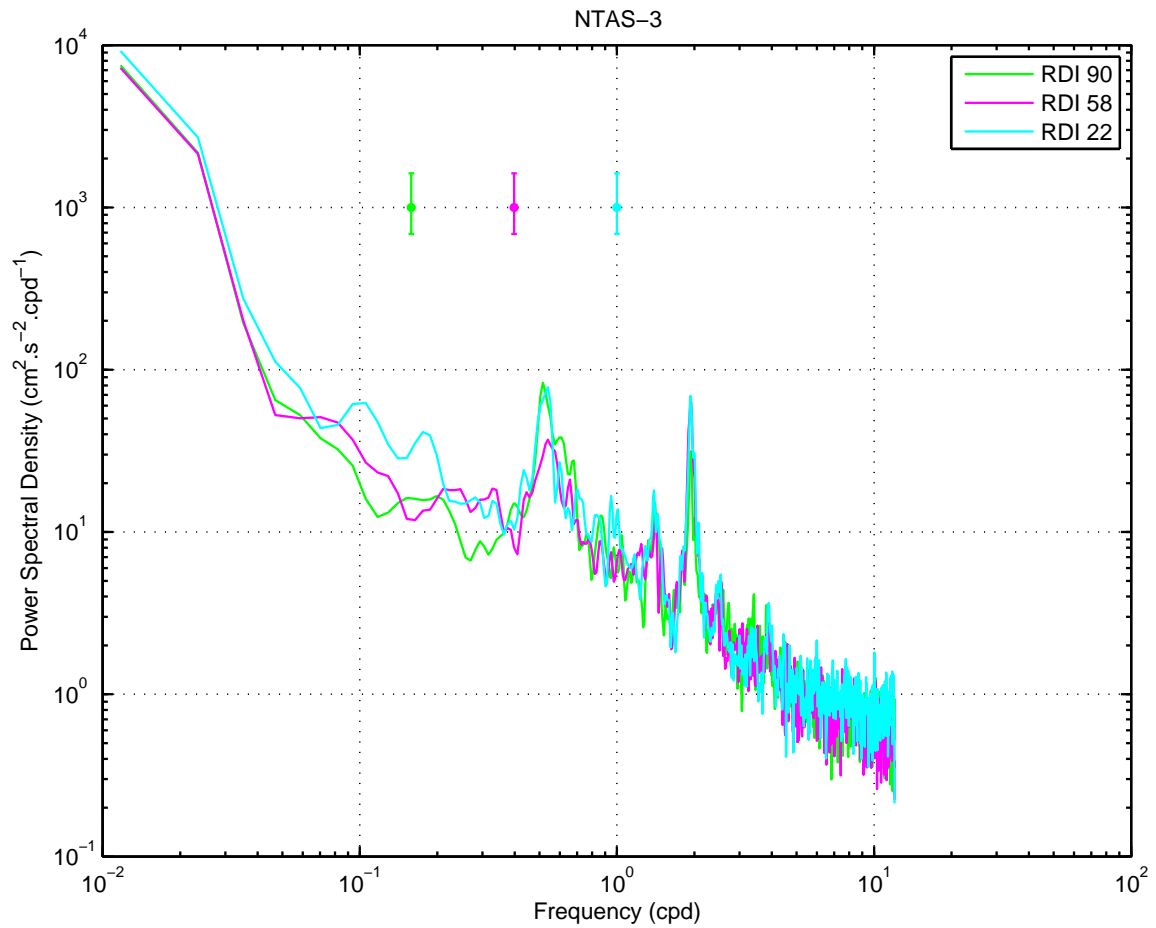
Figure 61: Spectra for the NTAS-3 velocities from the RDI WorkHorse ADCP. Aquadopp data (6 m) were bad and are omitted from the figure.
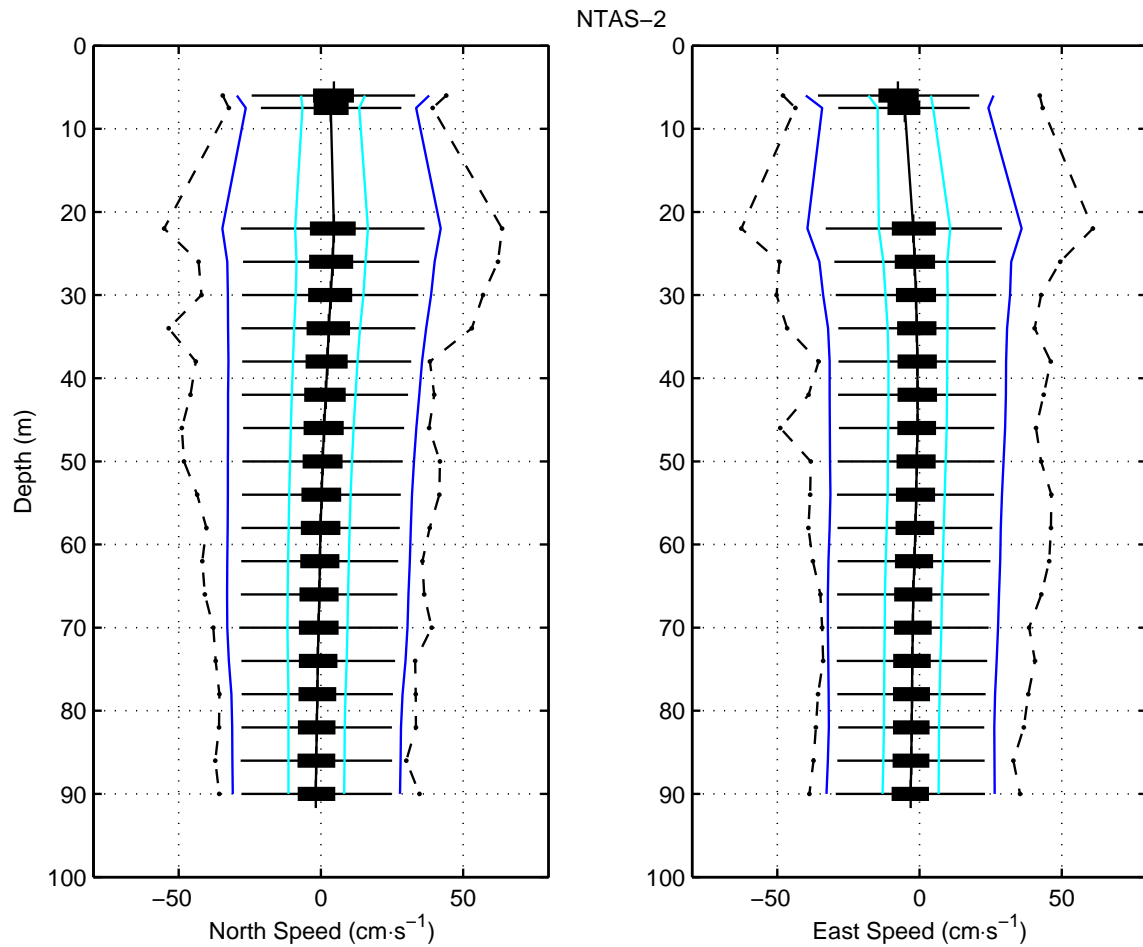
Figure 62: Vertical profile of all velocity data on NTAS-4. The data are shown as horizontal box-and-whisker plots. A + and the solid line identifies the median value; a thick line denotes the interquartile range; a thin line extends between the outlier limits at each depth; and the dashed line between dots indicates the maximum and minimum values. Cyan and blue lines indicate one and three standard deviations from the mean respectively. (a) Northerly current speeds. (b) Easterly current speeds.
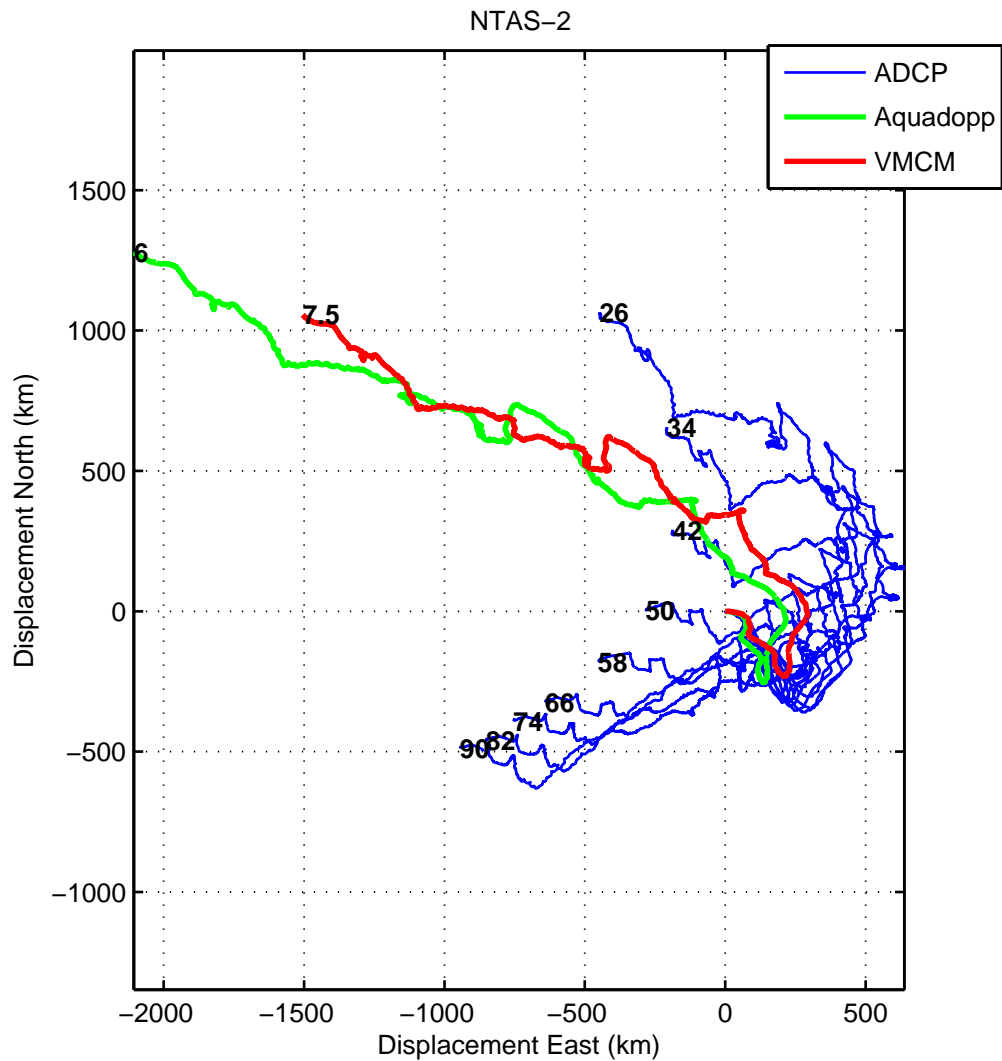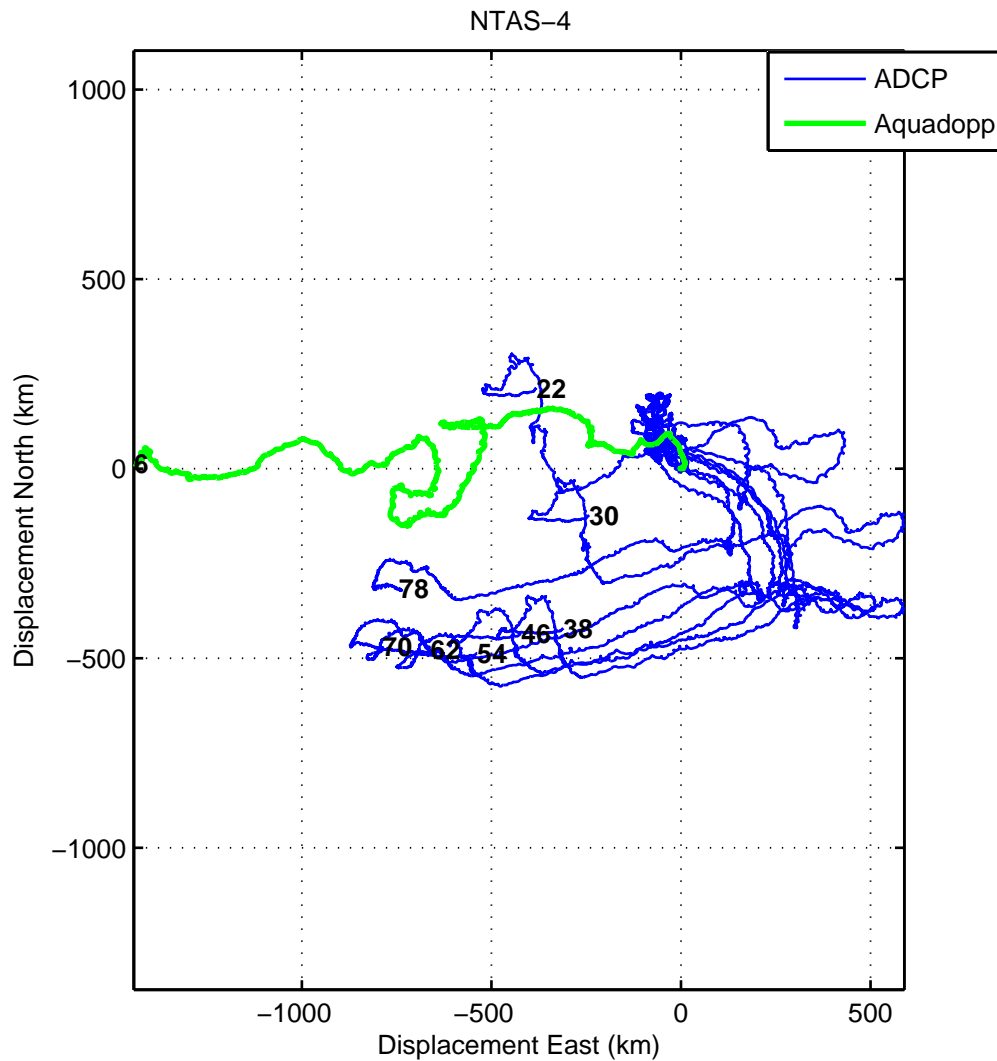
Figure 63: Progressive vectors of all velocity data on NTAS-4. The RDI data are plotted in blue, and the VMCM and Aquadopp are plotted in a thicker line. The final point of each series is labelled with the nominal depth of the sensor or bin.
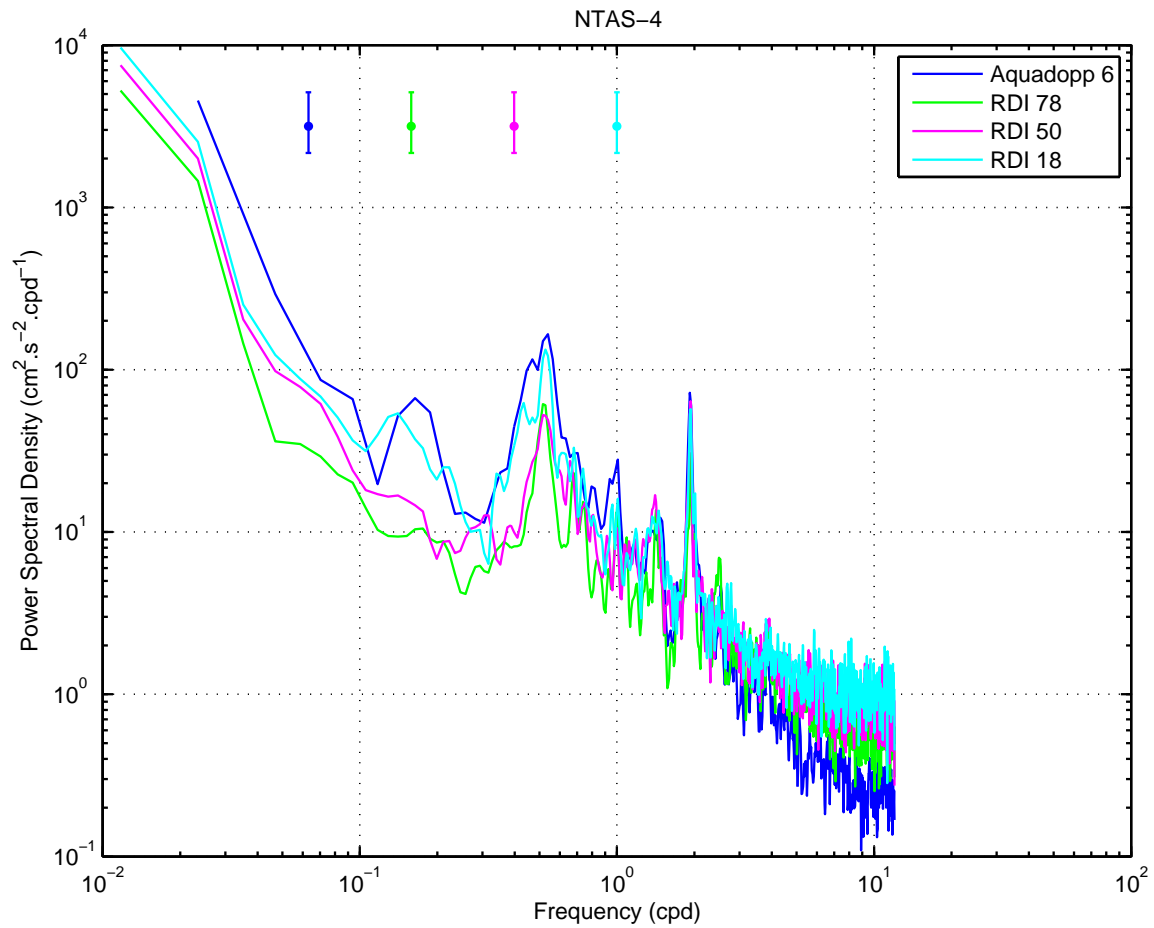
Figure 64: Spectra for the NTAS-4 velocities from the Aquadopp and RDI Workhorse current meters. The legend indicates the instrument and the nominal depth of the sensor.
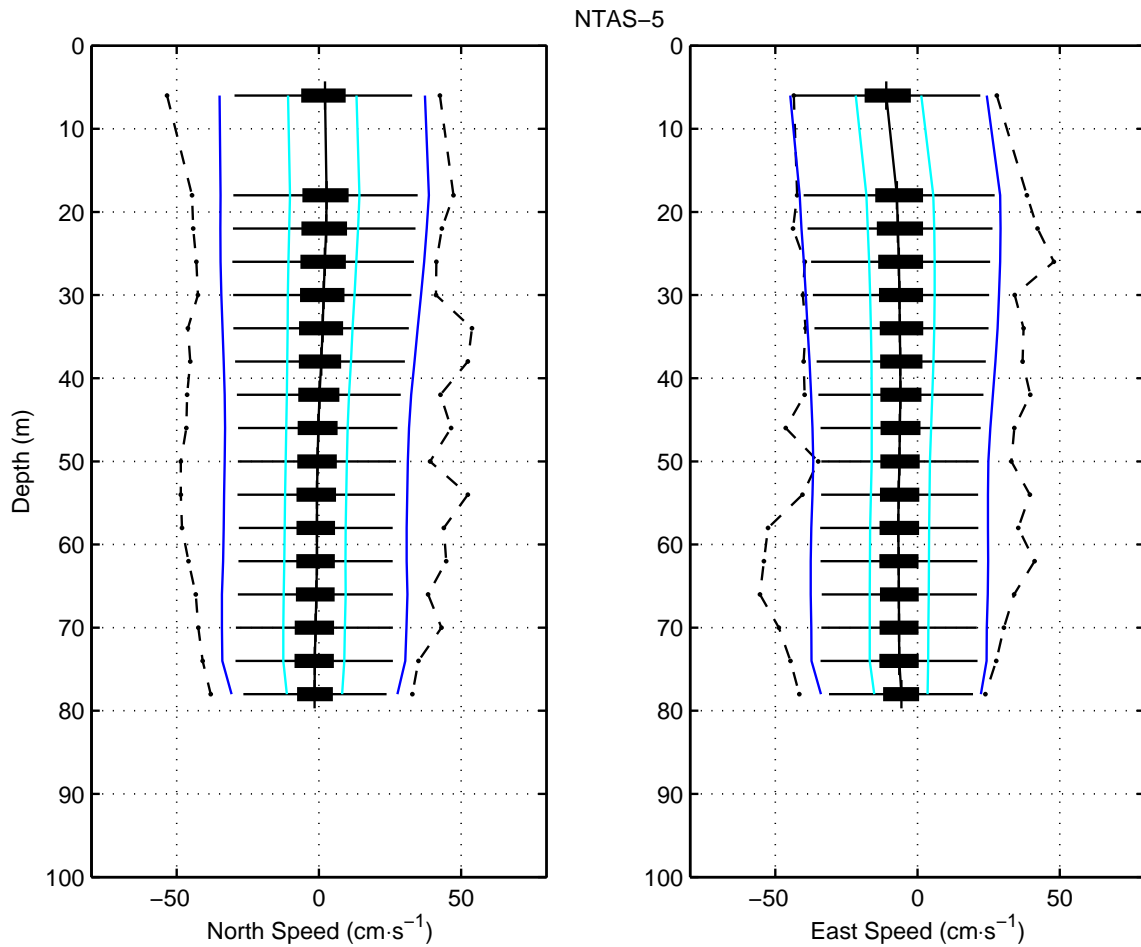
Figure 65: Vertical profile of all velocity data on NTAS-5. The data are shown as horizontal box-and-whisker plots. A + and the solid line identifies the median value; a thick line denotes the interquartile range; a thin line extends between the outlier limits at each depth; and the dashed line between dots indicates the maximum and minimum values. Cyan and blue lines indicate one and three standard deviations from the mean respectively. (a) Northerly current speeds. (b) Easterly current speeds.
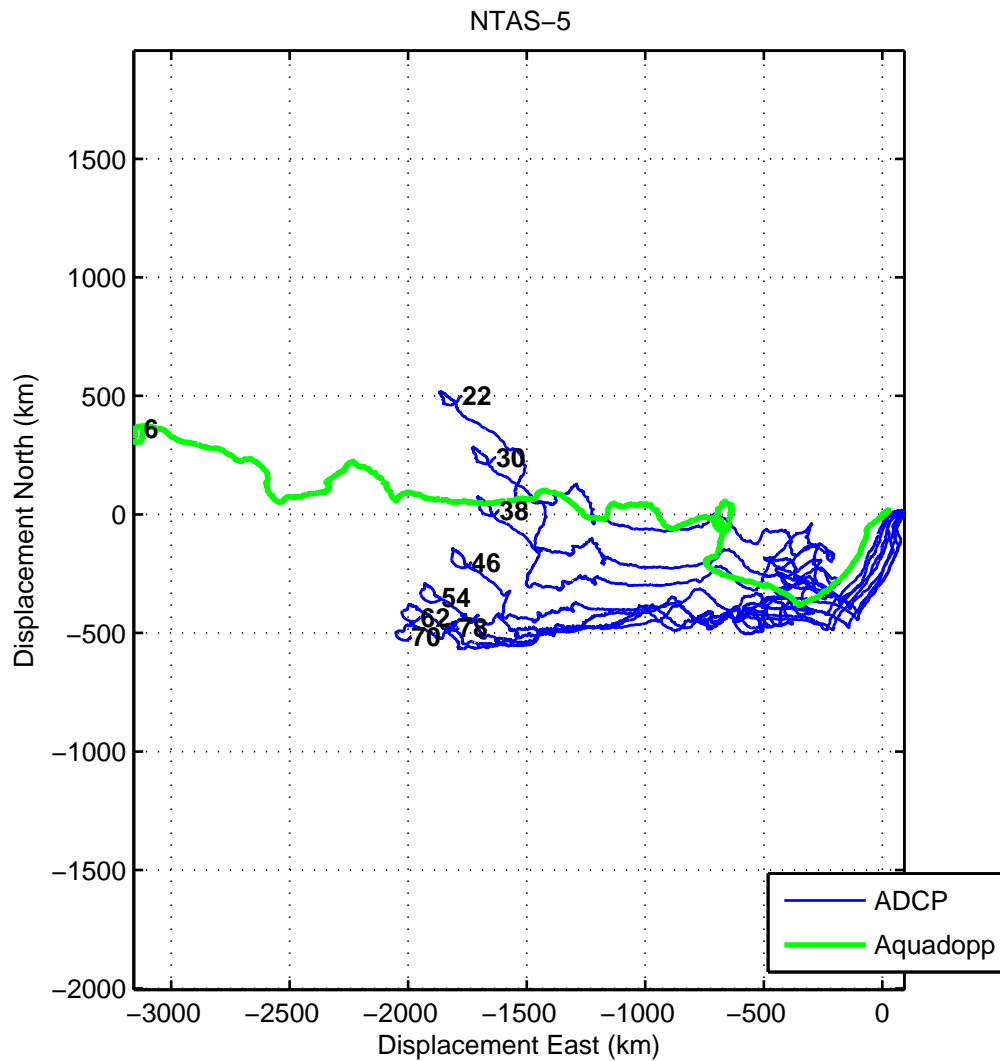
Figure 66: Progressive vectors of all velocity data on NTAS-5. The RDI bin data are plotted in blue, and the Aquadopp data are plotted in a thicker line. The final point of each series is labelled with the nominal depth of the sensor or bin.
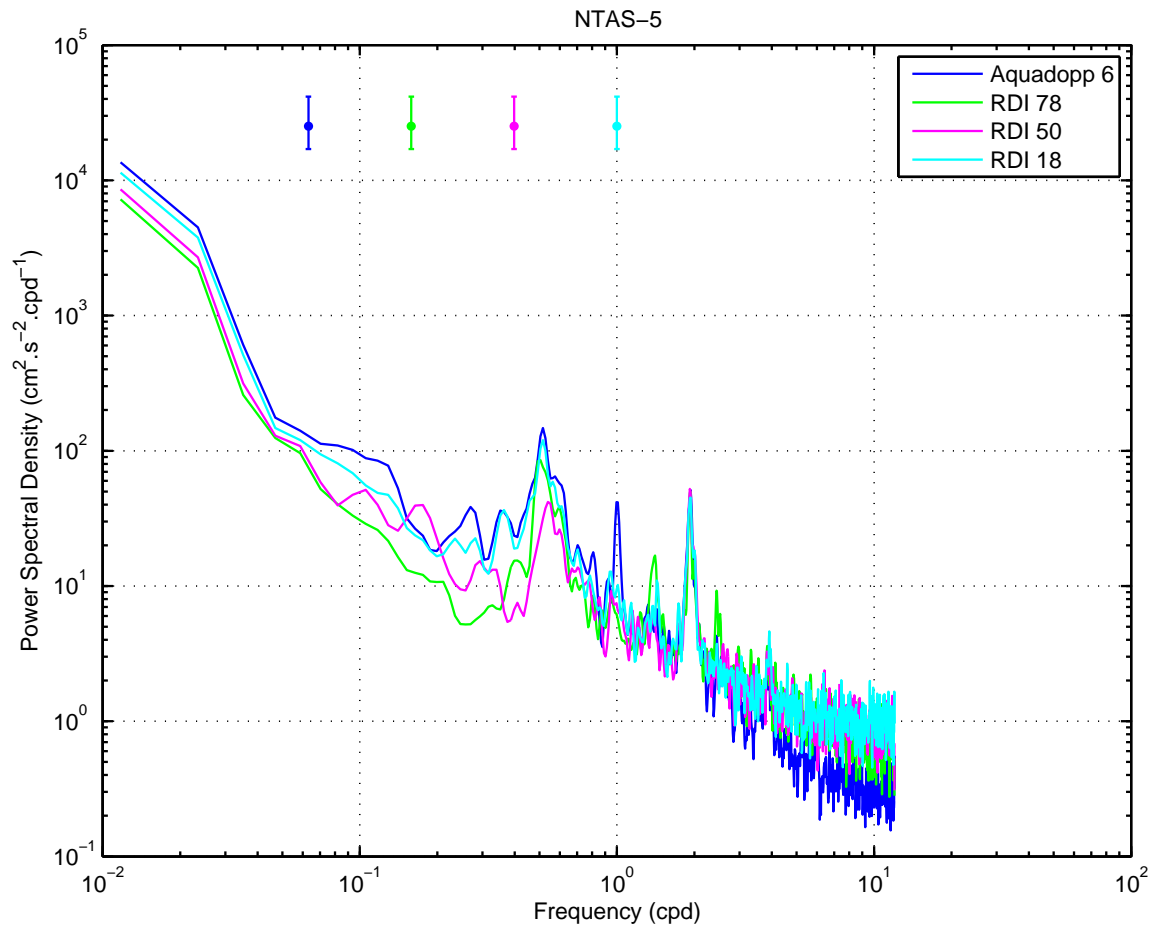
Figure 67: Spectra for the NTAS-5 current meters: the Aquadopp spectrum and a selection of the RDI spectra (deepest bin, middle bin, and shallowest bin) are shown. The legend indicates the instrument and the nominal depth of the sensor.

6.2   Inter-Deployment Comparisons

The complete five year record from NTAS-1 to -5 was examined (Figs. 68 and 69). Of particular interest appear to be the passage of mesoscale vortices

- near the beginning of NTAS-1 deployment (2001);

- during the turnaround of NTAS-1 and -2 (2002); and

- near the beginning of the NTAS-5 record (2005).

Vertical location and variability (Fig. 70) were determined for the common depth bins of the available RDI ADCP data.

Spectra from the long time series were constructed to demonstrate lower frequency signals, unresolved in the one-year deployments (Figs. 71, 72 and 73). The rotary spectrum of the shallowest common RDI ADCP depth bin is shown in Figure 74.

Due to gaps in the near-surface and maximum depth time series (see Fig. 52), progressive vector figures could not be created. Instead only a subset of the RDI ADCP bins (depths 22, 46, and 78 m) were used (Fig. 75).

NTAS North Speed
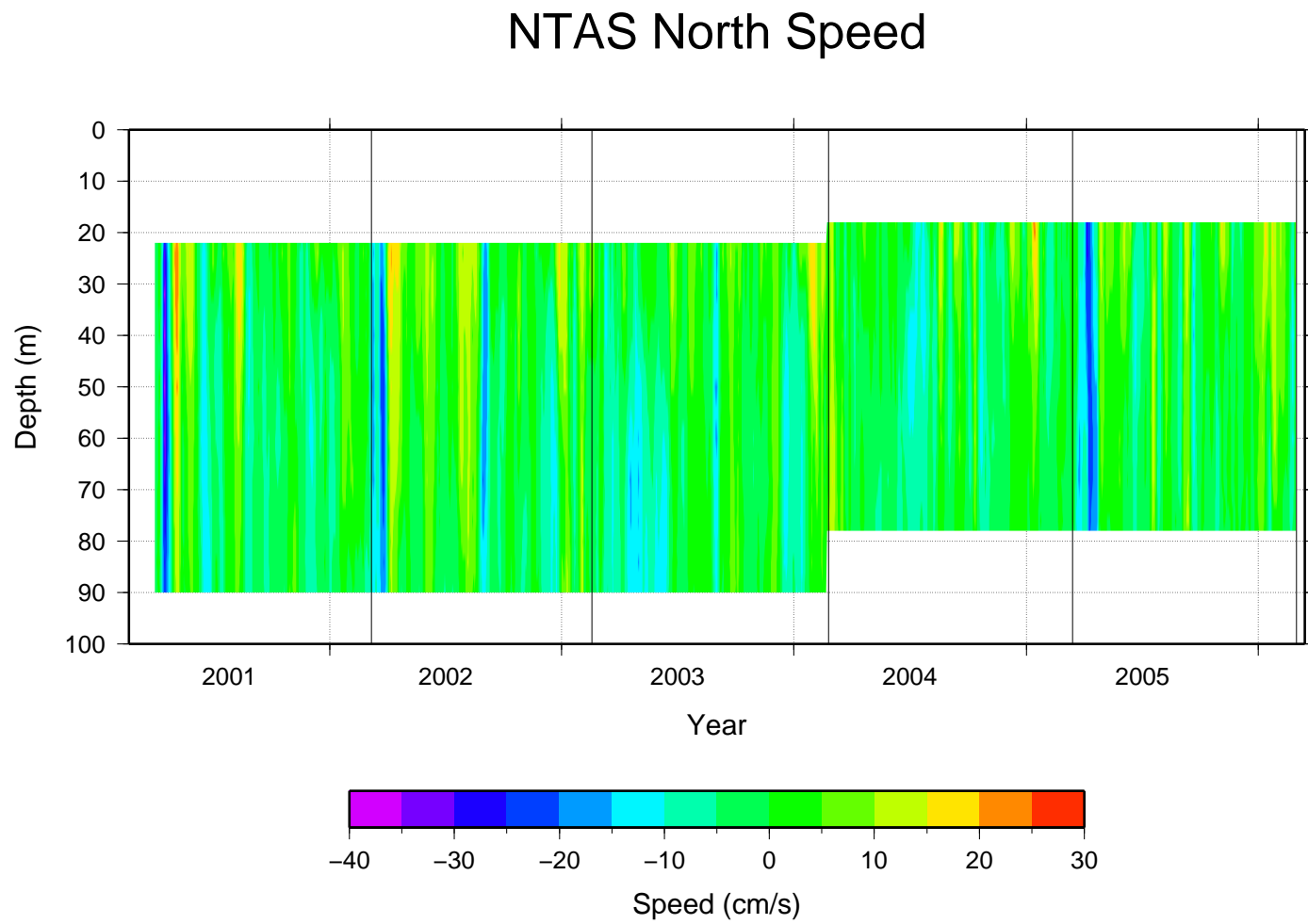
Figure 68: Northward current speeds from the RDI ADCPs on NTAS-1 to -5. Vertical lines indicate deployment turnaround times.
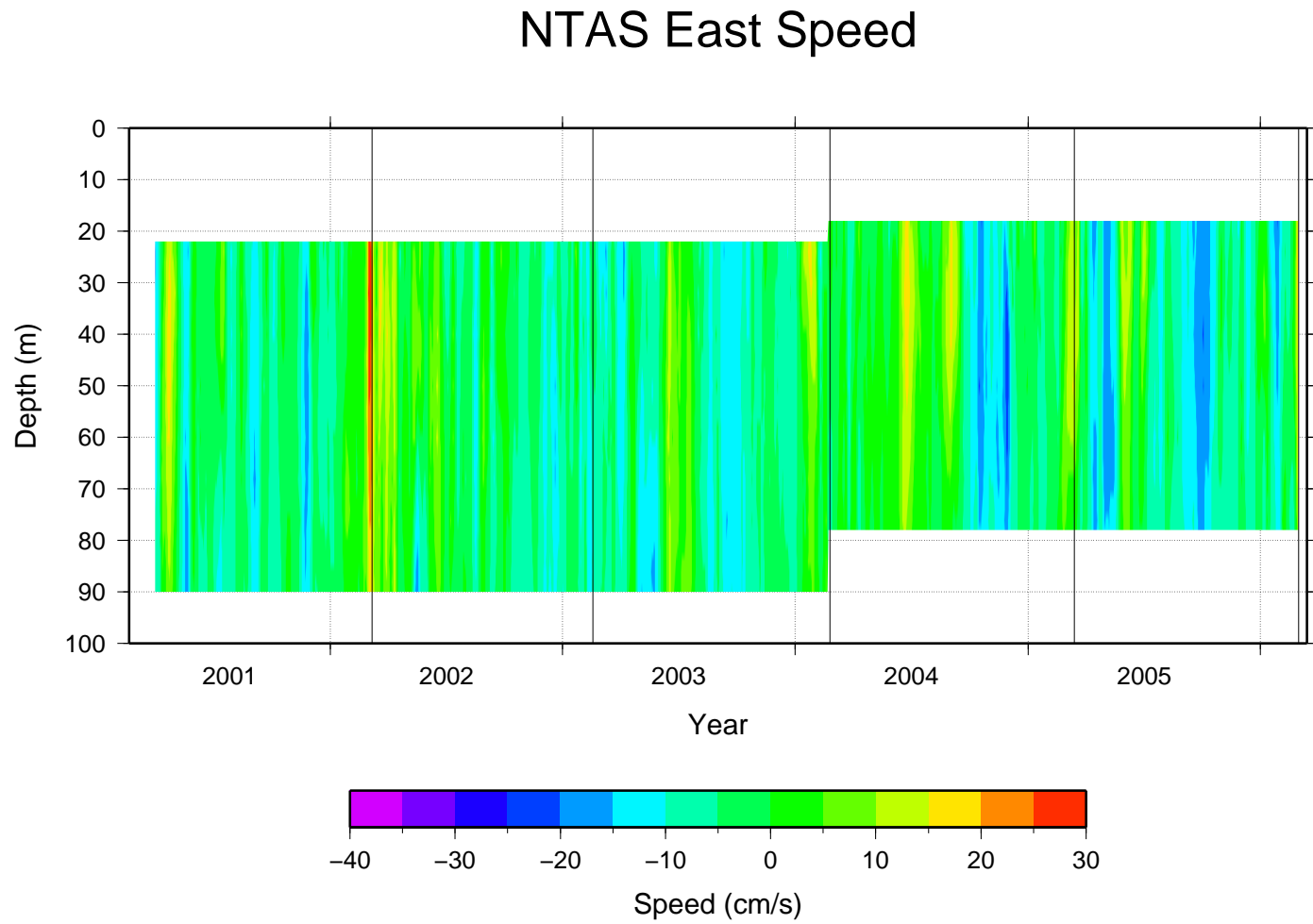
Figure 69: Eastward current speeds from the RDI ADCPs on NTAS-1 to -5. Vertical lines indicate deployment turnaround times.
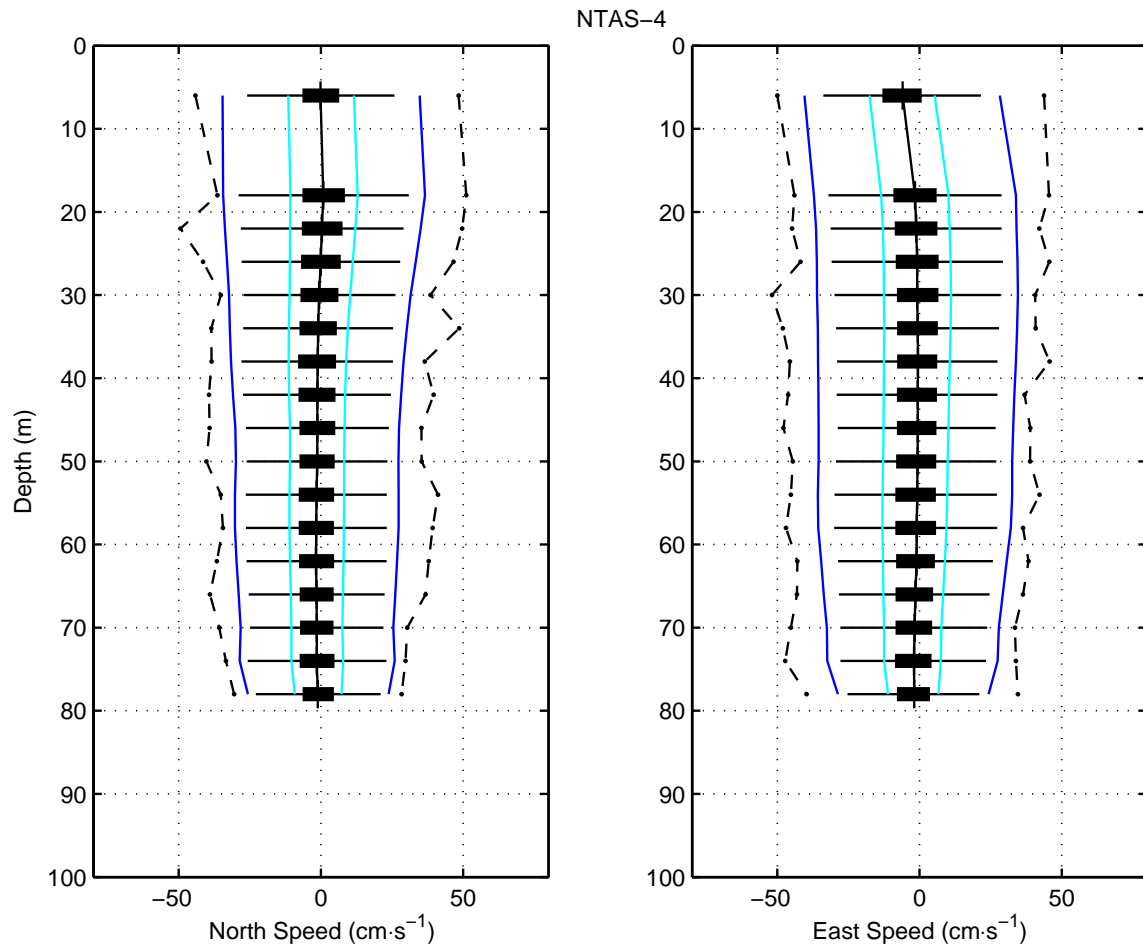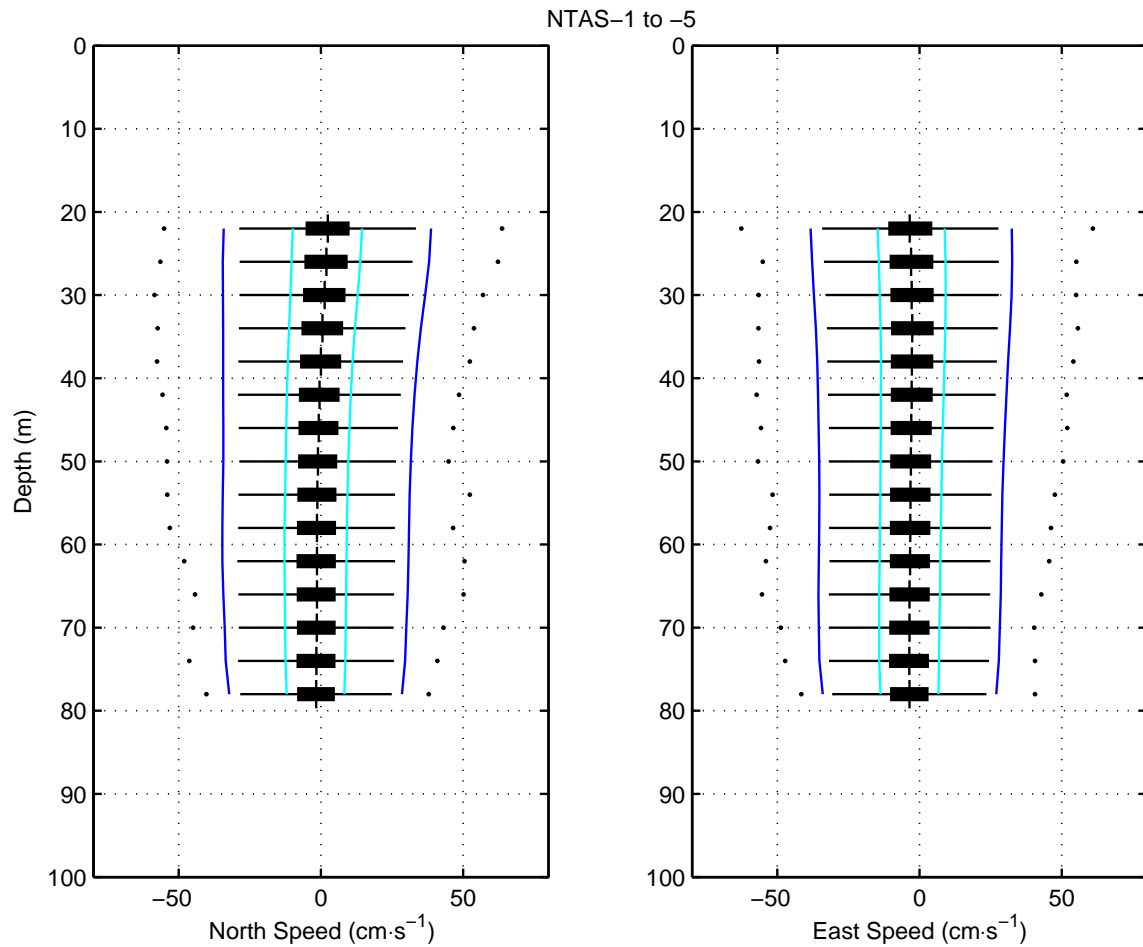
Figure 70: Vertical profile of all velocity data on NTAS-1 to -5 deployments. The data are shown as horizontal box-and-whisker plots. A $+$ and the solid line identifies the median value; a thick line (box) denotes the interquartile range; a thin line (whiskers) extends between the outlier limits at each depth; and the dashed line between dots indicates the extreme (maximum and minimum) values. Cyan and blue lines indicate one and three standard deviations from the mean respectively. (a) Northerly current speeds. (b) Easterly current speeds.
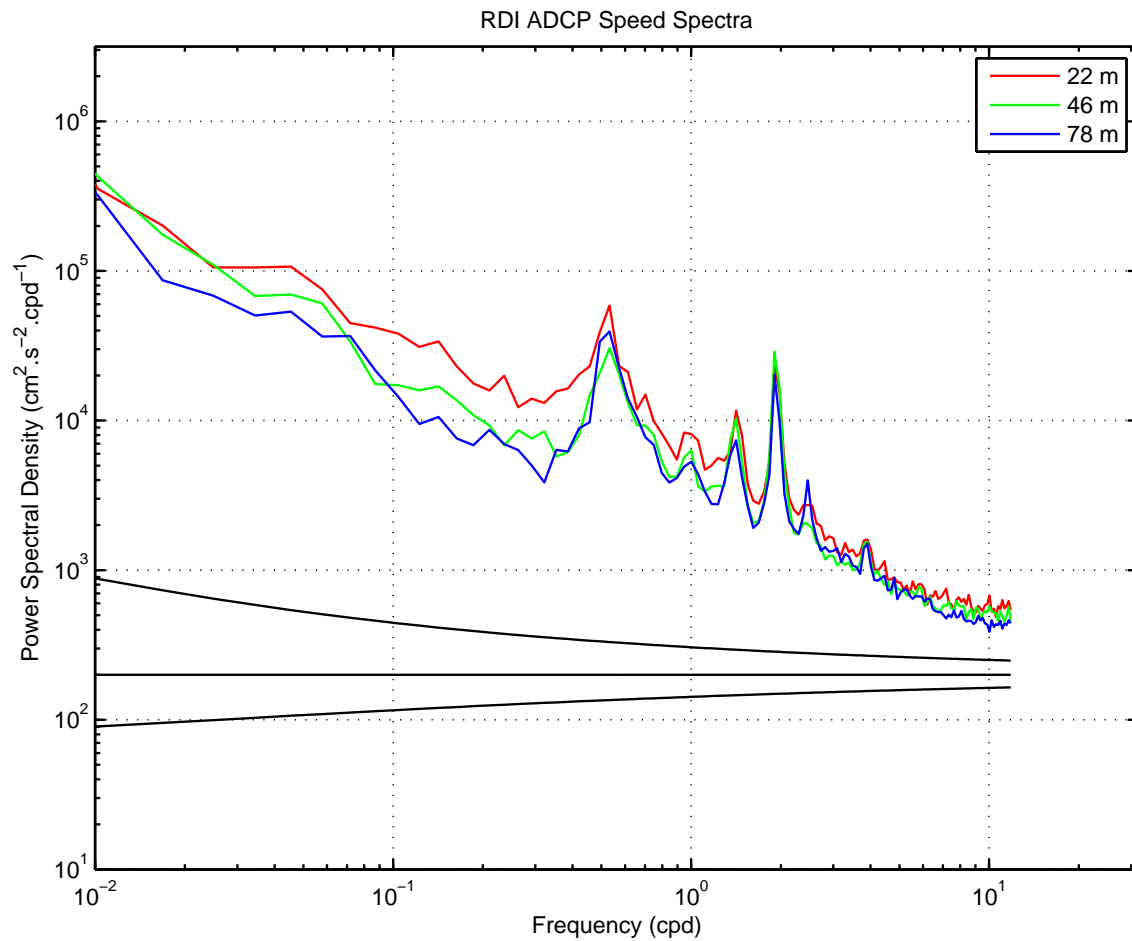
Figure 71: Current magnitude spectra on NTAS-1 to -5. Spectra are shown from the shallowest, mid-depth, and deepest common bins of the RDI ADCP.
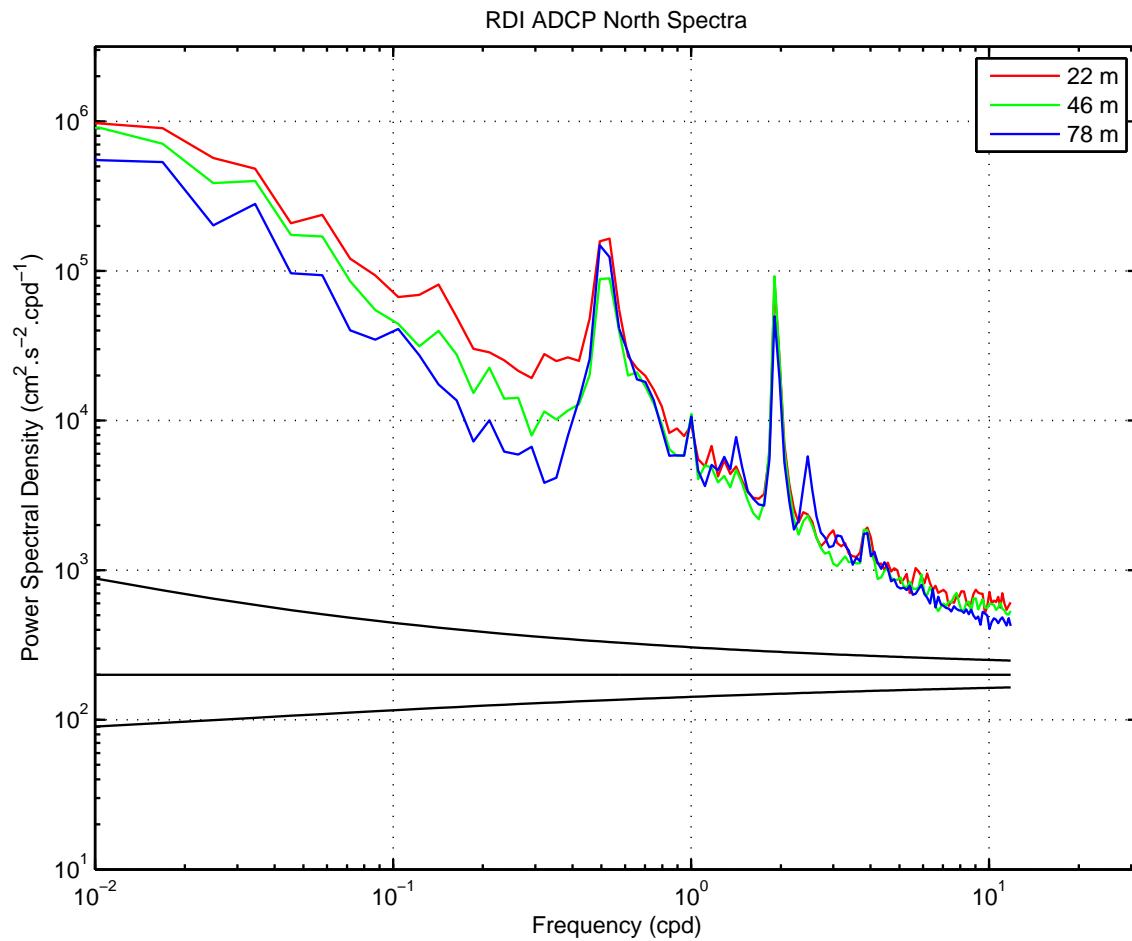
Figure 72: Northward current speed spectra on NTAS-1 to -5. Spectra are shown from the shallowest, mid-depth, and deepest common bins of the RDI ADCP.
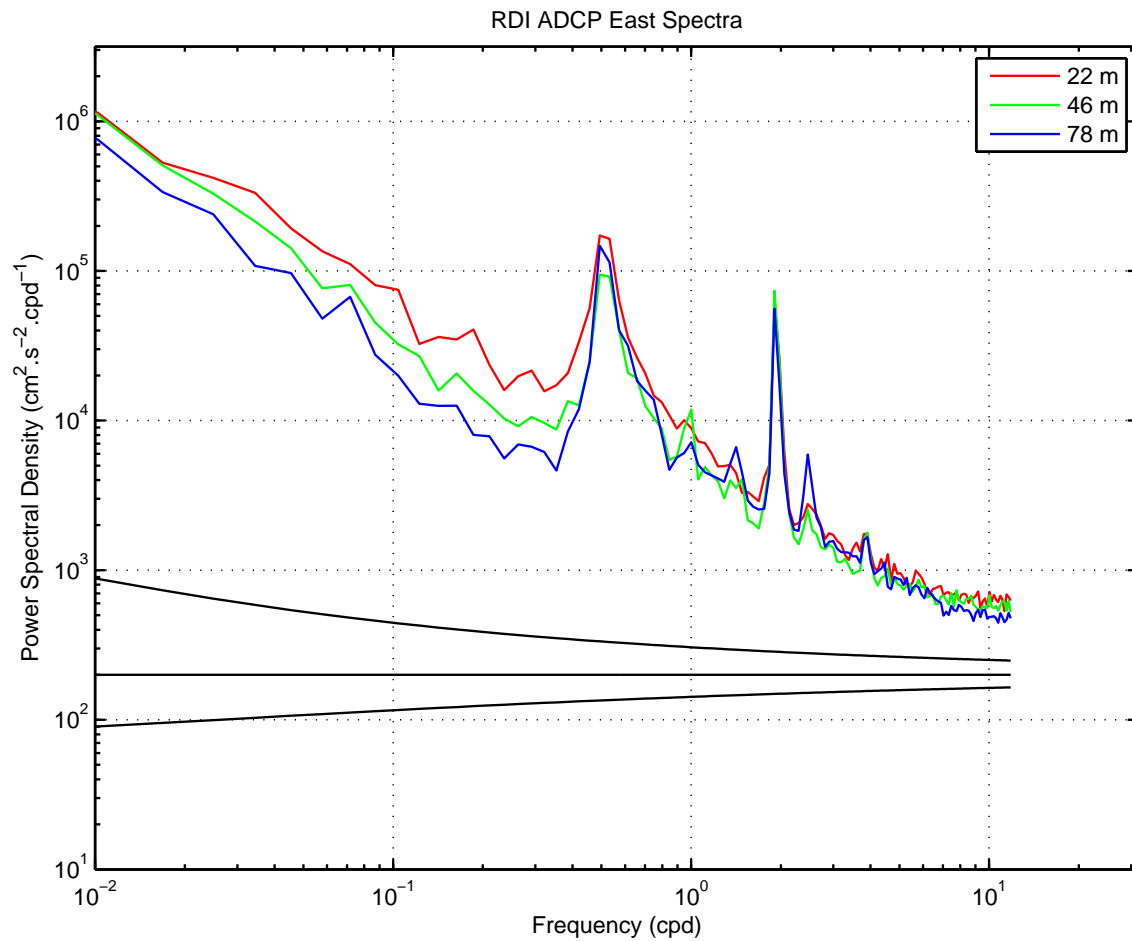
Figure 73: Eastward current speed spectra on NTAS-1 to -5. Spectra are shown from the shallowest, mid-depth, and deepest common bins of the RDI ADCP.
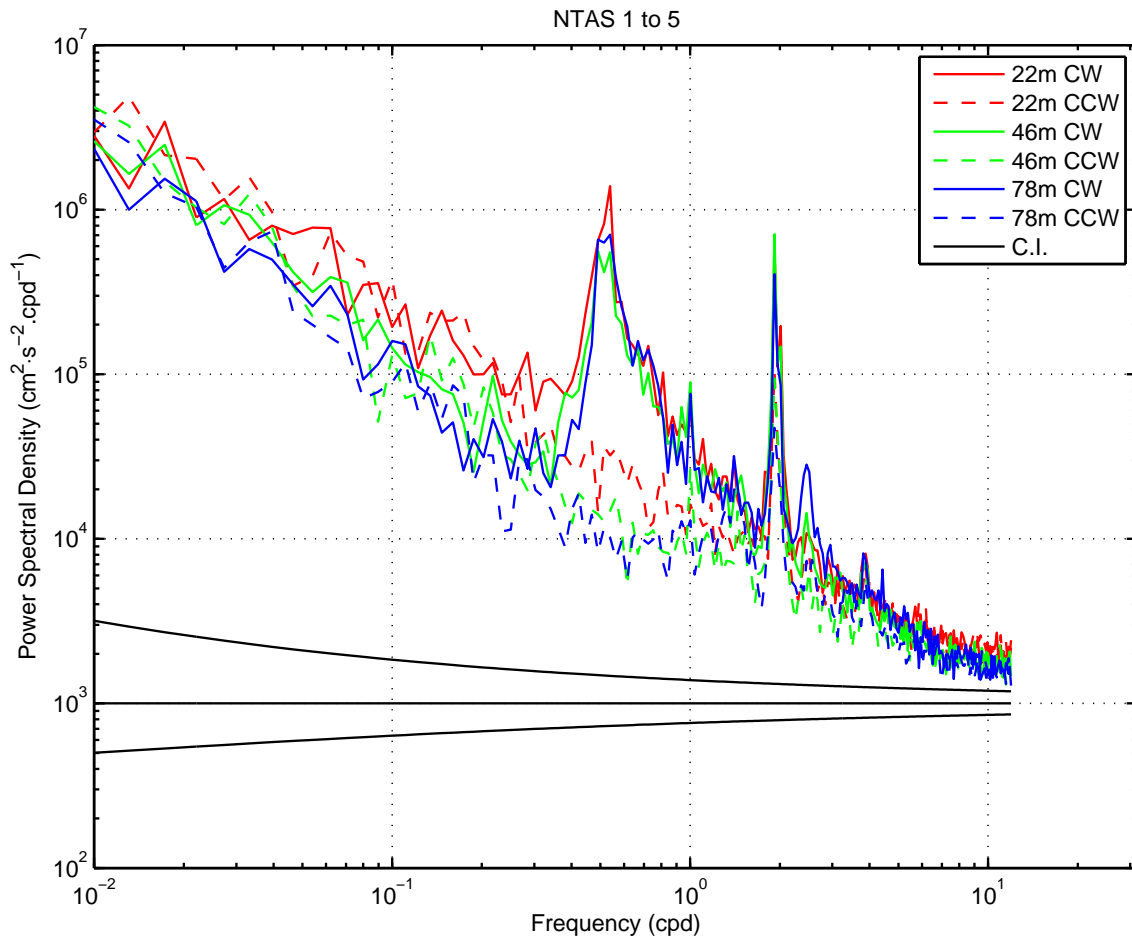
Figure 74: Showing the rotary spectra of velocities determined from representative RDI ADCP depth bins for the long time series of all NTAS-1 to -5 deployments. Spectra for the common near-surface (22 m), middle (46 m), and deepest (78 m) bins are shown. Clockwise (CW) spectra are shown with solid lines; counter-clockwise (CCW) spectra are shown with dashed lines. The frequency dependent confidence interval (C.I.) is shown below the spectra.
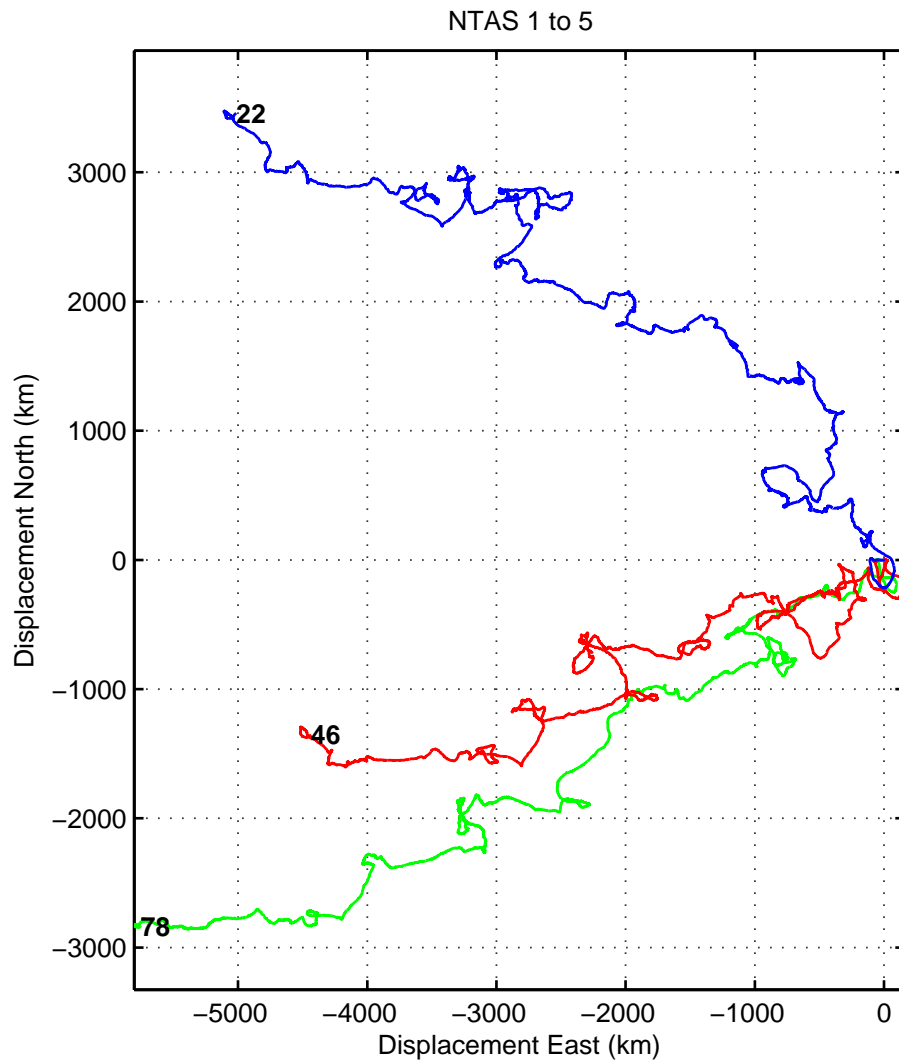
Figure 75: Progressive vectors of three depth bins (near-surface—blue, middle—red, and deepest—green) from the RDI bin data on all NTAS 1 to 5 deployments. The final point of each series is labelled with the nominal depth of the sensor or bin.

Acknowledgements

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Appendices

A   NTAS Velocity Statistics

Table A1: Gross statistical description of the various NTAS velocity time series. The first column provides the deployment number, the instrument depth and the instrument type. The second column provides reference for the following columns which show the mean, standard deviation and range (minimum and maximum values) of the northerly and easterly current components (North and East, in cm·s^{-1}), the magnitude (Spd, in cm·s^{-1}) and direction (Dir, in degrees clockwise from North). The means and standard deviations of directions were calculated using the Circular Statistics Toolbox for Matlab [*Berens*, 2009], assuming a von Mieses distribution for the directional data.

		Mean	Std Deviation	Range	
NTAS-1	North:	3.6	12.9	-55.3	55.3
(7.8 m)	East:	-8.1	12.2	-65.0	51.5
Aquadopp	Spd:	17.2	9.8	0.1	65.3
	Dir:	291.4	59.7	0.0	360.0
NTAS-1	North:	2.4	12.5	-44.8	49.0
(22 m)	East:	-2.5	11.6	-55.3	54.1
NarrowBand	Spd:	15.3	8.3	0.0	56.0
	Dir:	306.2	71.9	0.0	360.0
NTAS-1	North:	1.8	12.7	-56.5	52.3
(26 m)	East:	-2.2	11.9	-55.1	55.1
NarrowBand	Spd:	15.4	8.8	0.0	56.7
	Dir:	304.8	73.7	0.0	360.0
NTAS-1	North:	1.0	12.5	-58.5	53.0
(30 m)	East:	-2.0	11.8	-56.6	55.1
NarrowBand	Spd:	15.1	8.6	0.2	58.8
	Dir:	295.1	74.9	0.0	360.0
NTAS-1	North:	0.2	12.3	-57.4	53.0
(34 m)	East:	-2.0	11.6	-56.7	55.7
NarrowBand	Spd:	14.8	8.4	0.0	57.4
	Dir:	277.8	75.3	0.0	360.0
NTAS-1	North:	-0.5	12.1	-57.6	50.8
(38 m)	East:	-2.2	11.4	-56.4	54.1
NarrowBand	Spd:	14.6	8.3	0.0	57.8
	Dir:	262.6	74.8	0.0	360.0
NTAS-1	North:	-1.0	12.0	-55.7	48.6
(42 m)	East:	-2.4	11.3	-57.3	51.7
NarrowBand	Spd:	14.5	8.2	0.0	57.3
	Dir:	254.9	73.9	0.0	360.0
NTAS-1	North:	-1.4	11.9	-54.4	46.6
(46 m)	East:	-2.6	11.2	-55.8	51.9
NarrowBand	Spd:	14.4	8.2	0.0	55.8
	Dir:	251.7	73.1	0.0	360.0

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Table A1: (continued)

		Mean	Std Deviation	Range	
NTAS-1	North:	-1.7	11.7	-54.1	44.9
(50 m)	East:	-2.7	11.1	-56.8	50.5
NarrowBand	Spd:	14.3	8.1	0.0	57.3
	Dir:	249.8	72.6	0.0	360.0
NTAS-1	North:	-1.9	11.7	-54.0	44.8
(54 m)	East:	-2.8	10.9	-51.7	47.6
NarrowBand	Spd:	14.2	8.1	0.0	55.1
	Dir:	248.2	72.1	0.0	360.0
NTAS-1	North:	-2.1	11.7	-53.2	46.5
(58 m)	East:	-2.9	10.9	-47.2	45.9
NarrowBand	Spd:	14.2	8.1	0.0	54.6
	Dir:	247.2	72.1	0.0	360.0
NTAS-1	North:	-2.1	11.6	-48.1	50.5
(62 m)	East:	-3.1	11.0	-47.1	43.8
NarrowBand	Spd:	14.3	8.1	0.0	51.1
	Dir:	249.1	72.3	0.0	360.0
NTAS-1	North:	-2.0	11.5	-44.2	50.1
(66 m)	East:	-3.2	11.1	-49.1	41.4
NarrowBand	Spd:	14.2	8.1	0.0	50.6
	Dir:	251.8	72.3	0.0	360.0
NTAS-1	North:	-2.0	11.3	-45.0	42.5
(70 m)	East:	-3.2	11.1	-48.1	40.3
NarrowBand	Spd:	14.2	7.9	0.0	48.1
	Dir:	252.2	72.1	0.0	360.0
NTAS-1	North:	-1.9	11.1	-46.3	41.0
(74 m)	East:	-3.3	10.9	-43.9	40.5
NarrowBand	Spd:	14.1	7.7	0.0	46.5
	Dir:	249.8	72.0	0.0	360.0
NTAS-1	North:	-2.0	10.8	-40.3	37.9
(78 m)	East:	-3.3	10.8	-40.8	40.6
NarrowBand	Spd:	13.9	7.4	0.0	41.9
	Dir:	246.2	71.5	0.0	360.0
NTAS-1	North:	-2.1	10.6	-42.0	37.9
(82 m)	East:	-3.5	10.6	-39.0	40.3
NarrowBand	Spd:	13.8	7.2	0.0	46.8
	Dir:	244.5	70.4	0.0	360.0
NTAS-1	North:	-2.3	10.3	-38.6	38.1
(86 m)	East:	-3.9	10.4	-38.5	39.9
NarrowBand	Spd:	13.6	7.0	0.0	42.3
	Dir:	245.0	68.8	0.0	360.0
NTAS-1	North:	-2.4	10.0	-38.8	35.7
(90 m)	East:	-3.9	10.0	-37.6	39.2
NarrowBand	Spd:	13.2	6.8	0.0	40.6
	Dir:	244.9	67.8	0.0	360.0

continued...

Table A1: (continued)

		Mean	Std Deviation	Range	
NTAS-2	North:	4.3	11.3	-34.5	44.0
(6 m)	East:	-7.0	11.0	-48.0	42.3
Aquadopp	Spd:	15.8	8.1	0.3	49.9
	Dir:	299.5	59.2	0.0	360.0
NTAS-2	North:	3.5	10.0	-32.3	39.3
(7.5 m)	East:	-5.0	9.7	-43.6	43.3
VMCM	Spd:	13.2	7.5	0.1	44.3
	Dir:	300.4	61.2	0.0	360.0
NTAS-2	North:	3.8	12.8	-55.1	63.7
(22 m)	East:	-1.8	12.6	-62.7	60.9
Workhorse	Spd:	16.0	9.1	0.0	69.6
	Dir:	332.4	70.9	0.0	359.9
NTAS-2	North:	3.5	12.1	-43.0	62.3
(26 m)	East:	-1.5	11.2	-49.2	49.5
Workhorse	Spd:	14.8	8.3	0.1	73.2
	Dir:	335.5	70.8	0.0	360.0
NTAS-2	North:	3.0	11.9	-42.0	57.0
(30 m)	East:	-1.0	10.9	-50.3	42.8
Workhorse	Spd:	14.5	7.9	0.1	65.7
	Dir:	337.9	72.3	0.0	360.0
NTAS-2	North:	2.2	11.6	-53.6	53.1
(34 m)	East:	-0.7	10.5	-46.6	40.5
Workhorse	Spd:	13.9	7.5	0.1	62.8
	Dir:	339.8	73.9	0.1	359.9
NTAS-2	North:	1.5	11.3	-44.0	38.3
(38 m)	East:	-0.6	10.3	-35.5	46.1
Workhorse	Spd:	13.6	7.3	0.1	46.3
	Dir:	339.1	74.9	0.0	360.0
NTAS-2	North:	1.0	11.2	-45.8	39.9
(42 m)	East:	-0.6	10.3	-39.0	43.6
Workhorse	Spd:	13.4	7.3	0.2	47.9
	Dir:	334.1	76.1	0.0	360.0
NTAS-2	North:	0.5	11.0	-48.9	38.0
(46 m)	East:	-0.7	10.3	-49.0	41.0
Workhorse	Spd:	13.2	7.3	0.1	54.3
	Dir:	323.0	77.1	0.1	360.0
NTAS-2	North:	0.0	10.9	-48.2	41.9
(50 m)	East:	-0.9	10.2	-38.3	42.8
Workhorse	Spd:	13.1	7.2	0.1	48.2
	Dir:	302.4	77.6	0.0	360.0
NTAS-2	North:	-0.3	10.8	-43.5	41.7
(54 m)	East:	-1.2	10.1	-38.4	46.3
Workhorse	Spd:	13.0	7.1	0.0	46.5
	Dir:	282.4	77.2	0.0	359.9

Table A1: (continued)

		Mean	Std Deviation	Range	
NTAS-2	North:	-0.6	10.7	-40.3	38.3
(58 m)	East:	-1.5	10.0	-39.1	46.2
Workhorse	Spd:	13.0	7.1	0.2	46.2
	Dir:	268.8	76.5	0.1	360.0
NTAS-2	North:	-0.8	10.7	-41.7	35.7
(62 m)	East:	-1.8	10.1	-37.5	45.6
Workhorse	Spd:	13.0	7.2	0.0	46.9
	Dir:	262.7	75.5	0.0	359.9
NTAS-2	North:	-1.1	10.6	-40.8	36.3
(66 m)	East:	-2.1	10.0	-34.9	42.8
Workhorse	Spd:	13.0	7.2	0.2	49.3
	Dir:	256.9	74.6	0.0	360.0
NTAS-2	North:	-1.2	10.6	-37.8	39.0
(70 m)	East:	-2.3	10.0	-34.2	38.5
Workhorse	Spd:	13.0	7.0	0.1	44.9
	Dir:	252.2	74.0	0.0	359.9
NTAS-2	North:	-1.3	10.3	-37.0	33.1
(74 m)	East:	-2.5	9.9	-33.9	40.6
Workhorse	Spd:	12.9	6.9	0.3	42.0
	Dir:	250.6	73.2	0.0	360.0
NTAS-2	North:	-1.4	10.0	-35.7	33.3
(78 m)	East:	-2.7	9.8	-35.7	38.2
Workhorse	Spd:	12.6	6.8	0.1	40.5
	Dir:	248.5	72.5	0.1	360.0
NTAS-2	North:	-1.5	9.9	-35.9	33.4
(82 m)	East:	-2.8	9.7	-36.4	36.7
Workhorse	Spd:	12.6	6.7	0.1	41.8
	Dir:	245.4	71.8	0.0	359.7
NTAS-2	North:	-1.6	9.9	-37.2	30.0
(86 m)	East:	-2.9	9.8	-37.3	33.0
Workhorse	Spd:	12.6	6.6	0.2	38.8
	Dir:	243.8	71.5	0.0	359.8
NTAS-2	North:	-1.6	9.8	-35.8	34.6
(90 m)	East:	-3.1	9.9	-38.8	35.3
Workhorse	Spd:	12.7	6.7	0.2	40.8
	Dir:	242.6	70.8	0.0	359.9
NTAS-3	North:	-0.9	1.3	-3.9	3.9
(6 m)	East:	-3.0	1.0	-4.0	2.3
Aquadopp	Spd:	3.5	0.4	0.2	4.1
	Dir:	252.3	27.4	0.1	359.6
NTAS-3	North:	2.8	10.8	-49.1	53.6
(22 m)	East:	-4.9	11.2	-55.6	45.1
Workhorse	Spd:	14.6	7.8	0.2	71.2
	Dir:	298.4	65.4	0.0	360.0

Table A1: (continued)

		Mean	Std Deviation	Range	
NTAS-3	North:	2.2	10.4	-37.6	38.5
(26 m)	East:	-4.3	10.9	-47.0	40.0
Workhorse	Spd:	14.0	7.4	0.0	47.1
	Dir:	295.0	67.0	0.0	359.9
NTAS-3	North:	1.5	10.2	-37.8	38.5
(30 m)	East:	-4.0	10.7	-45.5	33.5
Workhorse	Spd:	13.6	7.2	0.1	53.2
	Dir:	287.7	68.5	0.0	360.0
NTAS-3	North:	1.5	10.2	-37.7	38.4
(30 m)	East:	-4.0	10.6	-45.4	35.8
Workhorse	Spd:	13.5	7.1	0.1	53.1
	Dir:	162.3	68.5	0.0	360.0
NTAS-3	North:	0.7	10.0	-38.9	37.8
(34 m)	East:	-3.8	10.4	-43.1	42.2
Workhorse	Spd:	13.2	7.0	0.1	52.4
	Dir:	277.0	69.6	0.1	360.0
NTAS-3	North:	-0.1	9.8	-41.2	37.9
(38 m)	East:	-3.8	10.1	-44.4	32.9
Workhorse	Spd:	12.9	6.8	0.1	45.8
	Dir:	265.9	69.6	0.1	360.0
NTAS-3	North:	-0.8	9.7	-38.9	37.7
(42 m)	East:	-3.8	9.9	-42.0	32.9
Workhorse	Spd:	12.7	6.6	0.1	45.3
	Dir:	257.2	69.4	0.0	360.0
NTAS-3	North:	-1.4	9.7	-44.8	37.6
(46 m)	East:	-3.9	9.7	-41.2	30.8
Workhorse	Spd:	12.7	6.6	0.1	44.8
	Dir:	249.1	68.7	0.0	359.9
NTAS-3	North:	-2.0	9.7	-47.7	41.8
(50 m)	East:	-4.1	9.6	-41.7	27.8
Workhorse	Spd:	12.7	6.6	0.3	47.9
	Dir:	242.6	67.8	0.2	359.9
NTAS-3	North:	-2.4	9.7	-44.1	42.4
(54 m)	East:	-4.2	9.5	-42.2	26.0
Workhorse	Spd:	12.8	6.6	0.1	46.3
	Dir:	238.0	67.1	0.1	359.9
NTAS-3	North:	-2.8	9.7	-36.0	45.2
(58 m)	East:	-4.3	9.4	-40.4	29.4
Workhorse	Spd:	12.9	6.6	0.0	47.8
	Dir:	235.1	66.4	0.0	359.9
NTAS-3	North:	-3.1	9.7	-37.0	42.9
(62 m)	East:	-4.4	9.5	-38.4	30.6
Workhorse	Spd:	13.0	6.7	0.0	45.4
	Dir:	234.1	65.7	0.0	359.9

Table A1: (continued)

		Mean	Std Deviation	Range	
NTAS-3	North:	-3.2	9.7	-41.0	35.9
(66 m)	East:	-4.6	9.7	-39.4	26.9
Workhorse	Spd:	13.2	6.6	0.1	43.5
	Dir:	233.7	65.1	0.2	360.0
NTAS-3	North:	-3.3	9.6	-37.5	32.0
(70 m)	East:	-4.6	9.7	-37.6	26.1
Workhorse	Spd:	13.2	6.6	0.1	42.0
	Dir:	233.7	65.5	0.2	359.8
NTAS-3	North:	-3.3	9.6	-36.2	32.3
(74 m)	East:	-4.5	9.7	-36.7	25.6
Workhorse	Spd:	13.2	6.6	0.1	38.3
	Dir:	233.6	65.9	0.1	359.9
NTAS-3	North:	-3.3	9.5	-36.1	33.8
(78 m)	East:	-4.4	9.7	-35.8	23.9
Workhorse	Spd:	13.1	6.6	0.1	37.6
	Dir:	232.4	66.0	0.0	359.9
NTAS-3	North:	-3.3	9.5	-33.4	37.2
(82 m)	East:	-4.3	9.7	-36.5	25.9
Workhorse	Spd:	13.0	6.7	0.2	38.4
	Dir:	231.9	66.5	0.0	359.9
NTAS-3	North:	-3.2	9.5	-33.1	34.6
(86 m)	East:	-4.2	9.7	-40.6	25.7
Workhorse	Spd:	13.0	6.7	0.0	42.3
	Dir:	230.6	67.1	0.0	360.0
NTAS-3	North:	-3.1	9.5	-35.1	34.1
(90 m)	East:	-4.2	9.8	-40.3	25.4
Workhorse	Spd:	13.0	6.7	0.1	42.9
	Dir:	230.9	67.1	0.2	360.0
NTAS-4	North:	0.1	11.6	-44.1	48.5
(6 m)	East:	-6.1	11.5	-50.0	43.8
Aquadopp	Spd:	14.8	9.1	0.0	55.8
	Dir:	269.6	65.2	0.0	359.8
NTAS-4	North:	1.1	11.8	-36.4	51.1
(18 m)	East:	-1.6	11.8	-44.0	45.5
Workhorse	Spd:	14.6	8.3	0.1	51.4
	Dir:	303.2	76.9	0.0	359.9
NTAS-4	North:	0.6	11.5	-49.4	49.7
(22 m)	East:	-1.1	11.7	-44.8	42.2
Workhorse	Spd:	14.3	8.2	0.1	55.6
	Dir:	295.5	78.3	0.1	360.0
NTAS-4	North:	0.2	11.1	-41.4	46.6
(26 m)	East:	-0.8	11.8	-41.9	45.6
Workhorse	Spd:	14.0	8.0	0.1	54.0
	Dir:	273.1	79.5	0.0	360.0

Table A1: (continued)

		Mean	Std Deviation	Range	
NTAS-4	North:	-0.4	10.6	-35.2	38.5
(30 m)	East:	-0.7	11.8	-51.9	40.7
Workhorse	Spd:	13.8	7.9	0.1	53.0
	Dir:	235.7	79.2	0.1	360.0
NTAS-4	North:	-0.9	10.4	-38.5	48.6
(34 m)	East:	-0.7	11.7	-48.1	40.8
Workhorse	Spd:	13.6	7.8	0.1	51.9
	Dir:	211.8	78.5	0.0	359.8
NTAS-4	North:	-1.3	10.1	-38.5	36.5
(38 m)	East:	-0.9	11.6	-45.6	45.7
Workhorse	Spd:	13.4	7.7	0.1	49.1
	Dir:	206.4	77.9	0.0	359.9
NTAS-4	North:	-1.3	9.9	-39.4	39.6
(42 m)	East:	-1.1	11.5	-46.2	36.9
Workhorse	Spd:	13.2	7.6	0.1	57.1
	Dir:	207.9	77.7	0.0	360.0
NTAS-4	North:	-1.3	9.6	-39.2	35.4
(46 m)	East:	-1.3	11.4	-47.8	39.0
Workhorse	Spd:	13.0	7.5	0.1	51.9
	Dir:	211.8	77.6	0.0	360.0
NTAS-4	North:	-1.3	9.5	-40.2	35.4
(50 m)	East:	-1.4	11.3	-44.5	38.9
Workhorse	Spd:	12.9	7.5	0.1	46.1
	Dir:	209.9	77.3	0.0	359.8
NTAS-4	North:	-1.5	9.6	-35.2	41.2
(54 m)	East:	-1.6	11.4	-45.2	42.2
Workhorse	Spd:	13.0	7.5	0.2	46.3
	Dir:	208.8	76.5	0.0	360.0
NTAS-4	North:	-1.5	9.6	-34.4	39.3
(58 m)	East:	-1.8	11.3	-46.9	36.4
Workhorse	Spd:	13.0	7.5	0.1	51.3
	Dir:	208.1	76.3	0.0	359.9
NTAS-4	North:	-1.4	9.4	-36.6	37.9
(62 m)	East:	-2.0	10.9	-43.0	38.3
Workhorse	Spd:	12.6	7.4	0.1	47.6
	Dir:	213.5	75.8	0.2	360.0
NTAS-4	North:	-1.4	9.2	-39.0	36.8
(66 m)	East:	-2.2	10.5	-43.1	36.4
Workhorse	Spd:	12.3	7.1	0.0	48.2
	Dir:	223.7	75.2	0.0	359.9
NTAS-4	North:	-1.4	8.9	-35.7	30.4
(70 m)	East:	-2.4	10.1	-45.3	33.5
Workhorse	Spd:	12.0	6.8	0.1	45.5
	Dir:	229.9	74.5	0.0	360.0

continued...

Table A1: (continued)

		Mean	Std Deviation	Range	
NTAS-4	North:	-1.3	9.1	-33.4	29.7
(74 m)	East:	-2.5	10.0	-47.2	33.9
Workhorse	Spd:	12.1	6.7	0.1	49.0
	Dir:	235.8	74.2	0.0	359.9
NTAS-4	North:	-0.9	8.2	-30.5	28.4
(78 m)	East:	-2.2	8.8	-39.7	34.6
Workhorse	Spd:	10.8	5.9	0.0	40.3
	Dir:	241.6	74.3	0.0	360.0
NTAS-5	North:	1.2	12.0	-53.4	42.5
(6 m)	East:	-10.2	11.5	-43.5	27.9
Aquadopp	Spd:	17.6	8.5	0.1	62.3
	Dir:	280.7	56.4	0.1	360.0
NTAS-5	North:	2.3	12.3	-42.0	48.5
(14 m)	East:	-7.1	11.8	-40.2	34.5
Workhorse	Spd:	16.8	7.9	0.1	50.9
	Dir:	291.2	63.4	0.0	360.0
NTAS-5	North:	2.0	12.2	-44.6	47.3
(18 m)	East:	-6.2	11.7	-42.3	38.5
Workhorse	Spd:	16.3	7.9	0.3	52.4
	Dir:	290.8	65.3	0.0	359.9
NTAS-5	North:	1.6	12.1	-44.2	43.2
(22 m)	East:	-5.8	11.7	-43.8	42.2
Workhorse	Spd:	16.0	7.8	0.3	55.2
	Dir:	288.5	66.0	0.0	359.9
NTAS-5	North:	1.2	11.9	-43.1	41.3
(26 m)	East:	-5.5	11.5	-39.7	48.0
Workhorse	Spd:	15.7	7.7	0.2	50.0
	Dir:	285.8	66.7	0.0	360.0
NTAS-5	North:	0.8	11.7	-42.5	41.2
(30 m)	East:	-5.3	11.3	-40.3	34.2
Workhorse	Spd:	15.4	7.5	0.1	47.2
	Dir:	282.4	67.0	0.1	359.8
NTAS-5	North:	0.4	11.4	-46.1	53.8
(34 m)	East:	-5.2	11.1	-39.4	37.3
Workhorse	Spd:	15.1	7.4	0.1	54.5
	Dir:	279.6	67.2	0.0	360.0
NTAS-5	North:	0.1	11.2	-45.2	52.4
(38 m)	East:	-5.3	10.9	-40.1	36.9
Workhorse	Spd:	14.8	7.3	0.1	57.0
	Dir:	275.0	67.2	0.0	360.0
NTAS-5	North:	-0.4	10.9	-46.3	42.8
(42 m)	East:	-5.4	10.6	-39.7	39.6
Workhorse	Spd:	14.4	7.4	0.2	49.5
	Dir:	270.1	66.6	0.0	360.0

Table A1: (continued)

		Mean	Std Deviation	Range	
NTAS-5	North:	-0.7	10.8	-46.6	46.5
(46 m)	East:	-5.7	10.4	-46.4	34.0
Workhorse	Spd:	14.2	7.4	0.1	51.4
	Dir:	266.4	65.8	0.1	360.0
NTAS-5	North:	-0.9	10.7	-48.5	39.1
(50 m)	East:	-5.9	10.3	-35.0	33.0
Workhorse	Spd:	14.2	7.4	0.1	49.6
	Dir:	263.3	65.3	0.0	359.7
NTAS-5	North:	-1.1	10.7	-48.5	52.4
(54 m)	East:	-6.1	10.3	-40.5	39.5
Workhorse	Spd:	14.2	7.5	0.1	54.8
	Dir:	261.0	64.7	0.1	360.0
NTAS-5	North:	-1.3	10.7	-48.2	44.0
(58 m)	East:	-6.3	10.4	-52.6	35.4
Workhorse	Spd:	14.3	7.7	0.1	57.2
	Dir:	260.3	64.3	0.0	360.0
NTAS-5	North:	-1.4	10.8	-45.9	44.8
(62 m)	East:	-6.4	10.4	-54.0	41.2
Workhorse	Spd:	14.3	7.9	0.2	54.8
	Dir:	259.8	64.2	0.3	359.8
NTAS-5	North:	-1.5	10.9	-43.3	38.4
(66 m)	East:	-6.4	10.4	-55.4	33.9
Workhorse	Spd:	14.4	7.9	0.0	58.3
	Dir:	258.5	64.3	0.0	359.9
NTAS-5	North:	-1.7	10.8	-42.4	43.1
(70 m)	East:	-6.5	10.3	-48.7	30.4
Workhorse	Spd:	14.3	7.9	0.1	54.9
	Dir:	257.3	64.0	0.2	360.0
NTAS-5	North:	-1.8	10.7	-40.9	35.0
(74 m)	East:	-6.5	10.3	-44.7	27.7
Workhorse	Spd:	14.3	7.9	0.3	48.6
	Dir:	255.3	64.0	0.0	360.0
NTAS-5	North:	-1.6	9.7	-38.1	32.9
(78 m)	East:	-5.9	9.4	-41.5	23.8
Workhorse	Spd:	13.0	7.1	0.1	43.7
	Dir:	254.0	64.2	0.0	360.0

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16. Abstract (Limit: 200 words)

This report presents velocity data from the Northwest Tropical Atlantic Station (NTAS) deployments 1 through 5, from March 30, 2001, to February 28, 2006. The NTAS project has maintained a series of moorings near 14°50′N, 51°00′W in the northwest tropical Atlantic for air-sea flux measurement. The moorings include a surface buoy outfitted with Air- Sea Interaction Meteorology (ASIMET) systems for determination of bulk air-sea fluxes and oceanographic sensors along the upper 120 m of the mooring line. This report describes and presents the velocity data recovered from current meters and Acoustic Doppler Current Profilers (ADCPs) during the first five years of the NTAS project.

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