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DREA oceanographic and atmospheric environmental data for Boundary 2001

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Abstract

A range of environmental data was collected by DREA in support of the Boundary 2001 experiment which took place from May 14 to June 1, 2001 at Strataform off New Jersey and on the Scotian Shelf. Some satellite data was also obtained in support of the Geoclutter experiment which took place from April 26 to May 7, 2001 at Strataform. The environmental data falls into three main categories: satellite imagery, meteorological data and oceanographic data. An overview of available data and description of instrumentation is presented.

Synoptic data

Visible and infrared imagery from NOAA's GOES8 (Geostationary Operational Environmental Satellite) was obtained from Environment Canada to provide a synoptic overview of weather conditions along the north-east coast of North America. Imagery was recorded every half hour for the period 1 to 31 May, 2001 covering both the Geoclutter and Boundary 2001 experiments. GOES imagery can also be obtained directly from NOAA's Geosynchronous Satellite Server at http://www.goes.noaa.gov/ where imagery is archived for up to three weeks.

The synoptic weather picture provided by the GOES8 imagery was augmented with one-day weather forecasts and one-day forecasts of surface waves from Environment Canada. Wave forecasts are produced by the WAVEWATCH III model developed at NOAA. The weather and wave forecasts are a convenient record as they are available in digital form while being reasonably accurate since they are one-day forecasts. More accurate hand-annotated weather and wave synopses could have been obtained but would have had to be digitized, an effort that was not considered necessary.

The final element of the synoptic environmental picture is the sea surface temperature (SST) imagery from the Advanced Very High Resolution Radiometer (AVHRR) sensor aboard the NOAA Polar Operational Environmental Satellites (POES). The SST data was obtained from the Johns Hopkins University Ocean Remote Sensing website at http://srbdata.jhuapl.edu/d0043/avhrr/gs. SST imagery was saved as single pass images and 3-day composites. Examples of synoptic data are shown in Fig. 1 for May 20, 2001.

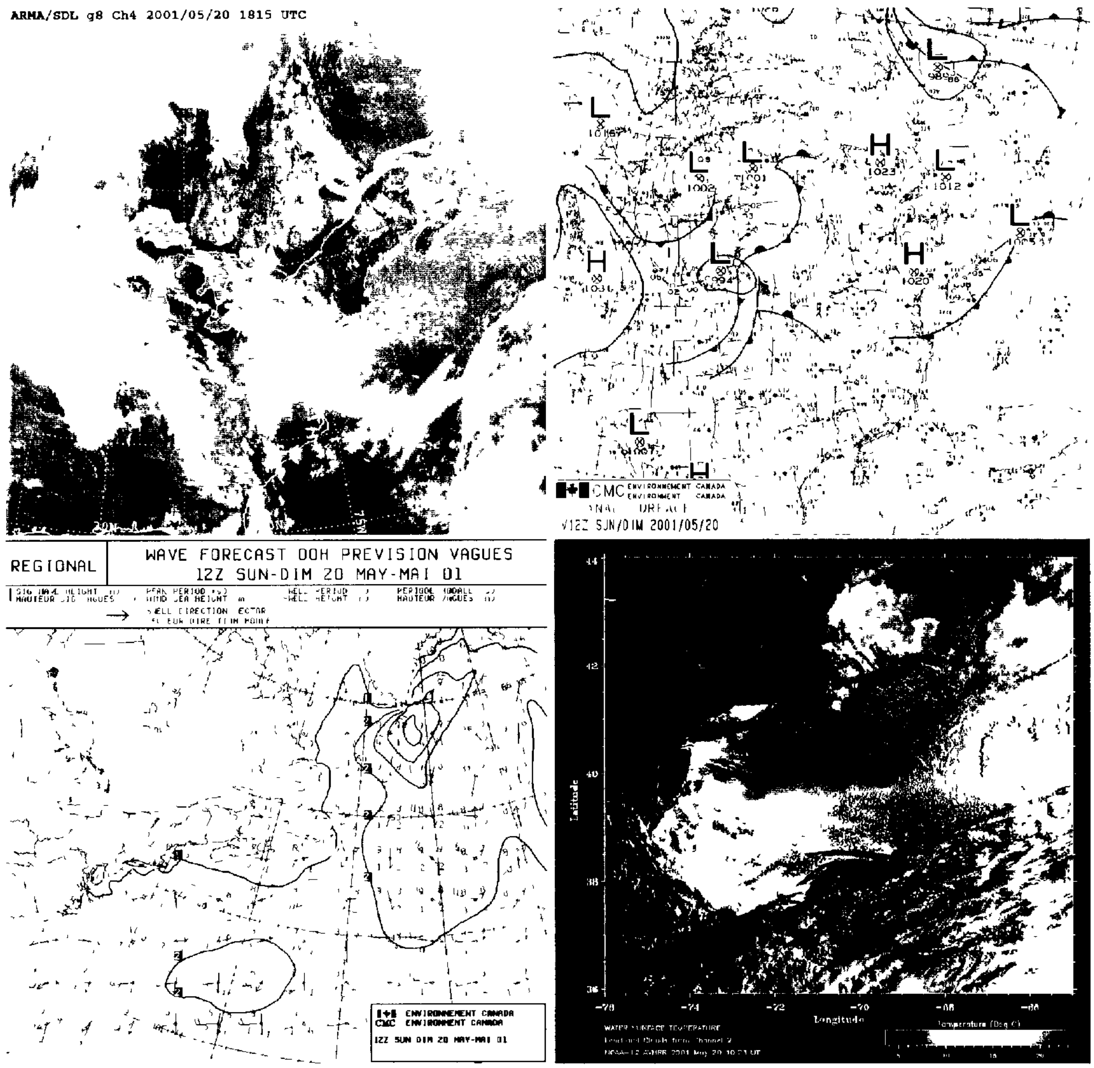

Figure 1 Synoptic data for May 20, 2001. Clockwise from top-left: GOES8 IR image, surface meteorological forecast, sea surface temperature and WAM surface wave forecast.

SAR satellite imagery

In addition to the wide area SST and GOES satellite imagery, imagery was obtained from Synthetic Aperture Radar (SAR) instruments aboard the Canadian Radarsat-1 and European ERS-2 satellites. The ability of space-based SAR to detect ships and estimate surface wind over the ocean is well documented (Refs.1-4) Furthermore, the brightness of a ship radar signature and analysis of the wake signature, when visible, can provide an estimate of the ship size, speed and direction. This information combined with estimates of surface winds can be used as inputs for ambient noise models. A summary of ship detection and wind estimate capabilities of space-based SAR can be found in Ref. 5.

Radarsat-1 and ERS-2 data, summarized in Table 1, was obtained by DREA and processed to backscatter image and ship/wind data products by the Canada Centre for Remote Sensing, Ottawa, Ontario. Data products were derived from Radarsat imagery using the Ocean Monitoring Workstation described in Ref. 2. An example of backscatter image and data products is shown in Fig. 2 for the Radarsat-1 image of May 3, 2001. Note that the solution for wind direction has a 180^0 ambiguity which must be resolved with additional information about the local wind direction.

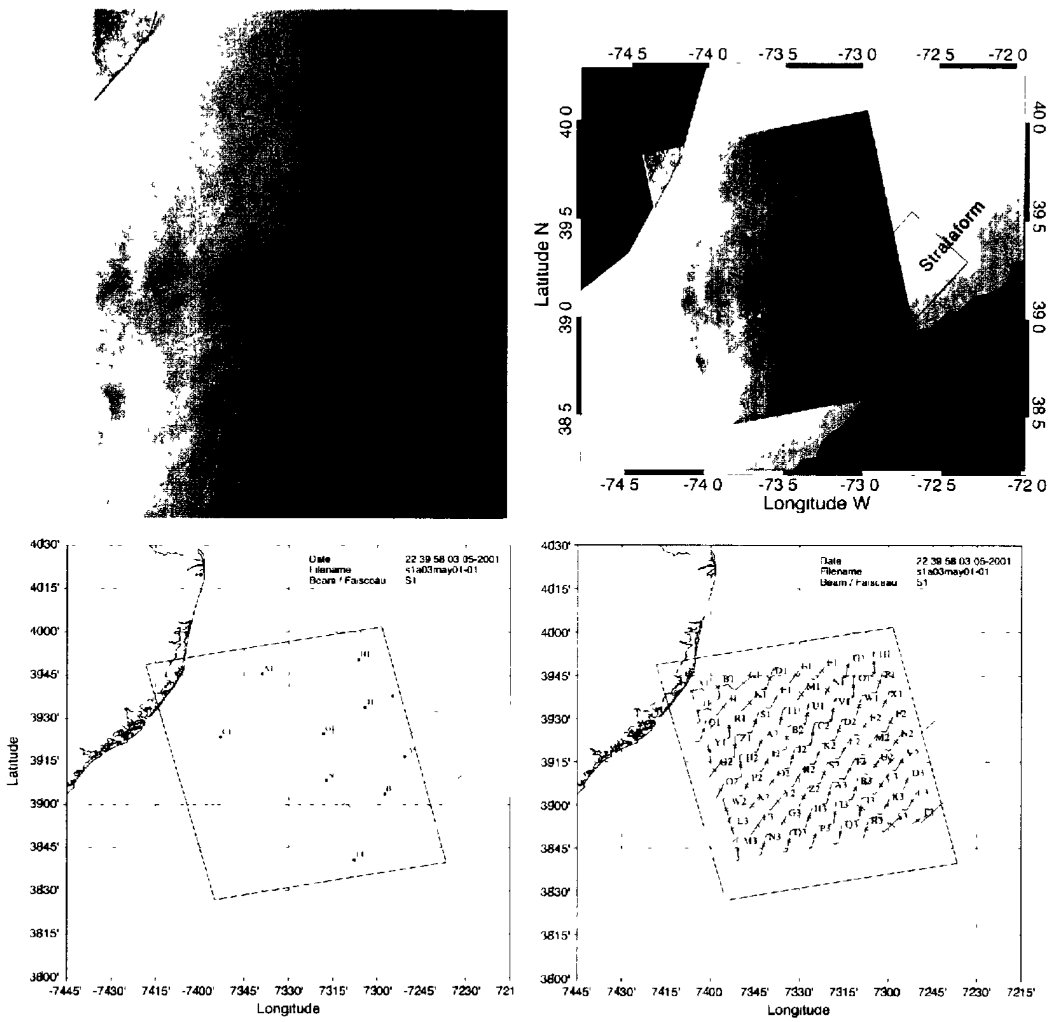

Figure 2 Radarsat-1 imagery and data products for 3 May, 2001 over Strataform area. Clockwise from top-left: Low-resolution backscatter image, backscatter image superimposed on bathymetry and coastline (New Jersey), wind detection product and ship detection product.

Table 1: SAR satellite imagery

date	time (UTC)	center lat (deg)	center lon (deg)	orbit	swath (km)	res. (m)	plat-form	beam mode
01/05/01	15:34 00	39.166	-72.633	Asc	100	25	ERS2	n/a
01/05/03	22:40 18	39.286	-72.735	Asc.	100	30	RSAT1	S2
01/05/10	22:36 10	39.434	-72.485	Asc	100	30	Rsat1	S1
01/05/11	03:07 00	39.417	-73.000	Dsc.	100	25	ERS2	n/a
01/05/17	22:31 55	39.273	-72.504	Asc	170	36	Rsat1	EXTL1
01/05/18	10:45.47	39.166	-72.705	Dsc.	100	30	Rsat1	S7
01/05/21	10:58 18	39.178	-72.918	Dsc.	100	30	Rsat1	S3
01/05/26	10:10 46	44.053	-61.301	Dsc.	100	30	Rsat1	S5
01/05/29	21 42 54	44.130	-61.383	Asc.	170	36	Rsat1	EXTL1
01/05/31	14·50 00	43.600	-60.600	Asc	100	25	ERS2	n/a

One reason the SAR data was obtained was to monitor the presence of internal waves during the trial. Internal waves have a signature in SAR imagery because they induce a slight modulation of the surface wave spectrum. The linear features in the south-west part of the backscatter image of Fig. 2 resembles an internal wave but, due its long wavelength and timing within the tidal cycle, it is believed to be due to an atmospheric internal wave. None of the SAR imagery exhibited any features that could be attributed to ocean internal waves. Although the Strataform area is known for strong internal wave activity in the summer months (Ref. 6) it was hoped that the relatively poor stratification of the water column typical of the winter and spring would minimize internal wave activity. This expectation is supported by the SAR satellite imagery.

In situ environmental data

A range of *in situ* environmental measurements were made with instrumentation deployed from Quest. Equipment included an autonomous ocean profiling instrument known as Seahorse, a meteorological buoy for surface met data, two 300 kHz acoustic Doppler current profilers (ADCP), ambient noise measured with a variety of sonobuoys and the underwater acoustic target (UAT) described in Ref. 7, a ship-board 120 kHz echo-sounder and the Quest's own meteorological sensors. Figure 3 illustrates the availability of DREA's environmental data. A detailed list of deployment times and locations is given in Table 2. A summary of data from the Seahorse, met buoy, ADCPs is presented in this section.

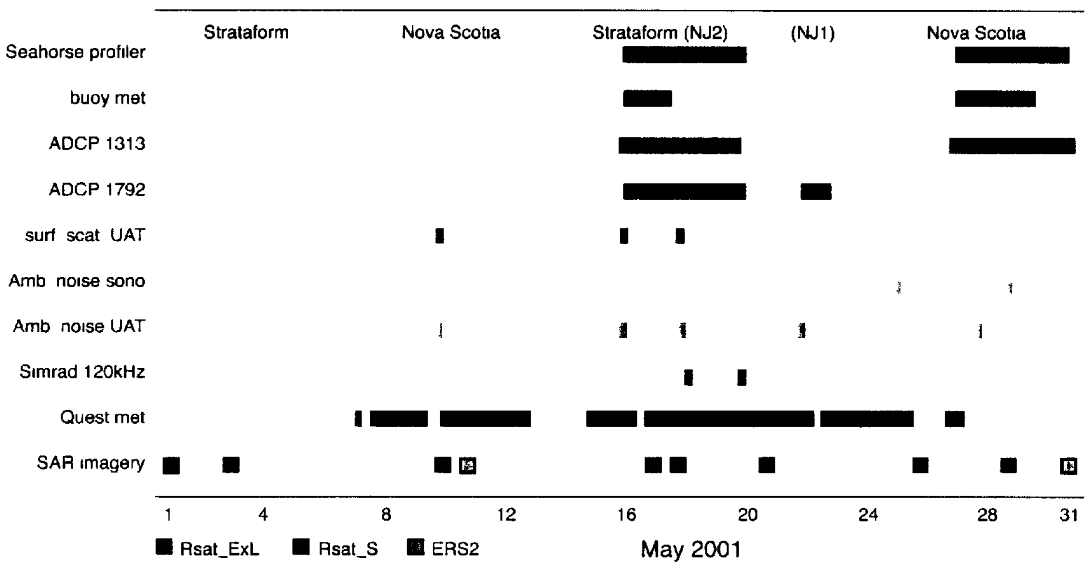

Figure 3 Q259 environmental dataset summary chart

Table 2: Times and locations of Q259 environmental measurements

instrument	stn.	location	depth (m)	deployed (utc)	recovered (utc)	comments
Seahorse profiler	NJ2	39 03 43N, 73 05 41W	80	May 16, 17 39	May 20, 14 15	-
met station	NJ2	39 03 43N, 73 05 41W	80	May 16, 17 39	May 18, 07:48	recording failed
ADCP 1313	NJ2	39 04 58N, 73 05 92W	70	May 16, 12·37	May 20, 12:45	-
ADCP 1792	NJ2	39 04.95N, 73 07 33W	74	May 16, 13 42	May 20, 17:00	-
ADCP 1792	NJ1	39 15 76N, 72 53 82W	77	May 22, 14·00	May 23, 14:32	-
ADCP 1313	NS1	44 03 66N, 61 11 36W	71	May 27, 11 49	May 31, 14:00	-
Seahorse profiler	NS1	39 03.43N, 73 05 41W	66	May 27, 18:27	May 31, 12.14	-
met station	NS1	39 03 43N, 73 05 41W	66	May 27, 18:27	May 30, 11 12	recording failed
surf scat., UAT	NS1	44 03 66N, 61 11 36W	73	May 10,12:42	MAY 10,12·43	cardiod up
surf scat., UAT	NJ2	39 03 38N, 73 07 01W	70	May 16, 16:23	May 16, 16 24	cardiod up
surf. scat., UAT	NJ2	39 03 38N, 73 07 01W	70	May 18, 14:02	May 18, 14·38	cardiod up
Amb. noise, sono	NS1	43 23 0 N, 64 42.70W	~70	May 25, 22:19	May 25, 22·25	quiet state
Amb. noise, sono	NS1	44 05 30N, 61 08.80W	~70	May 29, 09:49	May 29, 10·50	Rsat overpass
Simrad 120kHz	NJ2	around NJ2	~80	May 17, 20:40	May 17, 22·44	slight int. waves
Simrad 120kHz	-	NJ2 to NJ1	~80	May 20, 17:45	May 20, 19:45	-
Quest met	-	continuous	-	May 07, 22:00	May 31, 11·05	-

Acoustic Doppler current profilers

Two RD Instruments acoustic Doppler current profilers (ADCPs) were deployed during Boundary 2001. The instruments are both Model WHS300 "Workhorse Sentinel" which operate at 300 kHz. The ADCPs are autonomous instruments that measure acoustic backscatter, ocean current speed and current direction as a function of depth in the water column. Both ADCPs were fitted with additional firmware from RD Instruments to enable surface wave spectra to be measured. The ADCPs were mounted in a buoyant body called a "Streamlined Underwater Buoyancy System" (SUBS) tethered approximately 2 m from the sea bed. Once deployed, the instruments are free to rotate in response to currents. On-board compass and tilt meters measure the orientation of the ADCP enabling the vertical profile of current and its absolute direction to be resolved. The ADCPs are rated for use at depths up to 175 m although the pressure housings are rated for 500 m. The ADCPs can be left to make measurements at preprogrammed intervals for periods of up to one month. The data are recorded in on-board solid-state memory modules. Data are retrieved upon recovery. Profiles measured during Boundary 2001 were recorded every minute with a vertical resolution of 1-m.

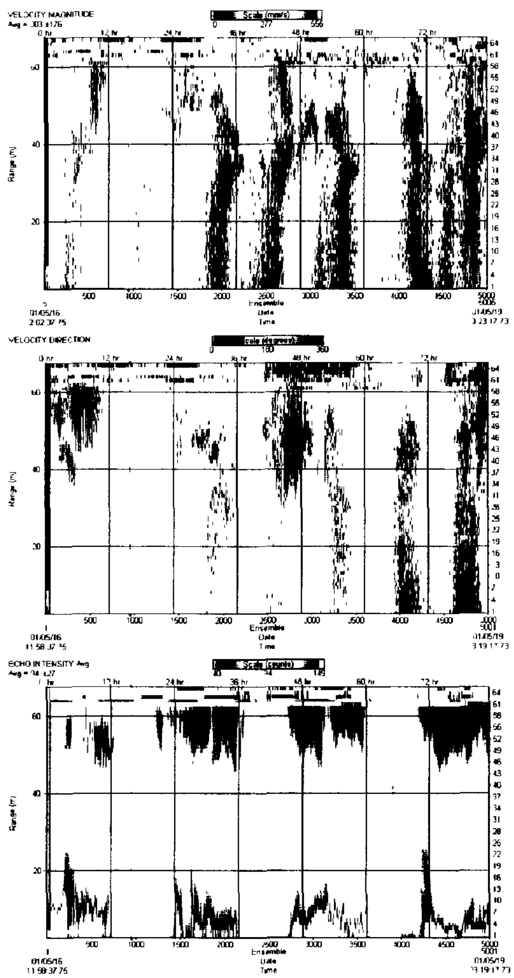

Figure 4. *ADCP data recorded at Strataform site NJ2 (39°03.4' N, 73°07.2' W). From top to bottom plots are: current magnitude, current direction and backscatter intensity.*

Figure 4 is an example of data from one of the ADCPs (good luck serial no. 1313) deployed at Strataform site NJ2 from 16 to 20 May, 2001. The upper two plots are current magnitude and direction which show circular tidal flows typical of the continental shelf. Baroclinic behavior where tidal circulation above and below the thermocline are out of phase is also typical of continental shelf waters. The bottom plot shows relative backscatter intensity at 300 kHz. A pronounced diurnal cycle can be seen where the backscatter increases every evening at dusk (times 12h, 36h and 60h on the backscatter plot). This is due to the nightly ascent of marine micro-organisms and fish to shallower depths.

Meteorological buoy

Sea surface meteorological measurements were made with a met station located on the Seahorse buoy. The system was manufactured by MetOcean Inc. (www.metocean.com), Dartmouth, NS. Measured parameters are wind speed and direction, barometric pressure, air temperature, and water temperature. Data are stored as one-minute averages in Flash-Card memory and are retrieved upon recovery of the buoy. For Boundary 2001, surface meteorological measurements were made to support surface acoustical scattering experiments and to monitor sea surface conditions to aid interpretation of SAR satellite imagery. An example of surface met data from site NJ2 on Strataform is shown in Fig. 4.

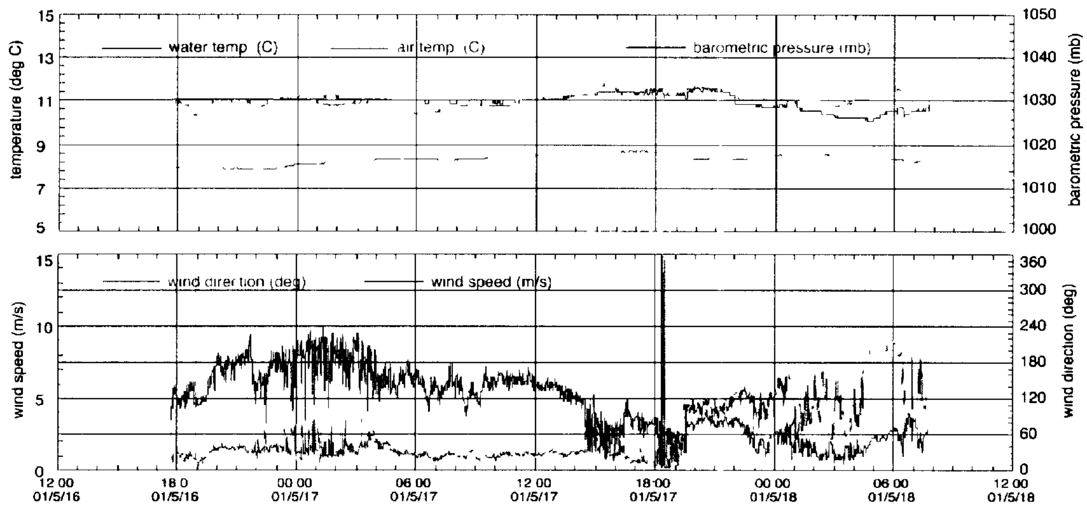

Figure 4. Surface met data from Strataform site NJ2 (39°03.4' N, 73°07.2' W).

Seahorse moored ocean profiler

The Seahorse is an autonomous profiling system for continuous conductivity, temperature and depth (CTD) measurements of the water column. It is manufactured by Brooke Ocean Technology Ltd. (www brooke-ocean com), Dartmouth, NS. The Seahorse sensor package isa Sea-Bird SBE-19 CTD. The Seahorse rides along a cable between a surface float and a mooring anchor and is designed for use to depths of 200 m. The system takes advantage of the wave-induced motion of its surface float to ratchet the profiler down the cable. When the Seahorse reaches a stop at the bottom of the cable it waits for a programmed period of time then releases the ratchet mechanism and floats to the surface using the cable as a guide. The CTD profile is acquired during the ascent. A schematic of the deployed configuration is shown in Fig. 5. Data is stored on board the Seahorse for later downloading to a PC when the instrument is recovered. Data obtained with the Seahorse at the Strataform NJ2 site is shown in Fig. 6. The salinity is derived from the measured conductivity using analysis software provided by Sea-Bird. The salinity, pressure and water temperature are used to calculate the density and sound speed profiles.

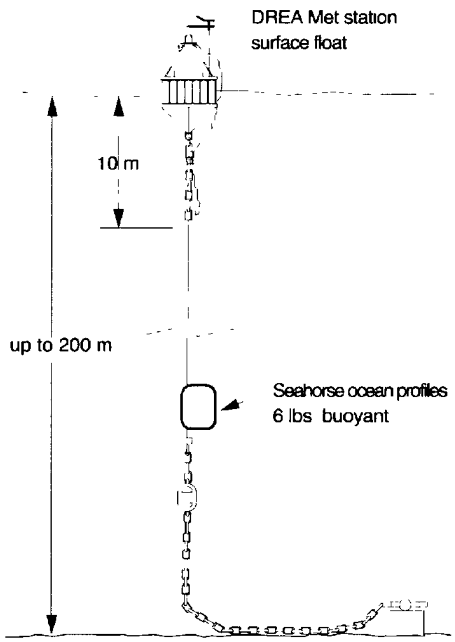

Figure 5 Seahorse mooring schematic showing met station on surface float.

Several observations can be made about the data displayed in Fig. 6. First, after May 17, the seahorse failed to go all the way to the bottom of its mooring before beginning its ascent and profile measurement. This was due to unusually calm weather conditions that resulted in a sea state of zero and flat calm water. Since the Seahorse relies on motion of its surface float to make the instrument go down, it was unable to descend during the calm period which lasted several days. Deeper profiles could have been maintained if the Seahorse had been programmed for longer intervals between profiles thus giving it more time to travel downward. For the NJ2 deployment the Seahorse was programmed to do a profile every 20 minutes. When the Seahorse was deployed a second time on the Scotian Shelf, it was programmed to do a profile every 30 minutes. On the Scotian Shelf deployment the Seahorse made 283 complete profiles.

The calm period beginning on May 17 may be associated with a saline water mass from the edge of Gulf Stream. SST imagery on May 17 and 20 indicates that the surface water temperature around the NJ2 site had a complicated structure with variations of up to 4°C. This suggests the influence of the Gulf Stream but the surface temperature measured by the Seahorse and met buoy were stable at around 10 - 11°C. SST imagery between May 17 and 20 was obscured by cloud. The Seahorse results and XBT and CTD measurements of other ships involved in Boundary 2001 indicate a great deal of variability in the oceanography at Strataform (Refs. 8, 9).

The salinity plot in Fig. 6 exhibits some spurious high-salinity areas late on May 17. These result in what appear to be instabilities visible on the density plot. It is believed that the spurious salinity readings are an artifact related to the vertical distance between the conductivity and temperature sensors on the Sea-Bird SBE-19 CTD (Ref. 10). Since the sound speed depends almost entirely on temperature, the artifacts in the salinity measurements do not appear in the sound speed plot.

A series of oscillations visible in all plots of Fig. 6 during the first half of May 16 is a low amplitude internal wave aliased to a low frequency by the 20-minute sampling interval of the Seahorse. The sound speed profile plot appears to be nearly identical to the temperature plot as is expected since the sound speed only depends on salinity to third order.

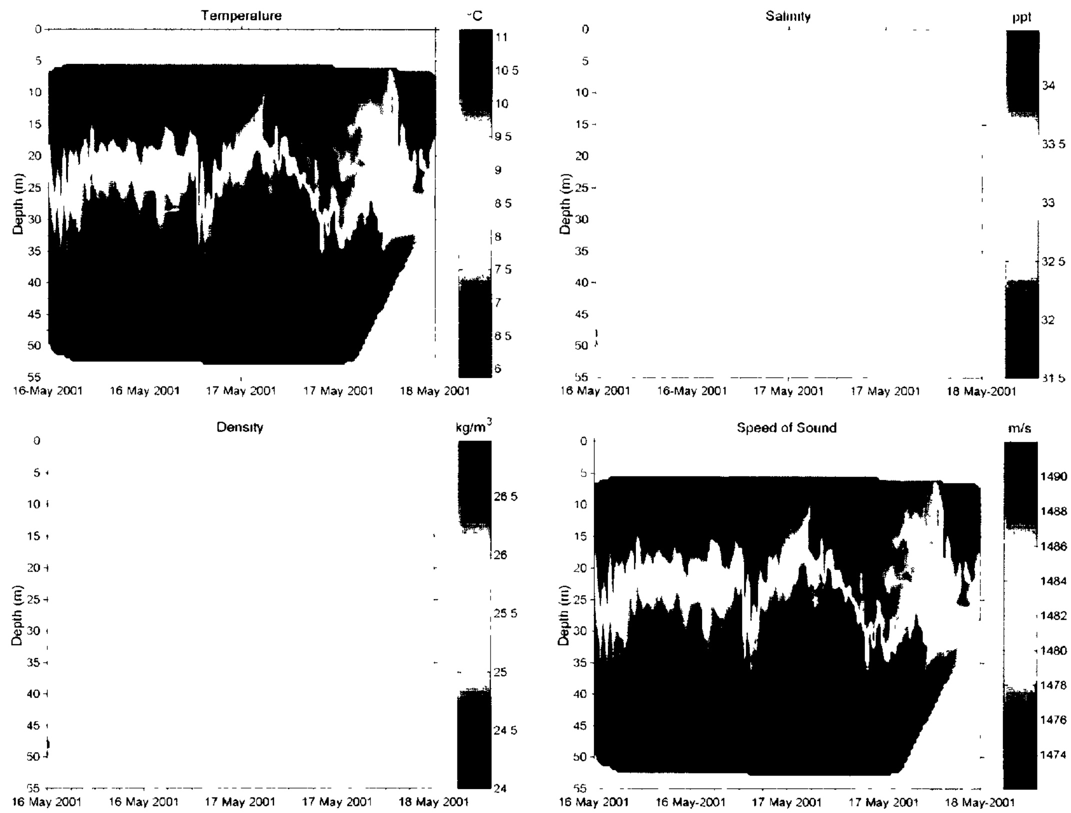

Figure 6. Seahorse data obtained at the Strataform site NJ2 (39°03.4' N, 73°07.2' W).

Summary

An overview of the environmental data collected by DREA during the Boundary 2001 experiment was presented. Synoptic data consisting of GOES satellite imagery, AVHRR sea surface temperature imagery, weather charts and WAM wave prediction charts are available for the entire month of May and cover part of the GeoClutter trial. Rararsat1 and ERS2 synthetic aperture radar imagery was obtained and processed to backscatter image, ship detection and surface wind products. An overview of the SAR imagery indicates that there little internal wave activity, an observation that is consistent with ship-board echo-sounder data. A series of successful deployments of oceanographic instruments was achieved during the trial including a surface met station, the Seahorse autonomous ocean profiler and ADCPs. The oceanographic data is being used to characterize the acoustic propagation environment prevailing during the experiment as part of on-going analysis.

Acknowledgements

The authors would like to thank Mark O'Connor, DREA for his efforts in programming, deploying and processing data from the met buoy, Seahorse and ADCPs. The contribution of designing, building and deploying many of the moorings by Roger Arsenault, DREA is greatly appreciated. Patric King of Environment Canada, Downview, ON assembled the GOES8 imagery and Serge Desjardins, Environment Canada, Dartmouth, NS provided the weather and wave forecasts. Finally, the authors would like to thank James Hamilton of the Bedford Institute of Oceanography, Dartmouth, NS for preparing the visualization of the Seahorse data shown in Fig. 6.

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