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ENVIRONMENTAL DATA ACQUISITION/ TRANSMISSION SYSTEM FOR SHIPS-OF-OPPORTUNITY

by

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ABSTRACT

An automated environmental data acquisition/transmission system has been developed for installation on vessels-of-opportunity to enhance meteorological and oceanographic data coverage on the continental shelf and offshore. The data from the vessels can be transmitted using HF radio, MSAT or GOES systems. Software and hardware for capturing the data, for quality control and for making these data available internationally are in place. A number of systems are now operational. Selected trawlers, Canadian Coast Guard vessels, and the Department of Fisheries and Oceans patrol and research vessels are contributing quality data to the environmental data base for Canada's east coast.

INTRODUCTION

Year round activities on the continental shelf off eastern Canada necessitate accurate forecasts of weather, sea state, ice and iceberg conditions. It is difficult to acquire sufficient meteorological and oceanographic data to support these forecast programs. The cost of maintaining permanent platforms offshore, and of conducting cruises to collect oceanographic information, has meant that there is a heavy dependence on data collected by ships-of-opportunity.

A method to improve data coverage and quality is to install automated environmental data acquisition/transmission systems on commercial trawlers and other vessels which frequent the remote areas of the continental shelf. To take advantage of these platforms for enhancing the offshore data coverage, the Department of Fisheries and Oceans (DFO) and the Atmospheric Environment Service (AES) initiated an instrument development project with financial support from the Panel on Energy Research and Development (PERD). This report describes the automated environmental data acquisition/transmission system (EDATS) that was developed for installation on ships-of-opportunity.

SYSTEM HARDWARE

The EDATS is comprised of a meteorological package, an expendable bathythermograph (XBT) system, a global positioning system (GPS), a compass, a controller and a real-time communications link (Fig. 1). The meteorological package includes an anemometer, temperature sensor, relative humidity probe and a pressure transducer, connected to a programmable datalogger. The controller, through a serial port, initializes the datalogger on power up and interrogates it every thirty seconds. Since Campbell Scientific dataloggers are widely used by AES and come with software to support off-the-shelf sensors, this unit is incorporated in EDATS. Sensors and dataloggers distributed by other manufacturers can also be integrated into EDATS with possible software and hardware modifications.

The XBT system is used for collecting temperature profiles. It consists of a launcher which is used to drop XBTs over the side, and a Sippican processor card installed inside the controller. This card is programmed to convert the signals transmitted from the XBTs through the launcher into temperature versus depth profiles depending on the XBT probe drop-rate.

The GPS and Compass, interfaced to the serial ports of the controller, are stand-alone units used to extract the ship's position, velocity over the ground and heading. EDATS systems currently use Furuno GPS-500, Sitex GPS-77P or Trimble NAVTRAC GPS. Other GPS units or output from a vessel's GPS can also be used. However, this may require modifications to the interrogation software in the controller, since the output string format used by different GPS manufacturers may vary.

Additional sensors such as light meters, sea surface temperature probes and others can also be integrated with EDATS with relative ease.

The controller, the central unit of the EDATS, is a rack-mountable PC with an IBM compatible 386 SX motherboard and a minimum of 6 serial communication ports. A remote display unit for the meteorological data can be interfaced with the computer if required.

At present the EDATS is capable of transmitting data using any one or combination of three different systems: an HF radio/Datahail communication system developed by Ultimateast Ltd. in St. John's, Newfoundland; an MSAT mobile satellite data communication link also distributed by Ultimateast Ltd.;

and a GOES Environmental satellite link manufactured by Synergenetics Inc. in Colorado. Each system has certain limitations. The HF/DataHail radio system was found to interfere with vessel's electronic equipment. Even though MSAT is satisfactory for meteorological messages, transmission of XBT messages would require data compression since MSAT transmission is restricted to 128 characters. GOES system can transmit significantly longer records, but the transmission window may be limited restricting the number of XBT messages in any given interval. However, all three systems can handle hourly meteorological messages, and the radio and the GOES can transmit XBT messages at a reasonable frequency.

In terms of data recovery all three systems proved to be satisfactory. However, the GOES communication system has three major advantages over the other two systems. First, both the HF radio and the MSAT systems are limited in coverage whereas GOES is global. Secondly, the data routing on land for the GOES system and the associated infra-structure are all in place and are currently in use across north America, whereas the data routing for the other two requires setting up of local infra-structure through non-governmental agencies. Thirdly, AES has a number of meteorological stations transmitting via GOES, and has the necessary software to capture the data, to assess its quality and to distribute internationally. Thus, of the three systems considered, GOES communication system has rendered itself to be the best choice.

SOFTWARE

The EDATS software, written in C and running on Microsoft MS-DOS operating system 5.0, consists of a suite of programs (Fig. 2) that can be executed simultaneously under the control of a multitasking, multiwindowing control program called Desqview 386. Automatic meteorological messages are generated at pre-set intervals by a set of routines that run in the background. These programs interrogate the sensors and the datalogger, perform the necessary computations to prepare the message and place it in the transmission queue.

EDATS software also includes a module to generate continual display of the weather information on a separate window on the computer monitor, and on a remote display unit if required.

Since XBT profiles are usually collected at irregular intervals, the set of routines that control this data stream is run on a demand basis. Keyboard entry of meteorological parameters or XBT profiles operate in the same manner. The files created by these programs are passed to the background program for processing and transmission.

METEOROLOGICAL DATA

The weather information is continually displayed on a separate window on the controller's monitor. The controller collects new information from the GPS, compass, datalogger and sensors, and updates the screen every thirty seconds.

The datalogger collects data from its meteorological sensors using a five second scan rate. Since the datalogger is interrogated every thirty seconds, six wind vectors (relative to the ship's heading) are averaged and the result is stored for retrieval by the controller. Also at thirty second intervals, instantaneous readings of air temperature, pressure, relative humidity and dew point are extracted from the datalogger. The dew point is calculated using the formula:

$$T_d = \frac{b}{\left(\frac{a}{\log_{10} RH + \left(\frac{aT}{b+T}\right) - 2}\right) - 1}$$

where T_d, dewpoint temperature
T, air temperature
RH, relative humidity
and, a and b are constants.

Over water, a = 7.5 and b = 237.3 (Tetens, 1930).

The GPS speed over ground (SOG) and course over ground (COG) and the ship's heading (from the compass, corrected for magnetic deviation) are combined with the relative winds to produce the true winds. Since the wind direction measured by the sensor is relative to the bow of the vessel, compass heading is used to correct the direction of the relative winds to true north. At present the magnetic deviation for the area of operation is entered at the time the system is set up; however, software can easily be modified to extract this information from a look-up table, if the magnetic deviation is expected to change significantly along the cruise track.

At low ship speeds the ship's velocity estimated by the GPS is often erroneous, thus corrupting the true winds. To reduce these effects the ship's speed is forced to zero when the SOG falls below the current threshold of 1.5 knots. The true winds are then calculated by vectorial addition of the relative winds (adjusted to true north) and the ship's velocity. The true winds, air temperature, pressure, relative humidity, dew point and other relevant information are displayed on the screen (Appendix A).

The platform also generates hourly meteorological messages. This is accomplished in two stages. Beginning at 10 minutes to the hour, the datalogger calculates thirty second averages of the wind speed and direction and stores the 20 sets of observations. Concurrently (also at 10 minutes to the hour), the controller collects data from the GPS and compass at 30 second intervals. In addition on the hour, the datalogger also computes 2-minute averages of air temperature, relative humidity and pressure, and calculates the dew point using the above formula. Additional calculations are carried out by the datalogger to compute three hour absolute pressure change, and the three hour pressure tendency, defined as the magnitude and sign respectively, of the difference between the current pressure and the pressure measured three hours earlier.

Thus at the end of the 10 minute period, the datalogger file will contain: 20 samples of relative wind speed, and direction relative to the bow of the vessel, two minute averages of air temperature, dew point and air pressure, the mean sea level pressure (corrected for barometer height above sea level), 3 hour pressure tendency, 3 hour absolute pressure change, datalogger supply voltage, program signature (to detect any program change or datalogger failure) and an array identification code for this file.

During the second stage, at the end of the 10 minute data accumulation period, the controller retrieves the data file from the datalogger, calculates the true winds, and prepares the meteorological message for that hour. A sample coded message and definition of the fields are given in Appendix B.

EDATS is also capable of generating hourly meteorological messages from keyboard input whenever required. All parameters listed in the Selected Ships' Code card: International meteorological Code for ships in symbolic form (WMO #8.TP.3) can be entered into this message (Appendix C). These entries can be used to append optional parameters to the next hourly automatic message, or to replace the corresponding values in that message.

XBT DATA

The XBT message can be generated from either real-time data transmitted from the probe after it is launched or from manually entered data. If real-time data is collected, the controller must be initialized with the probe type. Since, the XBTs are not equipped with pressure sensors, the depth is calculated as a function of time, using the manufacturer-supplied drop-rate equations, which vary for different probe types. Water depth and tow speed are optional parameters. However the water depth information is used to truncate the temperature profile in cases when the transmission from the probe continues even after the probe reaches the bottom. The processor card also generates a real time plot of the temperature versus depth profile.

At the end of the cast, the controller appends to the file the position and time information using GPS output. It also appends wind and air temperature fields (optional), and removes the start-up transients and other large spikes. The data are then reduced to less than 21 points using an algorithm developed for ships-of-opportunity XBT transmission by the Intergovernmental Oceanographic Commission of UNESCO (Szabados, 1992). Basically, this algorithm selects linear segments that will best represent the temperature profile and extracts the terminal values for each segment. These are compressed into an Intergovernmental Global Ocean Services System (IGOSS) message and sent to the transmission queue. A sample XBT message and the field definitions are given in Appendix D.

DATA ROUTING

GOES SYSTEM

A major advantage of using the GOES system for transmitting data from the ships to shore is that the necessary infrastructure for receiving, quality control and routing of the data onshore is already in place (Fig. 3). Messages transmitted from EDATS are received by the existing satellite downlink at Wallops Island, Virginia, USA and redirected to the National Meteorological Centre at Suitland, Maryland where they are checked for their geographical origin and placed on all respective nodes. The AES office located in Montreal, Quebec receives the data from Suitland and relays it to AES in Bedford, Nova Scotia, where the meteorological messages are separated from the XBT messages. The meteorological data is then checked for data quality and routed to the Tandem computer and distributed electronically for international access.

The XBT messages are sent to Meteorological and Oceanographic Centre in Halifax, Nova Scotia where they are checked and redistributed. The archive centre for the XBT data is at the Marine Environmental Data Services (MEDS) in Ottawa, where the messages are checked for gross errors in vessel position and temperature values, and stored in the archives.

HF RADIO AND MSAT SYSTEMS

Sealink Ltd. is responsible for receiving and routing the messages from both DataHail HF and MSAT satellite transmissions (Fig. 4).

Data from systems installed on board Canadian Coast Guard (CCG) and Fisheries and Oceans (DFO) vessels are received by the MNET controllers at CCG and DFO respectively, and then transferred to the Sealink site in St. John's, Newfoundland over the Public Switch Telephone Network (PSTN). Data from private vessels equipped with their own DataHail radio systems are extracted at the Sealink receiver site in Tors Cove, Newfoundland and relayed to their facility in St.John's via a leased telephone line. Sealink sends the messages to its computer in Halifax, Nova Scotia and then forwards these messages to AES, Bedford, Nova Scotia via the PSTN.

Messages from the MSAT system are received at Telesat Mobile Inc. in Ottawa and relayed to Sealink Ltd. in St. John's; messages are then forwarded to AES, Bedford as outlined above. The procedure for distributing the messages, after AES receives them, is the same for all three sets of transmissions.

VERIFICATION

The transmitted weather data from the vessels are collected from the AES Weather Service in Bedford, Nova Scotia. The ship reports are compared to analyzed meteorological maps from the Newfoundland Weather Centre and reports from nearby ships and buoys. The data quantity and quality are tabulated and analyzed on a daily basis, with weekly and monthly reports. Data quality is summarized as percent in agreement with the other sources, for the week in question. The data is also analyzed for faulty or suspect sensors and/or equipment. Data coverage and overall data quality are good as shown in Fig. 5 and Table 1 respectively.

Table 1. Overall data quality for the period April to December 1992 are shown below:

Parameters	Percentage
wind	94%
pressure	92%
temperature	100%
dew point	99%

Possible causes for discrepancies:

* weather maps may be in question, in the area of the ship's position
* winds from ships in port or near shore are subject to coastal effects

SUMMARY

EDATS, developed for installation on ships-of-opportunity, is an economic option for enhancing environmental data to supplement data collected as part of dedicated research cruises. The present system is designed around the commonly measured environmental parameters and uses international data formats. Enhancements could be made to EDATS to include additional sensors and equipment. The flexibility of sending data either by satellite or by HF radio enhances EDATS' potential for a variety of applications.

ACKNOWLEDGEMENTS

The idea for instrumenting trawlers-of-opportunity originated during a discussion with Capt. Hogan, then at Fisheries Products Intl. in St. John's, Newfoundland. The Panel on Energy Research and Development (PERD) provided a significant portion of the funding. The Canadian Coast Guard provided additional funding, and both Coast Guard and DFO provided access to two of their vessels for EDATS installation. Support from Atmospheric Environment Service in the form of funds and technical assistance contributed significantly to the success of this project. The development and testing of EDATS was possible through the cooperation from Mr. George Petten, owner of the M.V Carl Venture, Fishery Products International, and National Sea Products Ltd. who made the trawlers available for testing the system and, when EDATS became operational, for data collection. Technical support from Canadian Centre for Marine Communications was also invaluable.

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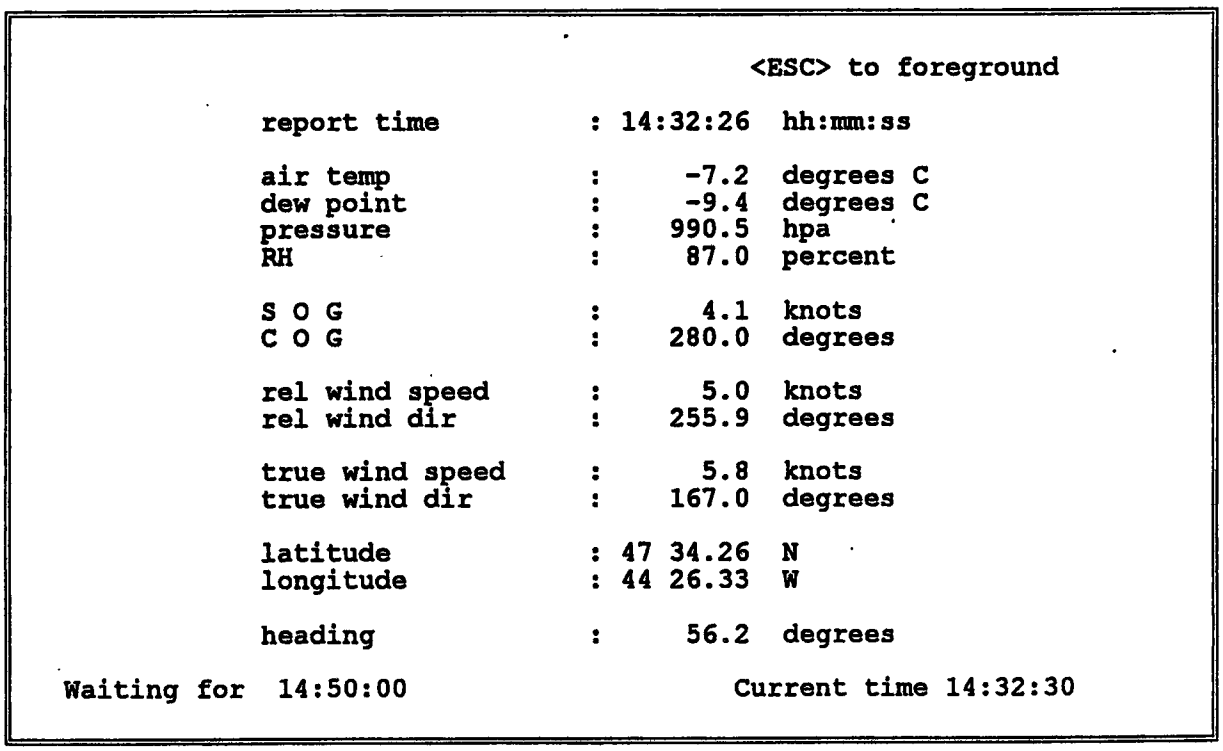
APPENDIX A

AUTOMATIC WEATHER WINDOW



APPENDIX B

Meteorological Message Format

Weather messages are transmitted in the International Meteorological Code for Ships format (REF X). A sample of this format is:

BBXX VCBT 28214 99466 70464 4//// /1611 10034 20022 40354 57023 7//// 22232 00019 21208 B1184 S2452

Message Type	BBXX	(MiMiMjMj)
BBXX		ship message identifier
Group 1	VCBT	(D....D)
VCBT		ship's call sign
Group 2	28214	(YYGGiw)
YY =	28	day of the month
GG =	21	indicates 2100 GMT
iw =	4	wind speed measured with an anemometer
Group 3	99466	(99LaLaLa)
99	indicates ship's position follows	
LaLaLa =	466	ship's latitude 46.6 North
Group 4	70464	(QcLoLoLoLo)
Qc =	7	quadrant of globe North lat and West long
LoLoLoLo =	464	ship's longitude 46.4 West
Group 5	4////	(iRixhVV)
iR =	4	precipitation field omitted
ix =	/	weather indicator omitted
h =	/	cloud height omitted
VV =	//	visibility omitted
Group 6	/1611	(Nddff)
N =	/	cloud cover omitted
dd =	16	wind direction 160 deg true
ff =	11	wind speed 11 knots
Group 7	10034	(1snTTT)
1	group indicator	
sn =	0	positive temperature
TTT =	034	air temperature 3.4 degrees C
Group 8	20022	(2snTdTdTd)
2	group indicator	
sn =	0	positive dew point
TdTdTd =	022	dew point 2.2 degrees C
Group 9	40355	(4PPPP)
4	group indicator	
PPPP =	0355	sea level pressure 1035.4 hectopascals
Group 10	57023	(5appp)
5		group indicator
a =	7	pressure is lower than it was 3 hours ago
ppp =	023	net change in the barometric pressure during the preceding 3 hours was 2.3 hectopascals
Group 11	7////	(7wwW1W2)
7	group indicator	

```
ww =            //      present weather is omitted
W1W2 =          //      past weather is omitted


Group 12        omitted (8NhClCmCh)

Group 13        22232   (222DsVs)
222                     group indicator
Ds =                    ship's course made good in the previous 3 hours was
southeast
Vs =            2       ship's average speed made good in the previous 3 hours was
                        6 to 10 knots

Group 14        00019   (0snTwTwTw)
0                       group indicator
sn =                    0temperature is positive
TwTwTw =        019     sea surface temperature was 1.9 degrees C

Group 15        21208   (2PwPwHwHw)
2                       group indicator
PwPw =          12      period of sea waves 12 seconds
HwHw =          08      height of sea waves 8 half-meters (4 meters)

Group 16        omitted (3dw1dw1dw2dw2)

Group 17        omitted (4Pw1Pw1Hw1Hw1)

Group 18        omitted (5Pw2Pw2Hw2Hw2)

Group 19        omitted (6IsEsEsRs)

Group 20        omitted (ICE ciSibiDizi)


Group 21        B1184   (Bbbbb)  ***EDATS defined***
B               group indicator
bbbb =          1184    datalogger supply voltage 11.84 volts

Group 22        S2452   (Sssss)  ***EDATS defined***
S               group indicator
ssss =          2452    datalogger program signature 2452
```

*****

Appendix C

Screen for keyboard entry of meteorological message

Screen #1:

SPREP	(Y or N)	N
STORM	(Y or N)	N
day/hour-z	(09/06)	10/18
wind indicator	(3 or 4)	4
latitude	(47.2N deg)	47.6N
longitude	(57.3W deg)	44.8W
lowest cloud height	(h code)	6
visibility	(VV code)	92
fraction of clouds	(N code)	8
wind direction	(deg true)	315
wind speed	(knots)	7
air temperature	(deg C)	-12
dew point	(deg C)	-18
pressure	(1023.6 hPa)	1005.8
pressure tendency	(a code)	7
amount of pres tend	(hPa)	2.5
present weather	(ww code)	02
past weather	(W1W2 codes)	23
fract of CL or CM	(Nh code)	8
low cloud type	(Cl code)	0
middle cloud type	(Cm code)	2
high cloud type	(Ch code)	0

<F1> to auto met <ESC> to main menu <END> to more man met
<F3> to Sippican X B T <SPACE> to send menu

Screen #2:

3 hr heading	(deg true)	0
3 hr speed	(knots)	0
surface temperature	(deg C)	-3
sea wave period	(PwPw code)	30
sea wave height	(HwHw code)	2
dom swell dir	(dw1dw1 code)	90
sec swell dir	(dw2dw2 code)	120
dom swell per	(Pw1Pw1 code)	80
dom swell hgt	(Hw1Hw1 code)	27
sec swell per	(Pw2Pw2 code)	20
sec swell hgt	(Hw2Hw2 code)	10
ice accretion cause	(Is code)	1
ice accretion thickness	(cm)	0
ice accretion rate	(Rs code)	1
sea ice concentra	(ci code)	6
sea ice develop	(Si code)	0
ice of land origin	(bi code)	0
ice edge bearing	(Di code)	1
ice situation	(Zi code)	0

<F1> to auto met <ESC> to main menu <END> to prev man met
<F3> to Sippican X B T <SPACE> to send menu

APPENDIX D

Bathythermograph Data Message Format:

Bathy messages are transmitted in a format similar to the weather messages. A sample of this format is:

JJXX 25013 2133/ 74733 05235 88888 01508 03516 20516 26518 99901 13517 15515 19514 36510 45511 62510 75509 66666 10176 DVCBTD

Message Type	JJXX	(MiMiMjMj)
JJXX		Bathy message identifier
	25013	(YYMMJ)
YY =	25	day of the month
MM =	01	month
J =	3	last digit of the year
	2133/	(GGgg/)
GG =	21	2100 GMT
gg =	33	minutes
/		omitted
	74733	(QcLaLaLaLa)
Qc =	7	quadrant of globe North lat and West long
LaLaLaLa =	4733	ship's latitude 47 deg 33 min North
	05235	(LoLoLoLoLo)
LoLoLoLoLo =	05235	ship's longitude 52 deg 35 min West
	omitted	(iuddff) optional true wind
	omitted	(4snTTT) optional air temperature
	88888	(8888k1)
8888		profile section identifier
k1 =	8	temperatures are at significant depths
	01508	(z0z0T0T0T0)
z0z0 =	01	depth in meters of first point i.e. 1 m.
T0T0T0 =	508	temperature in tenths (for negative temperatures, 500 is added to absolute value of the temperature). The code of 508 is represents a temperature of -0.8 degrees C.
	03516	(z1z1T1T1T1)
z1z1 =	03	depth in meters of next point i.e. 3 m.
T1T1T1 =	516	a code of 516 is represents a temperature of -1.6 degrees C

and so on.....

	99901	(999zz)
999		hundreds of meters identifier
zz =	01	this group gives the hundreds of meters to add to subsequent znzn depths, e.g.100 will be added to the depth of the next group making the resultant depth 113 meters
	66666	(66666)
66666		section identifier for optional fields
		10176(1ZdZdZdZd)
1		group indicator
ZdZdZdZd = 0176		total water depth in meters is 176
	VCBT	(D....D)
VCBT	ship's call sign	

*****

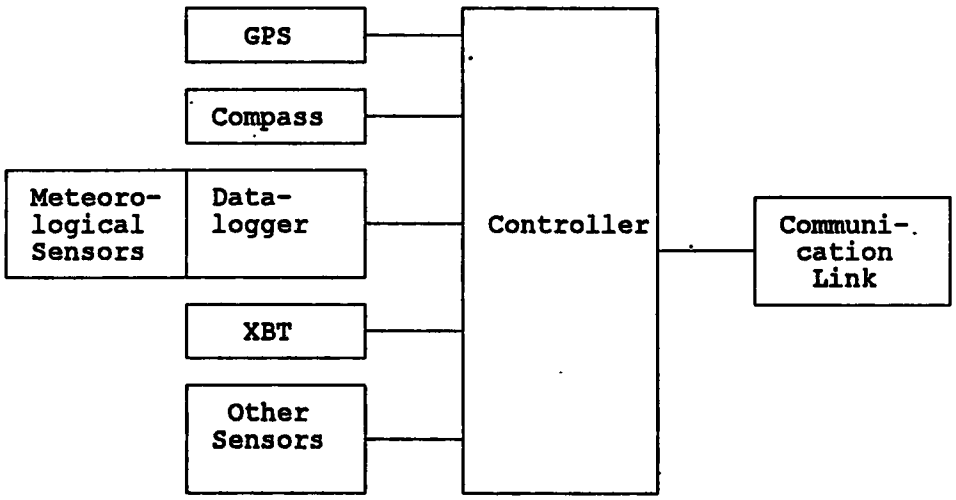


Figure 1. EDATS structure.

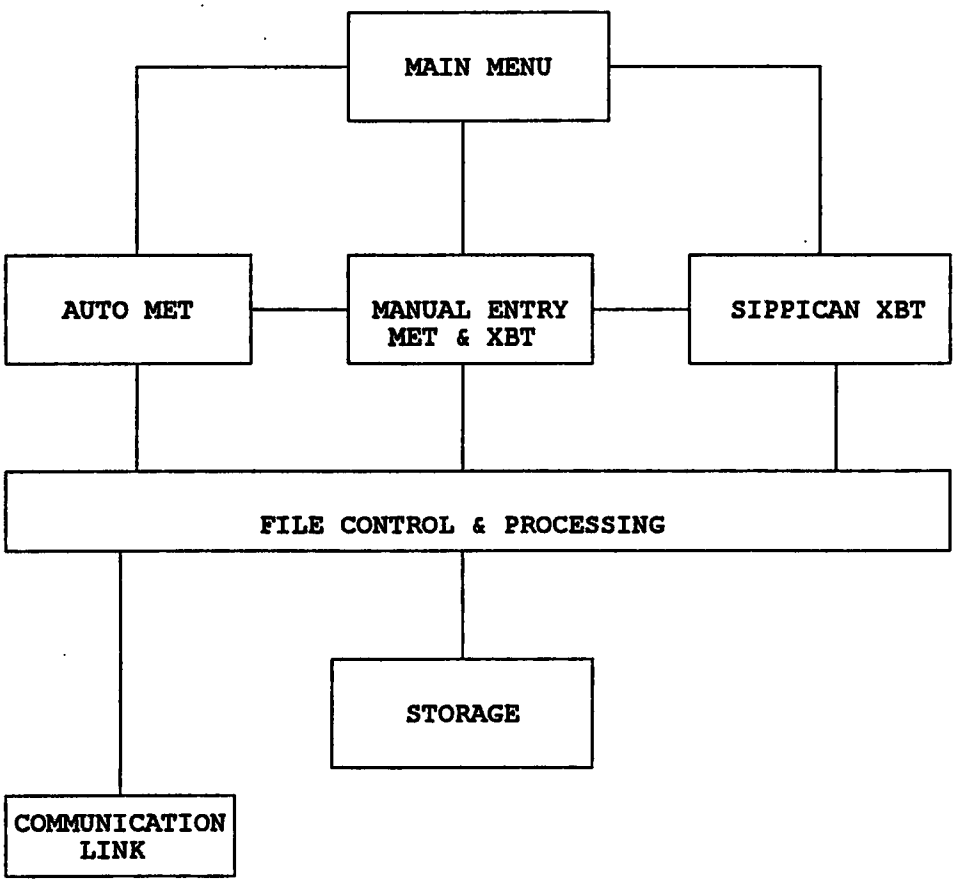


Figure 2. Flow chart of EDATS software.

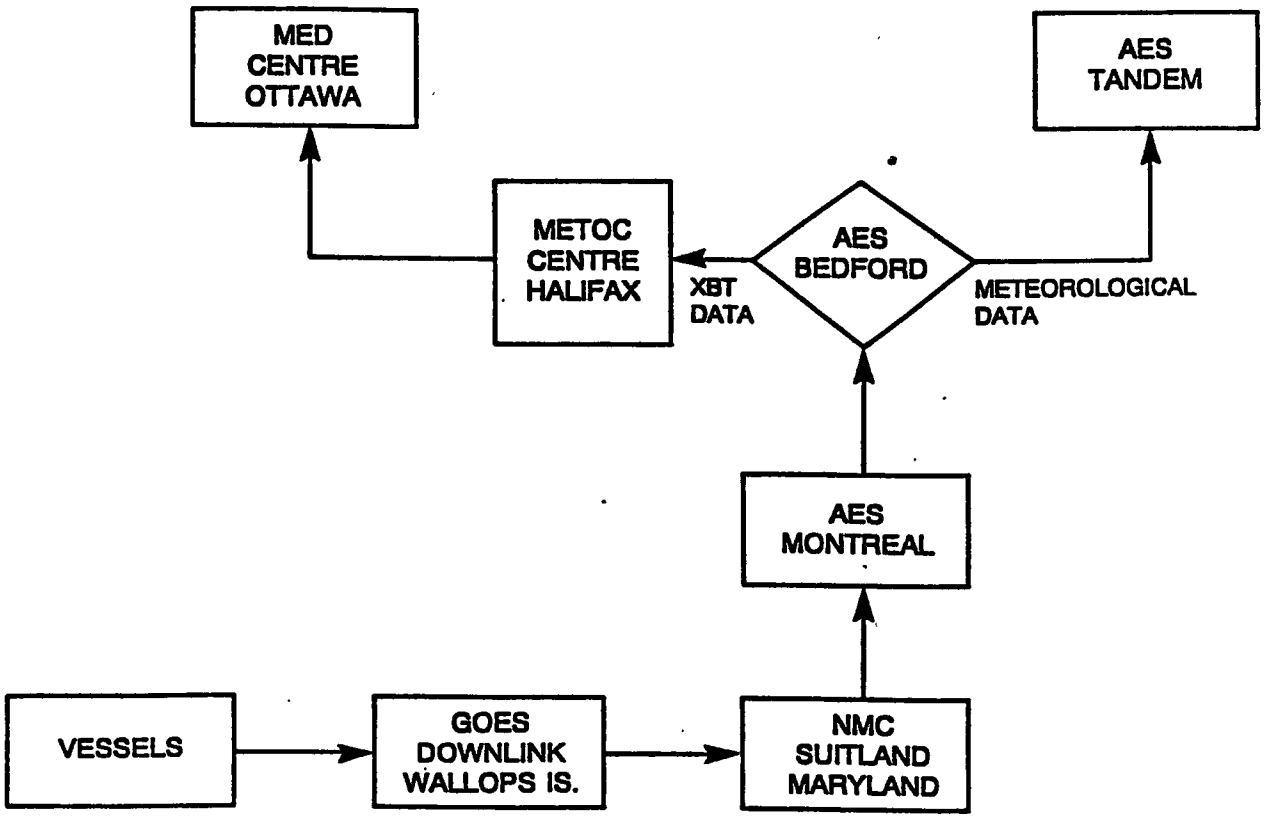


Fig. 3. Data routing: GOES.

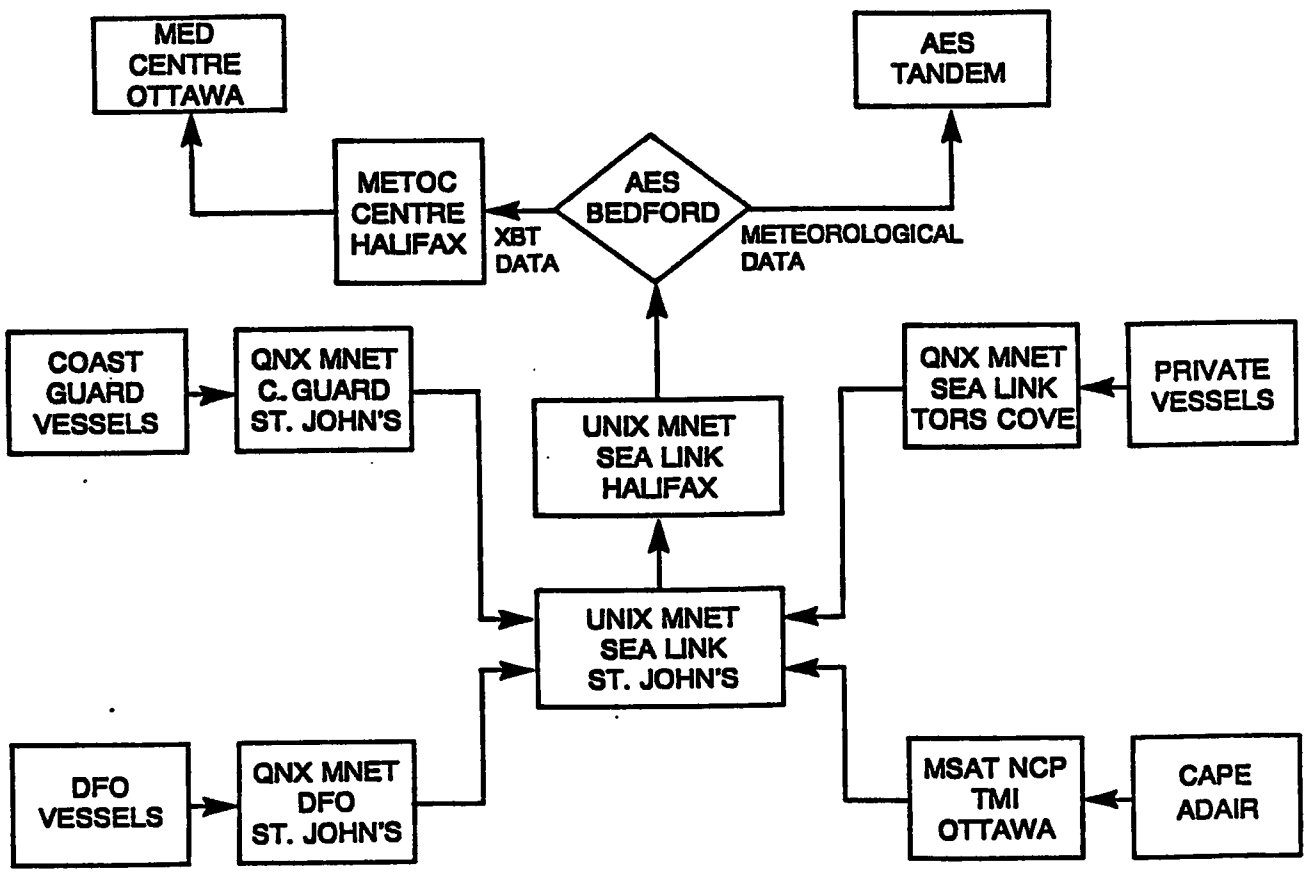


Fig. 4. Data routing: HF Radio and MSAT.

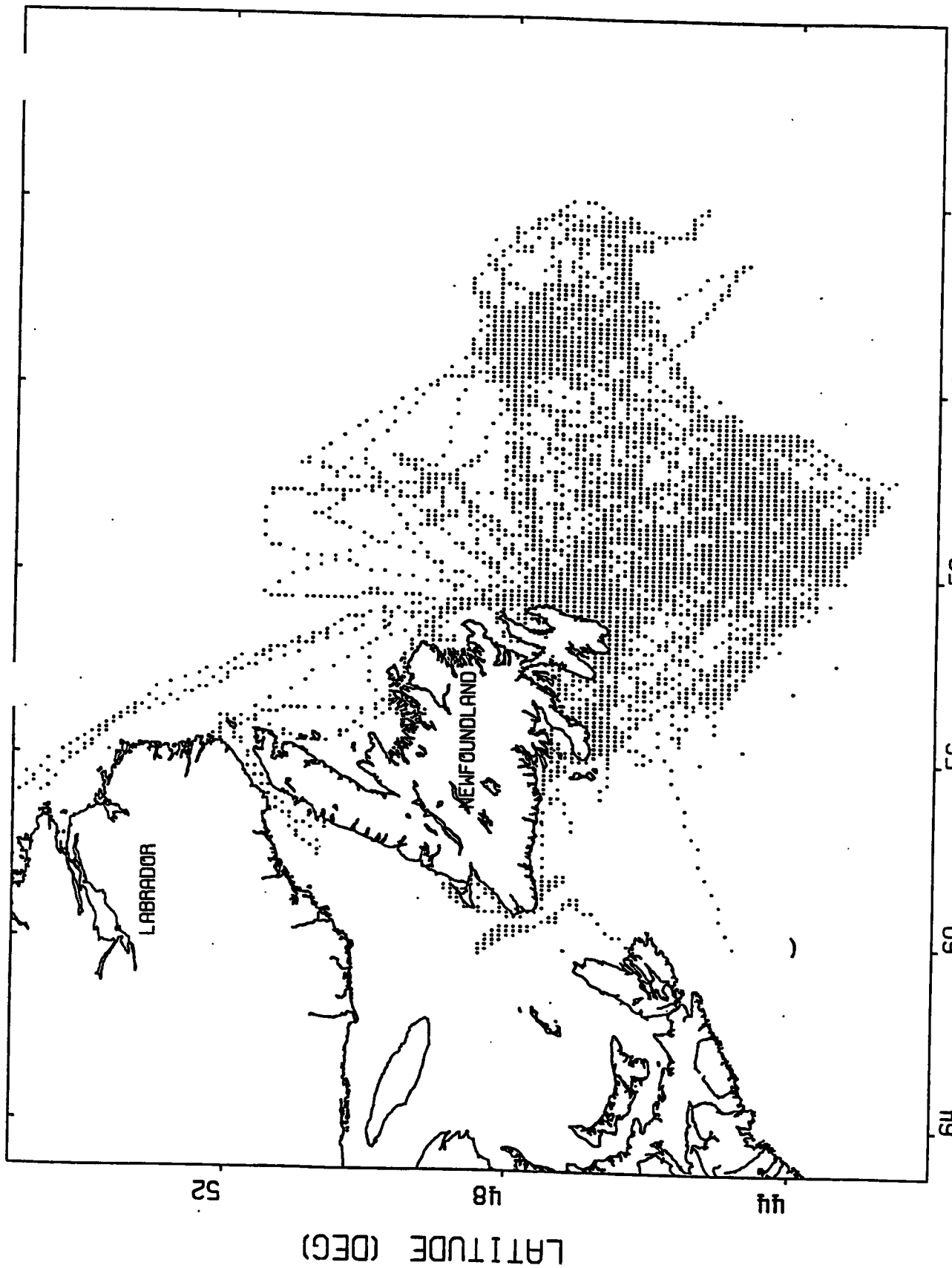


Fig. 5. Scatter diagram showing message locations from April to December 1992.

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