A WAVE CLIMATE STUDY OF THE NORTHERN BRITISH COLUMBIA COAST

FINAL REPORT

VOLUME I: WAVE OBSERVATIONS

PREPARED FOR:
MARINE ENVIRONMENTAL DATA SERVICES BRANCH
DEPARTMENT OF FISHERIES AND OCEANS

BY: SEAKEM OCEANOGRAPHY LTD.

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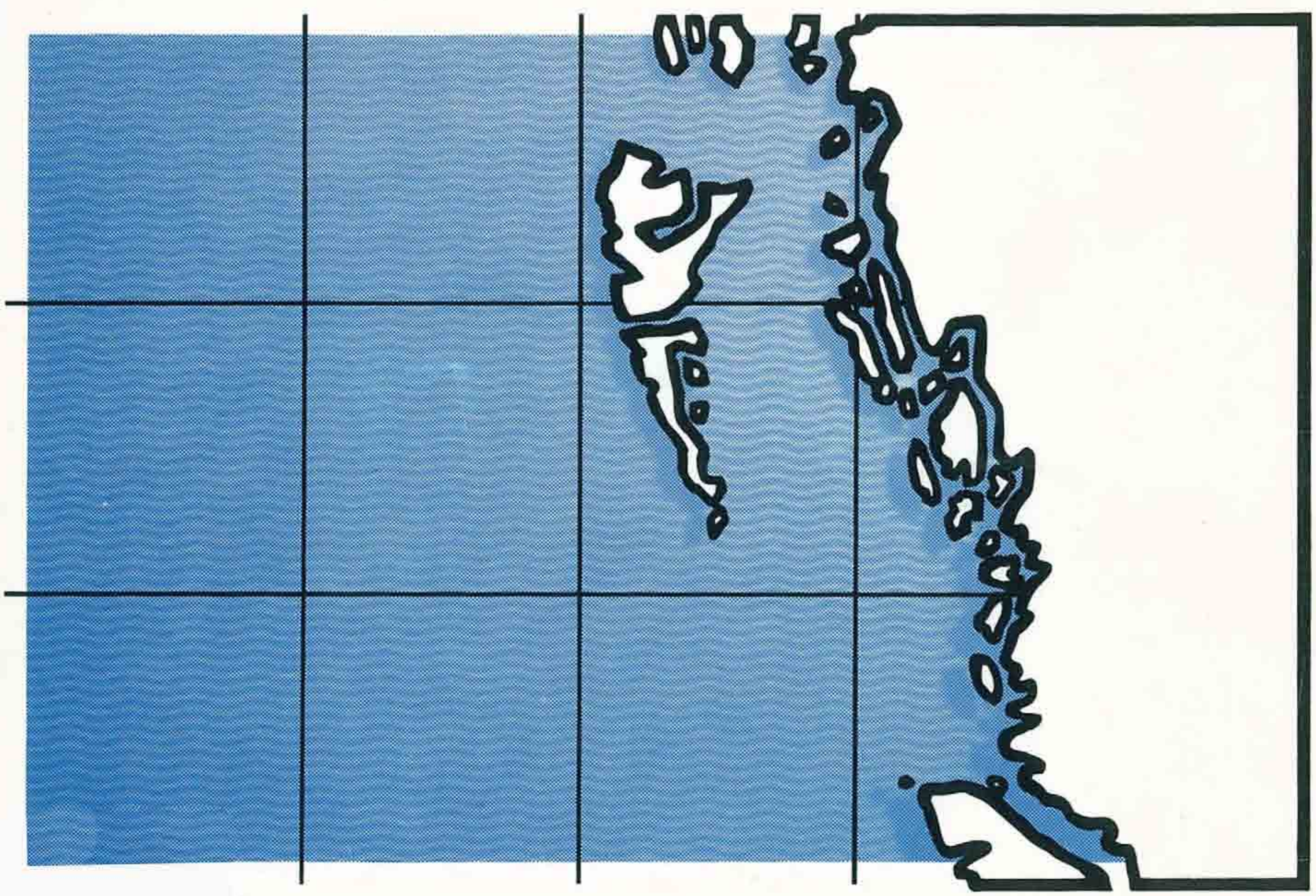

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A WAVE CLIMATE STUDY
OF THE NORTHERN BRITISH COLUMBIA COAST

Final Report

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Prepared for:

Marine Environmental Data Services Branch
Department of Fisheries and Oceans
Ottawa, Ontario

Volume I

Wave Observations

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LIST OF ACRONYMS

ADFS	Automatic Direction Finder System
AES	Atmospheric Environment Service
ARGOS	Service ARGOS, Toulouse, France: a data telemetry and position fixing service using TIROS satellites
CCGS	Canadian Coast Guard Ship
CCIW	Canada Centre for Inland Waters
CFPV	Canadian Fisheries Patrol Vessel
CRT	Cathode Ray Tube
CTD	Conductivity - Temperature - Depth sensor
DCP	Data Collection Platform
DIREC	Directional Wave Buoy (WAVEC) Receiver made by Datawell
ENDECO	Environmental Devices Corporation
GOES	Geosynchronous Operational Environmental Satellite
IOS	Institute of Ocean Sciences (Patricia Bay, British Columbia)
MEDS	Marine Environmental Data Service (Dept. of Fisheries and Oceans, Ottawa)
METOC	Meteorology and Oceanography Centre, (CFB Esquimalt)
NESDIS	NOAA Environmental Satellite Data and Information Service
RF	Radio Frequency
VHF	Very High Frequency
WAREP	Waverider Receiver made by Datawell B.V.
WAVEC	A directional, slope following wave buoy made by Datawell B.V.
WRIPS	Waverider Information Processing System, a modified 0.9 m Waverider buoy that processes data internally and transmits data summaries via satellite telemetry.

EXECUTIVE SUMMARY

From the fall of 1982 to the spring of 1984, a wave measurement program was conducted in Queen Charlotte Sound, Hecate Strait and Dixon Entrance on the Northern Coast of British Columbia. Six wave buoy mooring sites were chosen to provide good regional coverage. As part of the study, four different buoy types were used including two Datawell Waveriders, one ENDECO 956 WAVE-TRACK directional buoy, one Datawell WAVEC directional buoy and two Waveriders modified for satellite data transmission (WRIPS buoys). A satellite-transmitting weather station at McKenney Rock was also maintained in order to obtain over-water wind estimates in Queen Charlotte Sound. The goals of the study were:

1) to obtain operational experience and to verify the performance of the two directional wave buoys;
2) to design and implement a directional wave data processing scheme;
3) to supplement the relatively poor existing wave data base with concurrent wave and wind measurements at various locations;
4) to interpret the local wave climate in terms of both spectral and non-spectral properties; and
5) to critically assess the prerequisites for successful wave hindcasting of the area.

Operational Experience

No buoys were lost, although problems were encountered over the 18 month duration of the study with buoys going adrift and with system failures. The Datawell Waverider systems were reliable. The use of data loggers which digitize the analog signal from these buoys proved to be very efficient for data handling and eliminated the problems associated with analog recording. The two satellite-transmitting WRIPS buoys showed the best data return due to their facility for internal recording of spectral information. Because they do not require a nearby shore receiving station, they also provided flexibility in mooring site locations. ARGOS positioning of these buoys proved very useful when they went adrift.

The WAVEC directional buoy provided good quality data in an easily handled format. It did suffer from problems with the DIREC receiver, possibly because it was a prototype, and twice during the study the perimeter flotation pieces were dislodged. The ENDECO WAVE-TRACK system, unlike the WAVEC, does not transmit continuously. This feature posed problems in finding the buoy, in data acquisition during storms, and in trouble-shooting. The receiver suffered several component failures. The limited battery capacity of the buoy and its low buoyancy were drawbacks, but the small size of the buoy made it easy to transport and handle. The relatively limited information supplied in the digital output of the ENDECO receiver was circumvented by using a Sea Data logger to digitally record the analog data.

Directional Wave Data Processing

Two directional wave data processing schemes were established and run. The ENDECO WAVE-TRACK data underwent a 10-frequency Band-Pass directional analysis using a program supplied by ENDECO Ltd. The Datawell WAVEC data were processed using a Longuet-Higgins approach using a program developed by Seakem Oceanography Ltd. The ENDECO Band-Pass program proved to be computationally slow, and provided only limited frequency resolution. The processed records often contained spurious low frequency energy, possibly a fault of the design of the buoy, and wave directions were often inconsistent with those expected for low energy waves. The Longuet-Higgins program for the Datawell WAVEC records appeared to describe both the directional and wave height statistics of the wave field correctly.

Description of the Wave Climate

Along the northern coast of British Columbia, the meteorological climate is governed by the location and strength of two pressure systems, the Aleutian Low and the North Pacific High, with associated winds further modified by the coastal mountains. Generally, strong south-to-southeasterly winds will predominate in the winter with weaker north-to-northwesterly winds in the summer. From a storm analysis approach, two storm types appear to give rise to the more severe local conditions. The first consists of a large scale, deep low-pressure system which moves

eastward over the Gulf of Alaska to produce strong S-to-SE winds due to the tightening of isobars between the coastal mountains and the open ocean. The second is a smaller center over the Gulf of Alaska which deepens rapidly when it approaches the coast. Its severity is due to the fact that its speed of approach can match the group velocity of large deep water waves and thereby continually input energy into the wave field. Such a storm resulted in a 27 to 30 m wave observed once previously in Hecate Strait and in the severe sea states (20 m waves) observed in December 1982 during this study. An examination of the wind data from the weather station deployed at McKenney Rock, as well as from four Atmospheric Environmental Service weather stations at lighthouses in the study area, showed the expected seasonal climate, with the largest mean and maximum winds associated with E-to-SE directions. Topographic steering of winds by the coastal mountains and through Dixon Entrance was evident. A comparison of wind speed and direction statistics from this study with historical norms showed that both mean and maximum speeds were generally lower during the study, and that the direction distribution was considerably weighted towards the SE. An examination made of winds measured at the Cape St. James AES weather station and at McKenney Rock to determine the relationship between over-water winds and coastal-measured winds, showed that the lighthouse data were inadequate as input to a hindcast model.

Interpretation of the Wave Climate

The observed wave climate showed trends consistent with the seasonal changes in weather conditions and the location of the wave station. The most severe conditions were observed in Queen Charlotte Sound in winter and the least severe at Bonilla Island in Hecate Strait. Both Queen Charlotte Sound and western Dixon Entrance were exposed to significant swell energy. There was a general reduction in wave energy from west to east across Learmonth Bank in Dixon Entrance. Hecate Strait, though less open to swell waves than western Dixon Entrance, was more severe in terms of the occurrence of large waves. It appeared that the relative exceedance at low wave heights depended on the exposure of each site to offshore swell while for higher waves, the exceedance was related to the trajectory of storms causing severe conditions. The modal direction of waves reaching McInnes Island, in eastern Queen Charlotte Sound, was from the SSW to WSW reflecting the relatively unimpeded trajectory from the open ocean. Directions measured at Bonilla Island in

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Interpretation of the Wave Climate

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Hecate Strait showed considerable scatter with some along-strait alignment. The record having the largest significant wave height was obtained from Queen Charlotte Sound (11.4 m with an associated maximum wave of 18.5 m) while the largest individual wave was observed in southern Hecate Strait (19.8 m). There was some indication of a regional variation in the ratio of maximum to significant wave height. An extreme wave analysis predicted a 100 year significant wave height of 17 meters in Queen Charlotte Sound. These results as well as the seasonal statistics, showed that this area was comparable in wave climate severity to the Hibernia site on the Grand Banks of Newfoundland.

Wave Hindcasting

In order to develop a wave hindcast strategy for the Queen Charlotte Sound - Hecate Strait - Dixon Entrance area, various other properties of the wave field were examined. These included an analysis of wave groupiness, of wave refraction by currents or bathymetry, and of directional spectrum modelling. Seven storms were examined for correlations between a calculated Groupiness Factor and spectral or non-spectral properties. It was found that the Groupiness Factor was not particularly good for characterizing the nature of wave groups and further work categorizing wave groups and of the bound long wave was required.

Wave refraction analysis for different impinging wave periods and directions showed a large spatial variation in wave climate due to areas of relative convergence or divergence of the wave field. Both near-shore conditions and those due to refraction by Learmonth Bank were very sensitive to the exact period and incident angle chosen for the incoming swell. Short-lived transient swell events could occur due to a combination of the frequency dispersion of impinging waves with corresponding changes in wave travel direction. Refraction by currents did not appear to contribute significantly and can possibly be ignored in future modelling with the possible exceptions of the very shallow areas near Rose Spit and on the east side of the Queen Charlotte Islands.

An attempt was made to verify the "cosine-power" model representation of directional spread for the McInnes Island data. Using approaches accepted in the literature and a newly developed optimization procedure to estimate the goodness of fit, it was found that large errors were associated with highly directional seas. This was shown to be an unavoidable consequence of the fitting technique and not

necessarily a criticism of the model. A second parametric spectrum, the Wallops Spectrum, was examined as it has the unusual characteristic of being completely defined by a slope parameter (i.e. significant surface slope) and the peak frequency. Though there was generally poor correspondence between measured and predicted slope statistics from the model, the results overall were favourable and indicate its potential usefulness. The distribution of normalized slope and the behaviour of the RMS slope agreed well with theory.

Wave hindcast modelling was shown to be necessary due to the paucity of reliable, direct wave measurements in the study area. The suggested strategy includes the use of a discrete spectral model incorporating shallow water transformations with good resolution of land masses, bottom features and wave components. The spectrum should sufficiently resolve frequency and direction. A choice exists, depending on the application, between constant, or sequential constant ratio, frequency discretization with the former providing good resolution over high frequencies and the latter over the swell range. As the coastal weather stations were shown to be inadequate in supplying wind information, wind input to the model would have to come from a joint wind model (boundary layer and/or pressure field) with subjective editing to incorporate overwater winds when available. Three spatial grid scales would be required in order to resolve the different storm types mentioned earlier, as well as local bathymetry and land forms. This would incorporate a large grid scale, order of 60 kms, for the Gulf of Alaska, reduced to 10 - 20 kms for resolving smaller scale storms. Landforms and bathymetry also require a resolution of 10-15 kms which must be changed to 2.5 kms in areas such as Learmonth Bank.

A much larger Pacific Rim model is needed if swell development is to be modelled. Alternatively, swell could also be introduced along one of the grid boundaries, independent of local winds, and then be subject to model manipulations as it progresses in time and space. A third option involves treating swell separately and then adding it into the predicted spectra at the inshore site of interest. Both of the last two options require future work in order to characterize storm-produced swell and swell properties as well as the joint probability of sea and swell occurrences. In addition, before a major hindcast effort is undertaken, historical storms, inter-annual variablity, and over-water winds need to be better characterized. The major impetus for future work should lie in these areas.

ABSTRACT
(Volume 1)

A wave climate study was conducted of the Northern British Columbia coast of Canada from October, 1982, to May, 1984. Six wave buoys were used in the study: two Datawell Waveriders, two Adamo Rupp satellite-transmitting wave buoys, one ENDECO WAVE-TRACK directional wave buoy and one Datawell WAVEC directional wave buoy.

The Datawell WAVEC buoy produced good quality data, but there was some question about the ruggedness of the buoy design. The ENDECO WAVE-TRACK directional buoy suffered from a number of hardware problems, and the data showed spurious low frequency energy contaminating the spectra, and questionable wave directions for low energy waves.

The WAVEC data were processed using a Longuet-Higgins directional analysis while the WAVE-TRACK data underwent a Band-Pass analysis with software supplied by ENDECO Inc. The former proved to be the more efficient and more reliable processing method: the Band-Pass analysis was computationally much slower, had poor frequency resolution and the calculated directions were sometimes incorrect.

The seasonal and regional wave conditions at all sites agreed well with those expected. Background swell energy was prevalent in both Dixon Entrance and Queen Charlotte Sound. The maximum significant wave height and largest single wave were 11.4 and 18.5 meters in Queen Charlotte Sound, 10.7 and 19.8 meters in Hecate Strait and 9.0 and 15.2 meters in Dixon Entrance. Winter was the most severe season in terms of both mean and maximum wave heights. Wave height exceedances are of comparable magnitude to those on the Grand Banks off Canada's east coast, although the west coast data shows more frequent occurrence of long period swell.

1. INTRODUCTION

The waters of the northern British Columbia coast are comprised of Queen Charlotte Sound, Hecate Strait, and Dixon Entrance, which border the Queen Charlotte Islands on the south, east and north. These waters cover a major part of the continental shelf which lies along Canada's west coast. Long known for its fisheries resources, this region is steadily becoming more important for other reasons: shipping from the expanding port at Prince Rupert, potential oil and gas exploration, salmon enhancement projects, recreational boating, and the development of the northern British Columbia coastal communities.

The physical oceanography of this stormy and remote region has historically taken a back seat to more immediate concerns in the Strait of Georgia and the southern fjords. However, the rising interest in this area has required that more oceanographic and meteorological information be provided. Over the last three years (1981 - 84), the Department of Fisheries and Oceans has conducted current meter studies of the area. The research described here augments the Department of Fisheries and Oceans current meter program by providing wave climate information.

At the commencement of this study, the wave climate of the Queen Charlotte Sound - Hecate Strait - Dixon Entrance area was virtually unknown. During the exploratory drilling carried out by Shell Canada Ltd. in the late sixties, waves of greater than 18 m significant height with a maximum height of 27 to 30 m were observed (Watts and Faulkner, 1969; James, 1969). Taken together with lighthouse observations of 20 m wave heights at Cape St. James, these data had indicated that this area has one of the most severe offshore wave climates in the world. We deployed six wave recording buoys, of three types, at strategic locations in Queen Charlotte Sound, Hecate Strait and Dixon Entrance. The buoys were located so as to provide intercomparison of directional wave measurements, good spatial coverage of the wave climate, and data suitable for wave hindcasting and forecasting with numerical models. A weather station was also installed to provide wind velocity and barometric pressure observations near the sea surface for comparison with the wave data, the surface analysis weather charts and shore-based wind stations.

In particular, this study was designed to meet several objectives:

1. to verify performance of satellite-telemetering wave buoys and to gain and document operational experience in a harsh environment;

2. to assess the performance of two new types of directional wave buoys;

3. to design and implement directional wave data processing techniques and products;

4. to document the wave climate over a long enough period (18 months) to obtain good wave statistics, both directional and non-directional;

5. to critically assess the prerequisites for successful wave hindcasting (forecasting) models in this area;

6. to analyse and interpret the local wave climate in terms of
   - spectral properties
   - non-spectral properties
   - directional properties
   - statistical properties
   - local wind characteristics

In this first volume of the final report on the wave climate study, we present the results for the first four of these objectives. Our operational experiences with the various types of instrumentation are discussed, the data processing techniques which we developed are described, and the wave observations for the eighteen month period of the study are presented.

Volume 2 of the Final Report deals with the last two objectives: the prerequisites for successful hindcasting and the various wave properties.

2. DESCRIPTION OF THE STUDY AREA

The study area consisted of northern British Columbia coastal waters within a region delimited approximately by latitudes 50-55°N and longitudes 128-134°W (see Figure 2.1). Due to the presence of the Queen Charlotte Islands, this region of the continental shelf has been subdivided into the three areas known as Queen Charlotte Sound, Hecate Strait and Dixon Entrance. The shelf/slope break extends along the outer coastlines of both Vancouver and the Queen Charlotte Islands.

It is believed that Vancouver Island and the Queen Charlottes were once attached and later separated as a result of the northward movement of the Queen Charlotte Islands along a fault of the same name. Repeated periods of glaciation further modified the bathymetry and shoreline resulting in shallow shelf regions cut by troughs, with low sills at their seaward ends, and a coastline indented with numerous inlets and fjords. The Queen Charlotte Sound region is characterized by three of these troughs, the more northerly of which extends up Hecate Strait along the mainland shore to just north of Banks Island. The remainder of Hecate Strait consists of shallow waters (<100 m) which extend across the Strait between Graham Island and the mainland. The waters deepen again in Dixon Entrance as a result of another, bifurcated trough (400 m deep) extending to the shelf break. Between the two arms of this trough lies Learmonth Bank with a minimum depth of 35 meters.

The large scale weather patterns for the study area are related to the relative strength and location of two major air pressure systems over the Pacific: the Aleutian low centered over the Bering Sea and Gulf of Alaska, and the North Pacific High off California. With the former predominant in winter, and the latter in summer, this results in generally strong south to southeasterly winds in the winter and weaker west to northwesterly winds in the summer. As indicated by Thomson (1981), winds over the study area are greatly influenced by a channelling effect due to the mountainous coastlines and speeds tend to be reduced along the mainland shore. A general seasonal pattern prevails of calm, summer weather (June, July and August), rapid increase in storm frequency and strength late September through October and a more gradual decrease in storms in the spring from April to June. Local Squamish (outflow) winds can also occur in the winter, gusting seaward down inlets or fjords, however they would have little effect on the wave climate in the areas examined during this study.

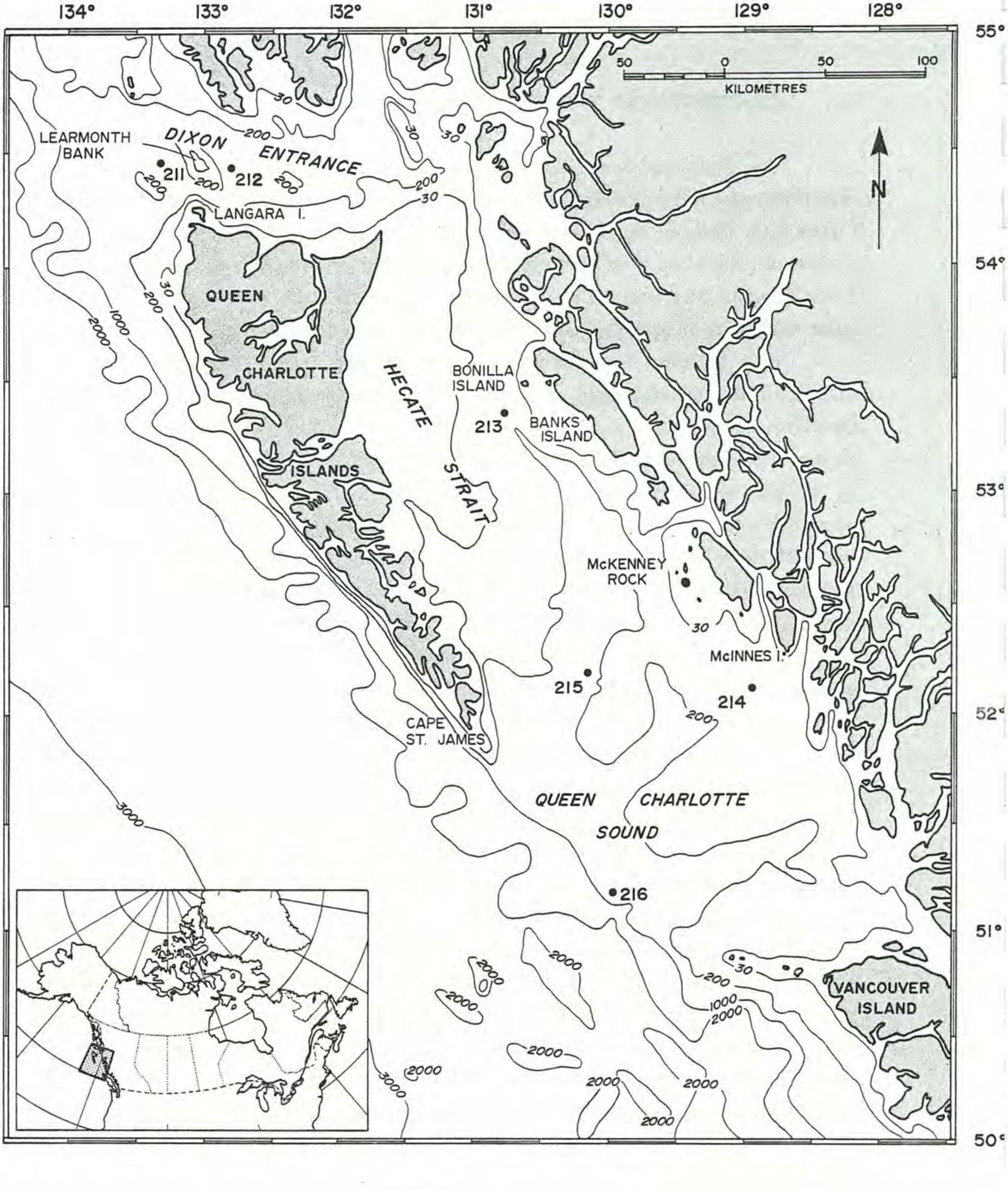


Figure 2.1 Study location map

Waters along the northern coast of British Columbia contain active areas of shipping and fishing and potentially extensive areas of oil and gas exploration and production. This area can be exposed to severe wind and wave conditions. However, there is little direct data other than from ships of opportunity and from exploratory drilling rigs in 1968 and 1969. It was during this drilling period that the largest reported wave in the study area was observed. It had an estimated height of 27-30 meters and occurred during an October storm when significant wave heights reached about 20 meters and winds were gusting to 160 km/hr (James, 1969). The rig SEDCO 135F was at the time located approximately 75 kms east of Cape St. James in 137 m of water. As a result of the much longer time series of wind measurements available, some hindcast modelling has been performed in order to estimate extreme waves for the region, (for example see Quayle and Fulbright, 1975). Wave refraction modelling has also been conducted in order to locate potential sites of wave amplification. However, without direct measurements of both wave height and period, as well as direction of wave travel, these models cannot be verified. One of the goals of this study was to develop a data base of concurrent wave measurements, over 18 months, from six locations and of nearby winds for future model verification. The chosen study sites are indicated on Figure 2.1.

The wave buoy locations were generally chosen as a compromise between areal coverage and proximity to a manned shore station. The two satellite transmitting buoys at Stns. 215 and 216 allowed for wave measurements at exposed locations, where it was expected that the most severe conditions would be observed. All of the stations, with the exception of 213, are exposed to easterly propagating swell waves from the open ocean. Some long period energy may reach Station 213 by travelling up Queen Charlotte Sound. All of the stations have reduced fetches to the east, especially true for Stations 213 and 214, while Stations 211 and 212 have land masses to the north and south limiting fetch in these directions. The presence of numerous banks and shallows can significantly affect wave direction and height. Refraction analysis has demonstrated that no significant long period energy travelling through Dixon Entrance will reach Station 213. It also indicates that Station 214 was positioned close to a potential area of wave energy focussing. The positions of Stations 211 and 212 were selected to assess the influence of Learmonth Bank on the local wave climate.

Four of the five weather stations were long term Atmospheric Environment Service (AES) stations at lighthouses near the wave buoys. Due to topographic or sheltering effects, the wind speed and direction measurements from the AES stations are affected by varying degrees of interference. We installed a satellite-transmitting weather station at McKenney Rock, where it was positioned to allow for good exposure to all wind directions.

3. INSTRUMENTATION

3.1 Overview

The testing of new wave measurement technology was an integral part of this project. Wave instrumentation has improved dramatically in recent years. Digital data logging equipment is now available to replace the strip-chart and analogue tape recording system that has been in use in Canada since about 1970; satellite transmission of wave data from buoys was introduced about 1980; and directional wave buoys began to be sold commercially in the early 1980's.

The project examined all of these new advances to test them on behalf of the Marine Environmental Data Service and to make recommendations on the best instrumentation to use.

The traditional method of wave measurement in Canada is to use Datawell Waverider buoys (Datawell, the Netherlands) with a WAREP receiver made by Datawell modified to record data on an analogue tape recorder. The WAREP has a strip chart recorder built into it which allows real-time examination of the wave data.

The problems with this instrumentation are as follows:

- The analogue data-logging facilities on the modified WAREP receiving stations are subject to various difficulties. Digitization of the data is laborious and requires specialized facilities. Good quality data tapes are becoming increasingly hard to find for reel-to-reel tape recorders. Data recording density on analogue tape is much less than on high density digital tapes.
- Transmission range of the buoys is limited by the VHF radio link to about 30 km. Since there are no internal data logging facilities, the buoys must be placed within 30 km of a shore station where the data can be recorded.
- The Datawell Waverider buoys measure only wave heave, not wave direction. Wave direction is often needed in engineering design of offshore structures.

As a part of this contract the following new instrumentation was assessed:

1. Digital Data Loggers

Sea Data data loggers were chosen because of their ability to store large data amounts on readily available inexpensive cassettes, their internal clock, digitization features, battery operation and their reputation for reliability.

2. Satellite-Transmitting Wave Buoys

Adamo Rupp Associates (Solans Beach, California) began to manufacture and sell satellite-transmitting wave (WRIPS) buoys in about 1980, using a 0.9 m Waverider buoy adapted to process data on board, to transmit the processed data to both the ARGOS and GOES satellites, and to record data internally. These buoys had not been used in Canada prior to this contract, except for one station on the east coast.

3. Directional Wave Buoys

At the time of the inception of this contract, directional wave buoys were just becoming available from three manufacturers: Nereides, France; Datawell, the Netherlands; and ENDECO, U.S.A. After much consideration, two of these systems were chosen for use with the study. The Datawell WAVEC buoy was chosen as the 'most likely to succeed' because of Datawell's long experience in wave measurement and knowledge of the extensive research which had gone into the directional wave buoy development. The ENDECO 956 WAVE-TRACK buoy was chosen as it measured wave directional components through a different "inverted pendulum" approach as opposed to the surface-following approach of the WAVEC. In addition, this buoy offered ease of management due to its small size and relatively light weight.

The following sections detail the experience which we had with each of the instrument systems that were used during the study. Tables 3.1 and 3.2 give further details.

Table 3.1

Buoy Positions

Station No.	Station Name	Buoy Type	Latitude	Longitude	Water Depth Metres	Water Depth Fathoms
211	Langara West	Waverider	54°26.9'N	133°19.4'W	293	160
212	Langara East	Waverider	54°26.2'N	132°48.3'W	381	208
213	Bonilla Island	ENDECO WAVE-TRACK	53°21.2'N	130°46.7'W	156	85
214	McInnes Island	WAVEC	52°06.8'N	128°57.5'W	189	103
215	Hecate Strait	WRIPS	52°11.6'N	130°20.5'W	370	202
216	Queen Charlotte Sound	WRIPS	51°18.5'N	129°57.6'W	270	148

Table 3.2

Instrumentation

Station	Station Name	Buoy Type	Receiver	Data Recording	Transmission/Type Frequency	Transmission Frequency (Mhz)	Recording	Typical Tape Endurance
211	Langara West	Datawell 0.9 m Waverider-F1 (heave only)	Datawell WAREP II-F	Sea Data Model 1236	continuous pulse width modulated signal	30.520	300' cassette tape	6.5 days
212	Langara East	Datawell 0.9 m Waverider-F1 (heave only)	Datawell WAREP II-F	Sea Data Model 1236	continuous pulse width modulated signal	30.320	300' cassette tape	20 days
213	Bonilla Island	ENDECO 956 WAVE-TRACK (heave and direction)	ENDECO 956 WAVE-TRACK	Sea Data Model 1236/3	18 min every 3 hours 3 channel FM	30.420	300' cassette tape	15 days
214	McInnes Island	Datawell WAVEC (heave and direction)	Datawell DIREC	Columbia Data Products 300D cartridge recorder	continuous digitally coded	30.120	DC 300 tape cartridge (450')	10 days (Note 1)
215	Hecate Strait	WRIPS (heave only)	N/A satellite transmitting	Internal Sea Data Model 633 cassette recorder	burst digital transmission to GOES/ARGOS	~401	300 or 450' cassette	15 months per 450' cassette (Note 2)
216	Queen Charlotte Sound	WRIPS (heave only)	N/A satellite transmitting	Internal Sea Data Model 633 cassette recorder	burst digital transmission to GOES/ARGOS	~401	300 or 450' cassette	15 months per 450' cassette (Note 2)

Notes: 1. 2-3 days if recording continuously
2. approximate

3.2 Datawell Waverider Systems with Digital Data Loggers

The Waverider buoy measures wave height (heave) using an accelerometer. The output of the accelerometer is double integrated (electronically) to produce a square wave signal which is proportional to wave height. This signal is continuously transmitted to the receiving station. The Waverider buoy can be used to measure waves with periods of 2 seconds to 30 seconds when the transfer functions are properly applied.

Two Waverider systems were deployed off Langara Island at stations 211 (Langara West) and 212 (Langara East), near Learmonth Bank. The larger (0.9 metre diameter) buoys were selected because of their additional buoyancy, as the moorings were in relatively deep water with strong currents. The two radio signals were received by two unmodified Datawell WAREP Mark II-F receivers installed at the Langara Point light station (a transmitting distance of 23 km). The two receivers shared a single receiving antenna through a custom-made antenna coupling device. The receivers were set to be permanently on, with the recording controls bypassed. The analog signal from each WAREP was output to a Sea Data Model 1236 cassette data logger operating in the burst sampling mode. All aspects of the sampling (including digitization of the signal) were carried out by the data logger. Eleven bit digitization of the heave signal was available. The sampling rate, recording duration and sampling interval were set using switches on the front panel of the logger and controlled by an internal clock/counter. This system was not capable of switching to a continuous recording mode when the wave height exceeded a preset threshold.

At Station 211 (Langara West), a sampling program of 34 minutes recording of data sampled at 0.5 second intervals every hour beginning on the hour, was selected. This gave a typical tape capacity of 6 days of data per 300 feet of cassette tape. At Station 212 (Langara East), there was a reduced sampling program of every three hours (0000z, 0300z, 0600z, 0900z, 1200z, 1500z, 1800z, 2100z). Typical tape capacity with this sampling regime was 20 days of data per 300 foot cassette tape.

3.3 ENDECO 956 WAVE-TRACK System

The ENDECO WAVE-TRACK system measures wave height and direction by a uniquely designed wave orbital following buoy (see Figure 3.1). The sensor package contains an accelerometer, and two tilt sensors consisting of small reservoirs of mercury with capacitance sensors to detect any movement of the mercury. These pitch and roll sensors measure buoy tilt induced by the shear in the wave orbital velocities acting on the "inverted pendulum" buoy shape (see Figure 3.1). Output from a two-axis flux gate compass is used to transform the measured tilt components to magnetic N/S and E/W. The WAVE-TRACK buoy experiences maximum tilts at wave crests and troughs with minimum tilts at mean sea level. The buoy is designed to measure waves having periods from 2 seconds to 30 seconds. The sensor signals are processed and multiplexed within the buoy for transmission as three FM signals (heave, tilt N/S, tilt E/W).

The buoy is powered by a lithium battery pack with a relatively limited lifetime. In order to reduce battery consumption, timing circuitry allows the operator to select the sampling duration and interval. Between transmissions, both the transmitter and sensor electronics are turned off to conserve power. A transmission schedule of 18 minutes every three hours was selected to allow for the required 9 month battery lifetime between servicing trips.

The receiving unit for this system (ENDECO 956 WAVE-TRACK receiver) was installed at the Bonilla Island light station, a distance of 15 km from the buoy. The receiver demultiplexes the three buoy signals and supplies both digital and analog outputs. Due to the rather coarse resolution of the digital output provided (8 bit in heave), Seakem elected to use a Sea Data Model 1236/3 data logger to digitize and record the data, along with a time counter and other parameters. This provided 11-bit digitization of the heave signal and 8-bit digitization of the two tilt signals. This Sea Data recorder was used in the continuous sampling/external enable mode such that the recorder was turned on whenever the receiver detected and locked onto a RF carrier signal. This compensated for any drifing of the timed buoy transmissions out of scheduled recording periods. The selected sampling program was for 18 minutes of buoy data transmission sampled at 0.5 second intervals every 3 hours.

3.4 WRIPS (Waverider Information Processing System) Buoys

Adamo Rupp and Associates have developed a highly modified Datawell Waverider buoy for use in remote locations, where normal telemetry of data to a shore station is not possible. It contains a Bristol Aerospace Data Collection Platform (DCP) which digitizes the accelerometer output, controls and executes

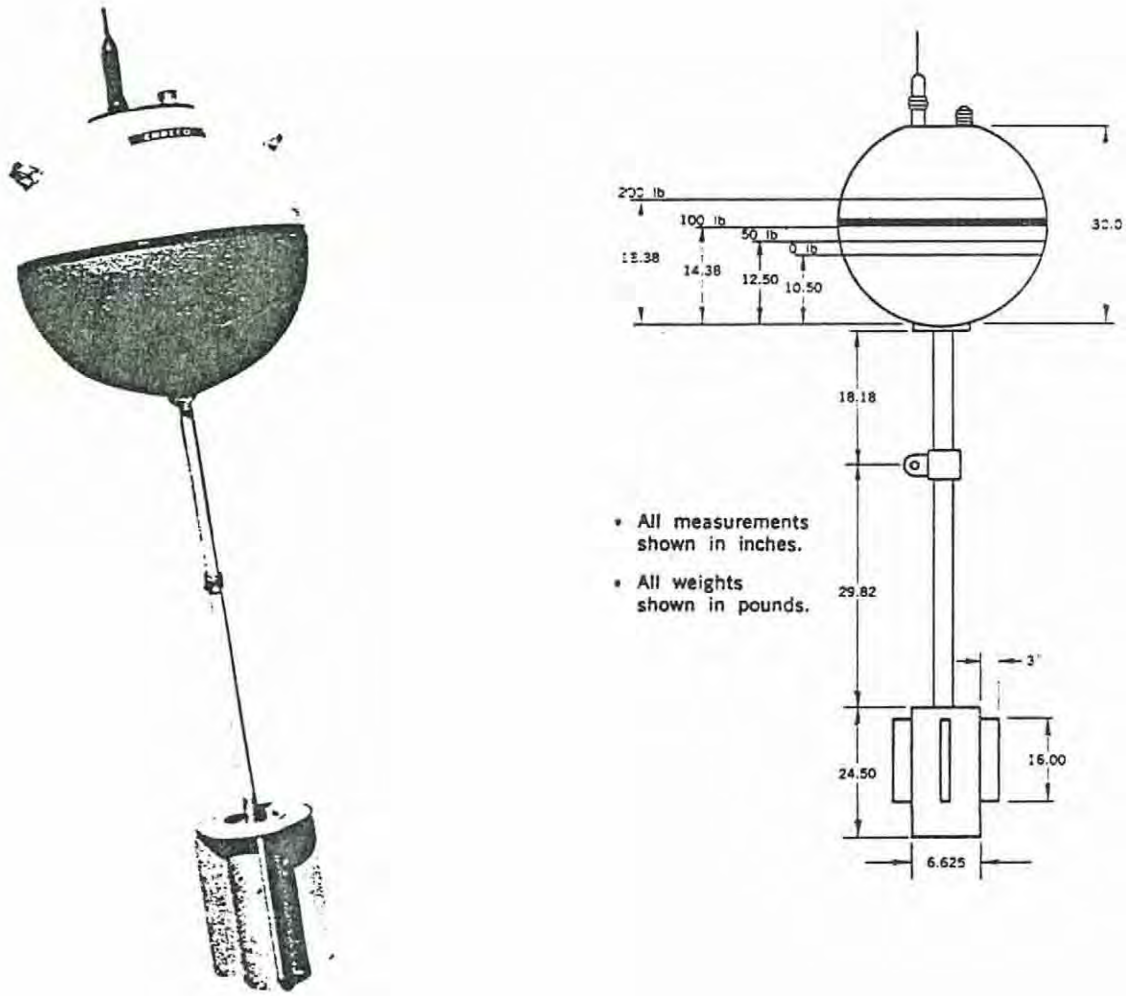


Figure 3.1 Schematic of ENDECO WAVE-TRACK Buoy.

spectral data processing. Data is recorded on an internal Sea Data Model 633 recorder, and processed data is transmitted via GOES and ARGOS satellite systems. The Leclanche batteries provided with the standard buoy have been replaced with eight lithium battery packs, giving the buoy an operational lifetime of more than 20 months.

The WRIPS system allows for near real-time acquisition of processed wave data, through the control and data distribution system at NESDIS. In addition, data summaries and updated buoy positions are also available through Service ARGOS. The timing of data acquisition, recording and transmission are controlled by the DCP with a three hour cycle starting with the GOES data transmission in an assigned time slot. As a result, the data acquisition periods do not coincide with the other wave buoy stations.

The sampling program utilized by the WRIPS buoy is approximately 34 minutes of data sampled at 1 second intervals, every one and a half hours. Though spectra are transmitted only every three hours, information on the significant wave heights and peak period for the mid-point of the cycle (i.e. for one and a half hours into the data acquisition/transmit cycle) are available. The transmitted spectra are written to the internal cassette, as well as one complete time series every 72 hours. In addition, whenever the significant wave height exceeds 4.88 m, the three hourly sampled time series are written to tape. No continuous recording option is available.

3.5 Datawell WAVEC System

The Datawell WAVEC system utilizes a Datawell Hippy-120 heave/pitch/roll sensor and a three- axis fluxgate compass mounted in a surface slope following buoy (see Figure 3.2). The heave signal is again obtained via a double integration of the accelerometer signal. Pitch and roll measurements are determined from the induced voltages in a pickup coil mounted on a gravity stabilized platform that moves in relation to two alternating magnetic fields generated parallel to the pitch and roll axis. The output of the three axis fluxgate compass is used to determine buoy orientation relative to the local earth's magnetic field. Heave, pitch and roll voltages, the three magnetic field components, status and battery voltage are sampled every 0.78125 secs and transmitted continuously to a DIREC receiver on shore.

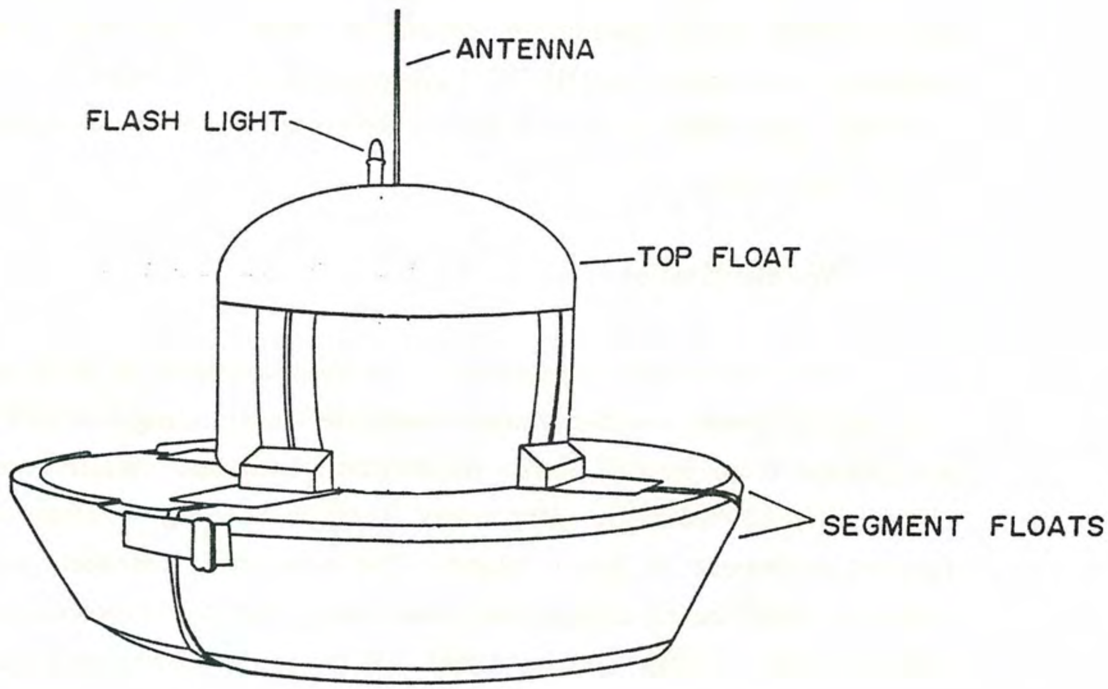


Figure 3.2 Schematic of a Datawell WAVEC Buoy.

The DIREC receiver contains a micro-processor which performs error checking of the transmitted data (for quality and continuity), and controls data output to the recorder. A computer terminal connected to the DIREC allows an operator to obtain real-time output, monitor battery voltage, and control the recording duration and interval. In addition, a continuous recording mode can be selected when wave heights exceed a pre-determined threshold. Time and date information are supplied at the start of each record cycle output to the auxiliary (recorder) port.

A Columbia Data Products 300D cartridge recorder was used to record the data. With a record duration of 34 minutes every three hours, a 450 foot tape was sufficient for approximately 10 days of recording. When in continuous mode, a cartridge was filled in 2 to 3 days. Recorded tapes were mailed to Seakem for further processing.

3.6 Weather Station

In order to obtain representative measurements of wind speed and direction over Hecate Strait, a self-contained satellite transmitting (via GOES) weather station was leased from Petro-Canada Exploration Ltd. and installed on McKenney Rock (52°39.1'N, 129°28.3'W). McKenney Rock is a small treeless outcrop of granite located southwest of Moore Island. The site was moderately well protected from waves by surrounding shoals and small islets, but the exposure to winds from ESE through south to NNW was excellent. A ten meter tower was erected on the island (elevation at tower base was 18 meters above high water) to carry the sensors. The following sensors were installed:

- wind speed (2)
- wind direction (2)
- air temperature(2)
- relative humidity(2)
- barometric pressure(1)

A Handar Model 530 Data Collection Platform (DCP) was used to sample output from the sensors and control the transmissions to the GOES satellite. The data from the weather station were sampled hourly and stored until the transmission time. Wind speed and direction were one minute average values. The system was powered by a 12-volt lead-acid battery which was recharged using a solar collection panel.

3.7 Atmospheric Environment Service Wind Data

Wind speed and direction measurements taken at Cape St. James, Langara Island, Bonilla Island and McInnes Island were collected to aid in interpretation of the wave data. The wind data were transcribed from copies of the weather observations archived at the Pacific Weather Centre in Vancouver. The wind speed and direction recorded are one minute averages. The exposure of the wind sensor varies between sites, and estimates of both wind speed and direction may be poor for certain wind directions (see Section 7 for details).

3.8 Moorings

The moorings used in this program can be divided into three types:

1) Waverider/WRIPS - four moorings in water depths between 270 - 381 metres.

2) ENDECO WAVE-TRACK - one mooring in water depth of 158 metres.

3) WAVEC - one mooring in water depth of 182 metres

For all moorings, the following principles were followed:

a) Taut-line moorings with subsurface buoyancy were employed to reduce vertical line tensions for Waverider/WRIPS and WAVE-TRACK buoys.

b) Synthetic line was employed in preference to wire rope for ease in handling and to minimize corrosion.

c) The mooring design was such that the surface buoy retained some reserve buoyancy under "worst case" conditions of a surface current of 1.51 m/sec (3 knots) and a current decreasing linearly with depth to 0.26 m/sec (0.5 knots) at the bottom.

d) Two rubber cords in series were employed at the exposed stations (211, 212, 215 and 216) allowing the buoys to follow very large waves without submerging.

A modified version of the computer model developed by W.H. Bell at the Institute of Ocean Sciences (Bell, 1977) was employed to analyse the effects of subsurface buoyancy and drag on the wave buoy and anchor loading.

For the Waverider/WRIPS buoys, the general mooring plan was to position subsurface buoyancy, of approximately 2600 N (600 lb), at a depth of 75 metres with a taut mooring line of 11 mm (7/16") nylon double braid rope running to the anchor. The surface tether was composed of 105 m of 13 mm (1/2") polypropylene single braid rope, two 15 m rubber cords, and a final length (30 m) of 13 mm (1/2") polypropylene rope attached to the ballast chain of the buoy.

The ENDECO WAVE-TRACK buoy required a similar mooring (despite the much shallower water depth of 156 m) due to the low buoyancy and high drag of the "inverted pendulum" design. For this installation, subsurface buoyancy of about 2600N (600 lbs) at a depth of 20 metres was employed, with a surface tether composed of 30 metres of 13 mm (1/2") polypropylene line and 17 metres of ENDECO 996 Mooring accumulator (rubber cord) connected to the mooring staff of the WAVE-TRACK buoy.

The mooring for the WAVEC was a "slack-line" mooring of three-to-one scope with a combination of negatively and positively buoyant synthetic line being employed to prevent both chafe on the sea floor and exposure of the mooring line to passing vessels. In addition, a nylon safety line was used to guard against over-extension of the rubber cord under extreme conditions. With the large buoyancy of the WAVEC buoy, such over-extension could result in mooring failure if a standard rubber cord was used.

4. OVERVIEW OF FIELD WORK

4.1 Scheduled Trips

The original schedule called for the installation of all the wave buoys in September, 1982, with a servicing trip to replace batteries and mooring components in July 1983, and the final recovery in April 1984. This basic schedule was followed but mooring failures, equipment failures and the late delivery of the WAVEC buoy meant that unscheduled field trips to the area were required. A local fishing vessel, the MV Arrawac Freighter, was chartered for the major service trips. Assistance from a number of government vessels was solicited for some of the contingency trips to recover defective equipment or re-deploy repaired equipment. Table 4.1 summarizes the deployment records for each station.

The buoys for Station 216 (Queen Charlotte Sound), Station 215 (Hecate Strait), Station 213 (Bonilla Island), Station 212 (Langara East) and Station 211 (Langara West) were deployed on the first trip to the study area during the period September 23 to October 7, 1982. Stations 215 and 216 (WRIPS buoys) were operational immediately upon deployment, but separate trips to Bonilla Island and Langara Island (by helicopter) were necessary to install the receiving and data logging equipment. Station 211 (Langara West) was brought into operation on October 22, Station 213 (Bonilla Island) on November 4, and Station 212 (Langara East) on November 6, 1982.

The satellite- transmitting weather station was installed by Petro Canada and Seakem personnel on McKenney Rock during the period October 25 to November 1, 1982. Poor weather conditions and difficult access to the area (helicopter from Port Hardy) hampered this work and greatly increased its expense. The weather station was brought into operation on November 1, 1982.

The WAVEC buoy was delivered to Seakem in January, 1983 and was deployed at Tofino, B.C. (near an existing Waverider at MEDS Station 103) for a test period from January 15 to April 12, 1983. The buoy was the first production unit of its type, so this deployment was considered necessary to allow for familiarization with the system and to provide a preliminary field trial in a relatively accessible location.

The scheduled service trip was conducted from June 29 to July 7, 1983. A new transmitter was installed in the WAVEC buoy at Station 214 (McInnes Island) and a repaired receiver set up at the shore station on June 30. The WRIPS buoy at

Table 4.1

Buoy Operation Log

Station	Time In (GMT) Hr/D/M/Yr	Time Out (GMT) Hr/D/M/Yr	Comments
211:			
Deployment I	0000/22/10/82	1700/03/12/83	hourly recording started at 0400/7/11/82
Deployment II	1900/03/12/83	2100/04/05/84	Mooring fouled and cut by fishing vessel in May, 1984
212:			
Deployment I	0300/21/10/82	0300/03/05/83	First good recording at 2205/6/11/82 Broken antennae lead on 3/5/83
Deployment II	0035/07/07/83	0000/22/11/83	Buoy failure in November, 1983
Deployment III	1200/22/01/84	0115/25/05/84	Final recovery in May, 1984
213:			
Deployment I	0014/05/11/82	1228/28/05/83	Time of last good record. Buoy adrift until recovery in July. No directional data from 1/3/83 to recovery
Deployment II	1625/18/09/83	1208/16/01/84	Buoy adrift in January, 1984
214:			
Deployment I	1650/19/04/83	1915/29/06/83	First recording at 2100/21/4/83 Last recording at 900/14/5/83. Transmitter/receiver problems.
Deployment II	1910/30/06/83	0600/25/10/83	Broke up on mooring in October, 1983
Deployment III	2124/20/02/84	1501/15/05/84	Problems with slope from 25/3/84 to final recovery
215:			
Deployment I	2257/01/10/82	1430/20/04/83	GOES transmission stopped 0157/20/1/83
Deployment II	1057/02/07/83	2300/24/10/83	Redeployed at 0230/2/7/83
Deployment III	2145/12/01/84	2200/20/05/84	Final recovery.
216:			
Deployment I	0153/30/09/82	1853/22/03/83	Buoy adrift from 28/2/83
Deployment II	0510/20/04/83	0000/03/12/83	GOES transmission stopped 5/11/83
Deployment III	1645/12/01/84	1200/21/05/84	Final recovery

Station 215 (Hecate Strait) was deployed on July 2, 1983. The Waverider buoy at Station 211 (Langara West) was serviced and re-deployed on July 6, 1983. The defective Waverider buoy at Station 212 (Langara East) was replaced on July 7, 1983.

A final recovery operation was carried out during the period May 14-25, 1984. In addition, the Petro-Canada weather station at McKenney Rock was serviced during this trip by personnel from Pro-Met and Seakem.

4.2 Contingency Trips

Throughout November and December, 1982, problems were encountered with data transmission at Station 213 (Bonilla Island - ENDECO WAVE-TRACK) during storms. In an attempt to alleviate this problem, the original receiving antenna (a high gain directional antenna supplied by the manufacturer) was replaced with a Kathrein omnidirectional antenna mounted on the light tower on the highest part of the island. This appeared to improve reception until very strong radio interference, caused by a malfunctioning radio beacon on the island, obliterated much of the transmissions from January until February, 1983. When this problem was resolved, we discovered that there was a failure in the demultiplexing circuitry of the receiver such that only one of the two tilt channels was being properly recorded. As a result, no directional information could be obtained from the data acquired from January to May, 1983.

On January 20, 1983, the GOES transmitter for the WRIPS buoy at Station 215 failed. It was returned to Bristol Aerospace for repairs.

On February 22, 1983, the WRIPS buoy at Station 216 (Queen Charlotte Sound) was discovered to be out of position. The buoy remained adrift with its position being closely monitored using the ARGOS system until March 22, 1983, when a recovery mission was mounted. By the combination of spotter aircraft and the assistance of the CFPV Tanu, which was directed to the buoy, a successful recovery was achieved. The cause of the mooring failure appeared to be a severed rubber cord.

The WAVEC buoy and shore station were deployed at McInnes Island during a trip to the area April 18 - 22, 1983. The WRIPS buoy at Station 216 was re-deployed and the WRIPS buoy at Station 215 (Hecate Strait) was recovered, as GOES transmissions from this unit had not been received since January 20, 1983. The failure was in the transmitter and did not affect the DCP operation, so no data were lost.

The Waverider buoy at Station 212 (Langara East) stopped transmitting on May 3, 1983. We suspected that the buoy had been cut adrift and an aircraft search, with radio direction finding equipment, was attempted but without success. No attempt was made to search for or recover the buoy by ship. This buoy was later recovered from its moored position in July, 1983, and it was found to have failed due to a broken antenna lead within the antenna spring which may have resulted from damage during deployment.

On May 14, 1983, data recording at McInnes Island ceased due to telemetry problems. Following consultation with the manufacturer, a service trip was undertaken on May 26, 1983, by helicopter to attempt to retune the DIREC receiver. This was unsuccessful and the DIREC was removed and returned to the manufacturer for repairs and modifications. This station was out of operation until June 30, 1984, when a new transmitter was installed in the buoy and a repaired receiver set up at the shore station during a scheduled service trip to the area from June 29 to July 7, 1983.

The ENDECO WAVE-TRACK buoy ceased transmitting on May 28, 1983. We assumed the cause to be battery exhaustion, but when we arrived to perform the servicing on July 2, 1983, the buoy was not on station. A ship and aircraft search was undertaken without success. The WAVE-TRACK buoy was subsequently recovered near Ketchikan, Alaska, in heavily damaged condition. It was returned to the manufacturer for repair.

Transmissions from the WAVEC buoy were no longer received after October 25, 1983. A mooring failure was suspected and two aerial surveys were undertaken to attempt to locate the buoy. Following the recovery of a single flotation segment from Rose Spit on Graham Island, it was concluded that the buoy may have broken up on its mooring. Inspection by a Coast Guard vessel revealed the buoy to be on station, supported by the top float only. The remains of the buoy (instrument canister plus top float) were subsequently recovered by the CCGS George Darby and returned to Victoria. Following consultation with the manufacturer, replacement flotation sections were prepared and shipped to Seakem.

On November 17, 1983, the WRIPS buoy at Station 215 (Hecate Strait) was discovered to be out of position. The position was monitored and a recovery mission mounted on November 24, 1983. As with the previous recovery, an aircraft was used to spot the buoy and direct a Fisheries Patrol Vessel (CFPV Kitimat II) to the buoy.

The crew of the Kitimat II were able to "lasso" the buoy and tow it to sheltered waters, where the buoy was then hoisted aboard. The cause of the mooring failure was a severed rubber cord.

On November 5, 1983, GOES and ARGOS transmissions ceased from the WRIPS buoy at Station 216 (Queen Charlotte Sound). The buoy was recovered from its mooring by the crew of the fishing vessel Jeannie Marie, on charter to the Pacific Biological Station, Nanaimo, B.C. When the buoy was returned to Sidney, the antenna housing was discovered to contain water. There was no obvious site where the water could leak into (or drain from) the housing with the possible exception of the rivets for the nameplate.

On November 22, 1983, the Waverider buoy at Station 212 (Langara East) began to exhibit a highly variable mean sea level and erratic surface elevation trace. This behaviour indicated a serious defect in the accelerometer (such as a twisted suspension).

In January, 1984, a service trip to the area was made possible through the generosity of the Tides and Current group and the Institute of Ocean Sciences. The WRIPS buoys at Stations 216 and 215 were re-deployed from the CSS Parizeau which was conducting CTD and current meter work in the area. In addition, the defective buoy at Station 212 (Langara East) was exchanged for an operational unit on January 22, 1984, by Tides and Currents personnel.

On January 5, 1984, the heave channel of the ENDECO WAVE-TRACK buoy failed. Following consultation with the manufacturer, the receiver was returned to Seakem for inspection and adjustments. During the period February 6 - 20, 1984, attempts were made to re-deploy the WAVEC buoy at McInnes Island and to return the ENDECO WAVE-TRACK system to operation. On arrival at Bonilla Island on February 10, 1984, very short (~5 seconds) transmissions from the buoy were observed. Poor weather conditions precluded a search for the buoy until February 16, 1984, when an unsuccessful ship search was conducted. In addition, Coast Guard helicopter pilots made several attempts to sight the buoy, without success. On March 15, 1984, the ENDECO buoy was recovered in Ketchikan, Alaska. The mooring line had been severed. The WAVEC buoy was re-deployed off McInnes Island on February 20, 1984.

The WAVEC buoy was damaged during high seas on March 25, 1984, resulting in the displacement of a single flotation segment and large mean buoy tilts.

On May 4, 1984, a fishing vessel reported that it had fouled and parted the Waverider mooring at Station 211 (Langara West). The crew managed to recover the buoy and left it at Shearwater, B.C. for retrieval by Seakem personnel during the final recovery operations.

No wave buoys were lost during the study and an overall 70% data return was maintained over the period of the contract despite the prototype nature of the directional wave buoys and the propensity of the fishing fleet to "fish out" the buoys.

5. DATA PROCESSING

5.1 Wave Data

At the onset of the study, a data handling scheme had to be established for the four different types of wave measuring systems. It was designed to have the following characteristics:

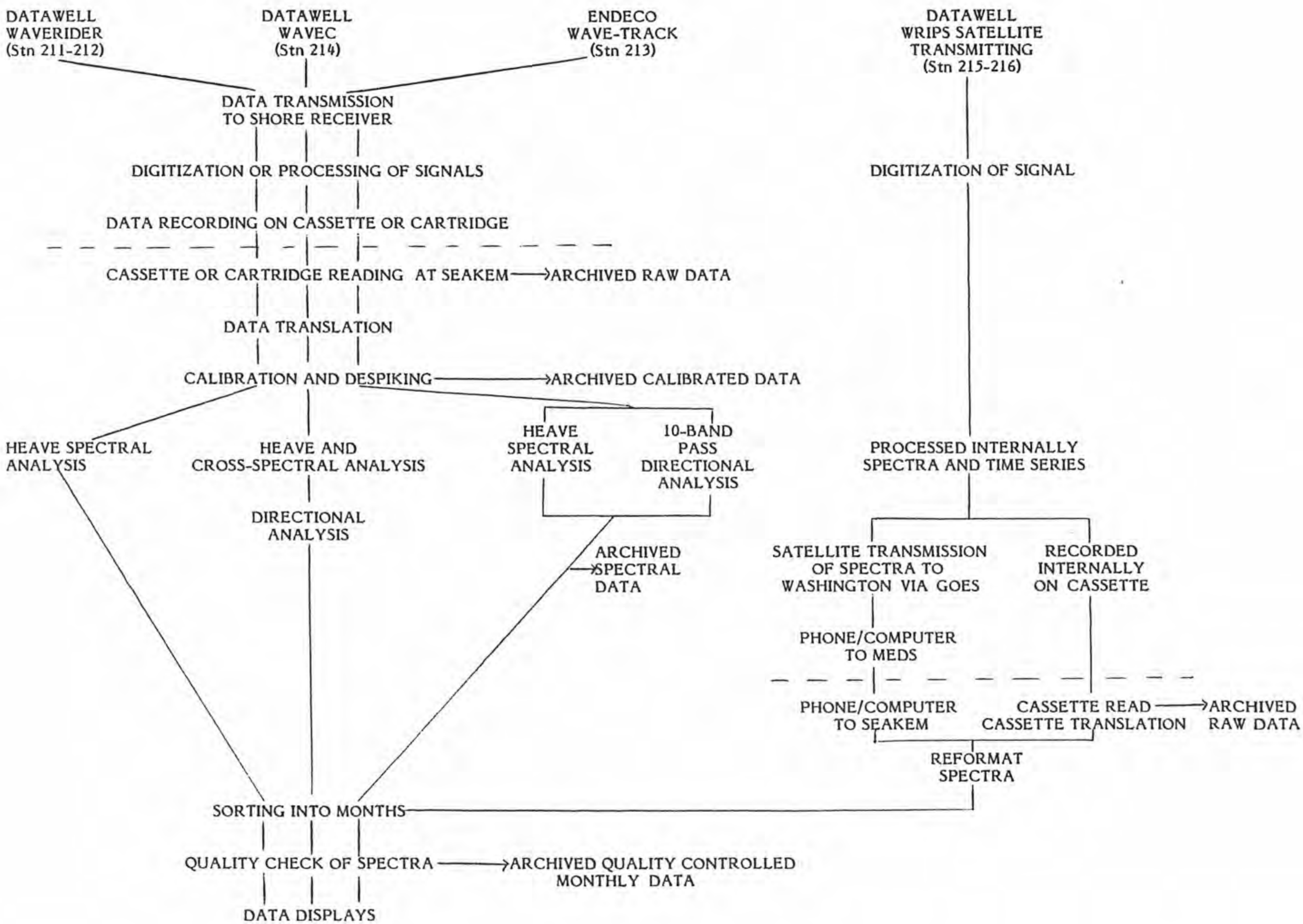
- Minimum delay between data recording and initial data processing to ensure that the instruments were operating properly.
- A system for logging and archiving the large amount of information being collected for future reference.
- A data processing scheme which would concentrate on the similarities between the instruments, ensure the maximum amount of data recovery possible, incorporate wave directional analyses and meet MEDS standards.
- Suitable methods to display the processed data.

Figure 5.1 contains a flow chart of the wave data handling procedure that was finally adopted. Once the data were recorded (i.e. non-WRIPS buoys), the cartridges and cassettes were mailed to Seakem for processing. A delay of more than a month could occur for some stations because incoming and outgoing mail from the lighthouses are dependent on helicopter visits which are at times delayed due to weather or mechanical problems. On only one occasion, July 2-9 for Station 211, was there data loss as a result of a break in tape supply to the lighthouses.

The two satellite-transmitting WRIPS buoys processed the heave data internally and sent processed spectral information via the GOES satellite to a receiving station in Washington, D.C. By phone/computer link, MEDS in Ottawa retrieved this information daily and, in turn, Seakem's computer acquired the data every night. The spectral information and selected time series were also recorded, on cassette, within the WRIPS buoys. These cassettes were retrieved during servicing of the buoys and the data were used to fill in gaps in the transmitted records.

Information logging was initiated with the lighthouse keepers writing on each cassette or cartridge the time and date of its insertion and removal. They also supplied, when necessary, details of any problems which could affect data recovery (eg. power failures; accidental data loss due to switch settings; equipment

FIGURE 5.1. INFORMATION FLOW CHART



malfunctions). This information became part of a work log which also included the dates of completion of each processing step, the dates that the chosen files were archived and the location of these files. During data translation and calibration, a computer- generated log file would detail specific information on each record (i.e. number of scans in the record, time and date) as well as any problems with the data (i.e. parity errors, missing scans, spikes). These were kept and later used to assess data quality and data return.

A standardized data processing scheme was developed for each wave buoy. Table 5.1 details the relevant processing information for each wave station. Briefly, wave data processing consisted of the following steps:

1) Data Transfer

At the beginning of the study, data cassettes from the Waveriders and Wave-Track buoy were read at CCIW and the files supplied on nine-track tape to Seakem. After February 1983, the cassettes, and later the WAVEC cartridges, were read in-house and the data transferred, without any modification, to a file for archiving and processing. During servicing of the WRIPS buoys, the internally- recorded cassettes were recovered and treated similarly.

2) Data Translation

During this step, record times were assigned, any instrument- supplied quality codes or scan counters were examined so that missing or bad data could be padded with flag values, and, if necessary, the data were converted to decimal representation.

Sufficient information was generally supplied by both the Sea Data recorders (Stn. 211, 212, 213) and the DIREC receiver (Stn. 214) so that unambigious time assignments could be made. However, minor complications arose when the time counters, for the recorders at Station 211 and 212, "wrapped-around" (i.e. overflowed) during a period of recording problems. The DIREC receiver at Stn. 214 incorrectly handled leap years (February 1984 had 29 days), so that subsequent record times were shifted by one day. The DIREC also did not record any time information during periods of continuous recordings.

TABLE 5.1

DATA PROCESSING INFORMATION

	211	212	213	214	215	216
Sampling Schedule (Hrs)	1.0	3.0	3.0	3.0 (1)	3.0 (2)	3.0 (2)
Sampling Duration (Min)	34	34	18	34	34	34
Sampling Interval (s)	0.5	0.5	0.5	0.78125	1.0	1.0
Block Size for Spectral Analysis	256	256	256 (2048 for Band-Pass Analysis)	256	256	256
No. of Frequencies	60	60	60 (10 for Band-Pass)	64	27	27
Frequency Resolution (hz)	.0078125	.0078125	.0078125 (Heave) (3)	.005 if F <.2 .01 if F > .2 (4)	.00390625 (5)	.00390625 (5)
Lowest Frequency (hz)	.0390625	.0390625	.0390625 (Heave) .038 (Band Pass)	.035	.03125	.03125
Maximum No. of Blocks	16	16	8	10	8	8

Notes:
1. In 1984 data, buoy was set to record continuously if the RMS wave amplitude >1.0 m. ($H_s > 4.0$ m)
2. During normal operations, a spectrum was calculated every 3.0 hours while the raw time series were written onto tape every 3 days. During storm conditions, the raw time series for each record was recorded.
3. The frequency assignments for the 10 frequency Band-Pass analysis were .038, .047, .060, .075, .097, .127, .171, .225, .292, .417 hz.
4. Two band averaging was performed for frequencies greater than or equal to .2 hz.
5. This was true for the first 20 frequencies; for higher frequencies band averaging was performed (4, 4, 6, 9, 13, 21, 43 bands averaged for frequencies 21 to 27 respectively).

3) Data Calibration and Despiking

The raw data, as scaled voltages, were converted to SI units and examined for spikes. The spike criteria was set as four times the standard deviation of the record or the instrument measurement range, whichever was smaller. If a spike was found it was replaced by an interpolated value. In order to maximize the amount of data which later passed through the spectral analysis, the data from Stn. 211, 212 and 214 were treated as blocks of 256 scans. If more than seven consecutive spikes were found, or if more than 10% of the data were bad, the block was rejected and a new one started. For WAVEC data (Stn. 214), a cross-spectral analysis must be performed between the heave and slope measurements, so each of the three data channels must simultaneously conform to the acceptance limits. This is also true for WAVE-TRACK data (Stn. 213), however the block size was set to the entire record because the 10 frequency Band-Pass directional analysis requires an uninterrupted time series. In this case, if seven spikes in a row were found, the largest unbroken section of data was saved. This requirement generally resulted in more data being rejected for the WAVE-TRACK buoy than for either the Waveriders or WAVEC buoy.

4) Spectral Analysis

For both the Waveriders and the WAVE-TRACK buoy, a spectral analysis was performed on the heave time series. This required an initial separation of each 18 or 34 minute record into blocks of 256 points, which in turn were demeaned and passed through a Fast Fourier Transform. The Fourier coefficients were then corrected using the instrument specific transfer functions and combined to obtain energy density values for each frequency. These were then truncated to lie between 2 and 30 seconds. Ensemble averaging of the spectral values from each block was performed and spectral statistics calculated. These statistics were stored in a header and included the spectral moments, significant wave height, spectral peakedness, spectral width parameter, spectral narrowness parameter, peak period, average period, average apparent period, and apparent crest period. Details on the transfer functions applied and definitions of the spectral statistics are included in Appendix 3.

A similar procedure was used for the WAVEC data (Stn. 214) except that a cross-spectral analysis between the heave and NS and EW slope time series was required. This resulted in nine co- and quadrature spectral estimates which, as in the heave spectral analysis, were truncated to lie between 2 and 30 seconds and ensemble averaged. Because of the higher frequency resolution obtained (see Table 5.1), two-band averaging was also performed for frequencies above or equal to 0.2 hz, to reduce the number of frequency estimates stored.

5) Direction Calculation - Datawell WAVEC

The mean direction, angular spread and cosine spread factor were calculated for each frequency band according to the method of Longuet-Higgins et al. (1963) and Hasselman et al. (1980) using selected co-and quadrature spectral estimates in the following manner:

The directional spectrum can be written as:

$$E_n(f,\theta) = E(f)\,D(f,\theta)$$

where

$E(f)$ is the uni-directional heave spectrum

and $D(f,\theta)$ is a spreading function such that

$$\int_0^{2\pi} D(f,\theta)\,d\theta = 1$$

$D(f,\theta)$ can be written by the expansion:

$$D(f,\theta) = 1/2 + \sum_{n=1} (a_n \cos(n\theta) + b_n \sin(n\theta))$$

which is normally truncated at $n = 2$

The values for the coefficients a_n and b_n are obtained from the cross-spectral estimates:

$$a_1 = \frac{QD\,12\,(f)}{K\,E(f)\,\pi} \qquad\qquad a_2 = \frac{CO33(f) - CO22(f)}{K^2\,E(f)\,\pi}$$

$$b_1 = \frac{-QD\ 13(f)}{K\ E(f)\pi} \qquad\qquad b_2 = \frac{-2CO23(f)}{K^2\ E(f)\pi}$$

where K is the wavenumber, 1 = heave, 2 and 3 = slope

CO## = co-spectral estimate and QD## = quadrature spectral estimate

The various directional properties of interest for each frequency were obtained. These included:

mean direction (according to Hasselman et al., 1980):

$$\theta_m\ (f) = \mathrm{Tan}^{-1}\left(\frac{-QD13(f)}{QD12(f)}\right)$$

angular spread (according to Longuet-Higgins et al., 1963):

$$S_1(f) = \left(\frac{CO11(f)\ \ -\ \text{fact } 1}{CO11(f)\ \ +\ \text{fact } 1}\right)^{1/2}$$

where

$$\text{fact } 1 = 1/K^2\ *\ \left(\left(CO22(f) - CO33(f)\right)^2 + \left(2\ CO23(f)\right)^2\right)^{1/2}$$

Cosine spread (according to Hasselman et al., 1980):

$$S_2(f) = \frac{2 * \text{fact } 2}{CO11(f) - \text{fact } 2}$$

where

$$\text{fact } 2 = 1/K\ *\ \left(QD12(f)^2 + QD13(f)^2\right)^{1/2}$$

The mean direction was corrected for magnetic declination. The direction at the spectral peak was determined and stored, along with the other spectral statistics, in the record header. The angular spread, $S_1(f)$, also known as the long-crestedness parameter, can be scaled by 90° and is then almost equal to the RMS angular deviation of energy when the spectrum is narrow. The cosine spread is the power to which a cosine function, used to model the directional spread, is raised. i.e., when $D(f,\theta)$ has the form:

$$D\,(f,\theta) \sim \cos^{S_2(f)}(\theta - \theta_m(f))$$

The cosine spread value has been the accepted method for describing directional spectral shape. The shape can also be described by calculating directly the moments of the Longuet-Higgins expansion or by assuming various other distributions such as a Poisson Kernel or wrapped normal.

6) Direction Calculation - ENDECO WAVE-TRACK

The ENDECO 10 frequency Band-Pass directional analysis software provided by ENDECO Inc., was used to obtain estimates of mean wave direction and spread. A 26 frequency Band-Pass analysis was also available but was not used. The procedure involved sending each entire 18 minute heave and tilt record individually through an FFT, correcting with the instrument transfer functions, applying a band-pass filter for each of the 10 frequency bands required, then performing an inverse FFT to reconstruct a single frequency time series of the three channels. A zero-crossing analysis on the reconstructed heave signal located the wave crests, and the direction at each wave crest was then calculated from the corresponding tilt values. These directions were summed, averaged, the standard deviation (or angular spread) found, and the direction corrected for magnetic declination.

ENDECO Inc. also supplied software to perform an equivalent Longuet-Higgins type directional analysis. This software was tested but was not used routinely to process data. The Longuet-Higgins approach assumes a surface following buoy, and in our opinion the method used to convert the ENDECO buoy tilts to equivalent surface slopes was not adequately justified.

7) Sorting

The spectral records were sorted into monthly files. For the ENDECO WAVE-TRACK buoy, a second program was necessary to extract the direction at the spectral peak from the output of the directional program and to insert it into the proper record header of its heave spectral file.

8) Satellite Data

Every night, the computer at MEDS would be automatically contacted and any data from the WRIPS buoys would be transferred to the Seakem computer. These files were then sorted by station and formated to conform to the output from step 7 and to allow proceeding to step 9.

The internal cassettes from the WRIPS buoys were read using a Sea Data reader. The file, consisting of spectral records and time series, was sorted such that two new files were generated, one containing the spectral information in the same format as that obtained nightly from MEDS and the other, containing the time series information, resembling the output of step 3.

9) Quality Control

Every spectral record was checked visually for quality by plotting the data on a CRT Graphics terminal. Bad records were flagged and not used in any of the data displays. In most cases, a "bad" record was one for which too few data blocks (less than 7) were available for ensemble averaging thus reducing the confidence in the spectral estimates. Other problems encountered included spurious low frequency energy (for Stn. 213 - WAVE-TRACK buoy) and phone line interference resulting in frequency scrambling of the transmitted spectral information for the WRIPS buoy.

10) Data Displays

Monthly data reports (Appendix 5) were produced including time series of selected spectral parameters, scatterplots, contoured energy density by frequency and time, and tables of root-mean-square wave height as a function of wave period band. Displays of wave height exceedance as well as persistence plots of significant wave height, period and peak direction were developed for the seasonal summary data (See Appendix 4). On a non-routine basis, directional stick plots by frequency band, and tables of energy density by frequency and direction were produced to describe the directional wave information from the ENDECO WAVE-TRACK and Datawell WAVEC buoys, respectively. In Appendix 3 are descriptions of the software developed for wave data processing as well as a list of the various parameters available for display from each instrument.

11) Data Archiving

The data files produced after steps 1, 3, 4, 5, 6, 8 and 9 were all backed up on nine-track tape. The raw data files from Step 1 and the monthly checked spectral files of Step 9 have been sent to MEDS for archiving and information dissemination. Details on files, file structure and tape formats are included in Appendix 3.

5.2 Meteorological Data

Meteorological data from the McKenney Rock satellite-transmitting weather station were processed by Petro-Canada who then supplied the time series of measurements on nine-track tape, as well as various data products included in the monthly data reports (see Appendix 5). Meteorological data were collected hourly at McKenney Rock.

It was found to be much more efficient to manually transcribe the wind information for the four Atmospheric Environment Service weather stations, residing on the original log sheets in the Vancouver office, then to wait for the data to become available on nine-track tape. This transcription was performed monthly by a university student working part-time. The data were then typed into a computer file and time series of wind speed and direction were plotted.

The measurements at the AES weather stations were performed at variable intervals, though generally six to eight measurements per day were taken. Only 8-point compass wind directions were available for the AES data. Persistence statistics could not be calculated for the AES stations because of the irregular collection of data, but they were produced for the McKenney Rock data. Other summary displays, included in Appendix 4, are scatterplots of wind speed by direction and the percent exceedance of wind speeds.

6. INSTRUMENT PERFORMANCE AND DATA QUALITY

The operational records of both the wave and meteorological stations are depicted graphically in Figures 6.1a and b. Table 6.1 summarizes the monthly, seasonal and overall data return of the study. Two percentages are given in the table. The first represents the amount of good data recorded when the buoy was in operation (i.e. actual recovery) and the second, in parentheses, the amount of good data recorded over the period the buoy was deployed (i.e. expected recovery). Station 211 had the best operating history of all the buoys, while the two WRIPS buoys, Stn 215 and 216, had the best data return while in operation due to their ability to record data internally, eliminating transmission problems. The ENDECO buoy at Stn 213 had the poorest operational record though the low percentages in January and February, 1983 were not directly related to a problem with the buoy or receiver but due to external radio interference with the data transmission to shore. There were also no directional data available from this buoy during the spring of 1983 due to failure of a filter in the receiver, which was not taken into account in the percentage calculations. The prototype WAVEC buoy positioned at Station 214 had very good data return while in operation. However, the data during the spring of 1984 may be questionable as a result of structural problems with the buoy when a flotation segment became dislodged.

In general, low data returns were a result of major hardware problems or the buoy going adrift. There were five instances of mooring failure with the details summarized in Table 6.2. In all but one case, it is clear that the mooring was fouled and cut by unknown vessels. Fishing activity was taken into account during the selection of deployment sites. There were no signs of extreme wear or corrosion with the exception of one 12 mm stainless steel shackle in the WAVEC mooring which underwent uneven wear due to a mismatching in the curvature of the shackle and the eye to which it was attached. As the moorings were winched up sufficiently to clear the anchor from the bottom during recovery, mooring failure due to weakening is unlikely. Severe biological fouling of the rubber cords and of the buoys themselves was observed particularly at Station 211. Algal growth on the upper surface of the wave buoy significantly reduced its visibility at long distances.

Severe radio interferences from October 1982 to January 1983, a broken antennae in May 1983 and a damaged accelerometer in November 1983, resulted in data loss from Station 212. During the early part of 1983, severe signal interference

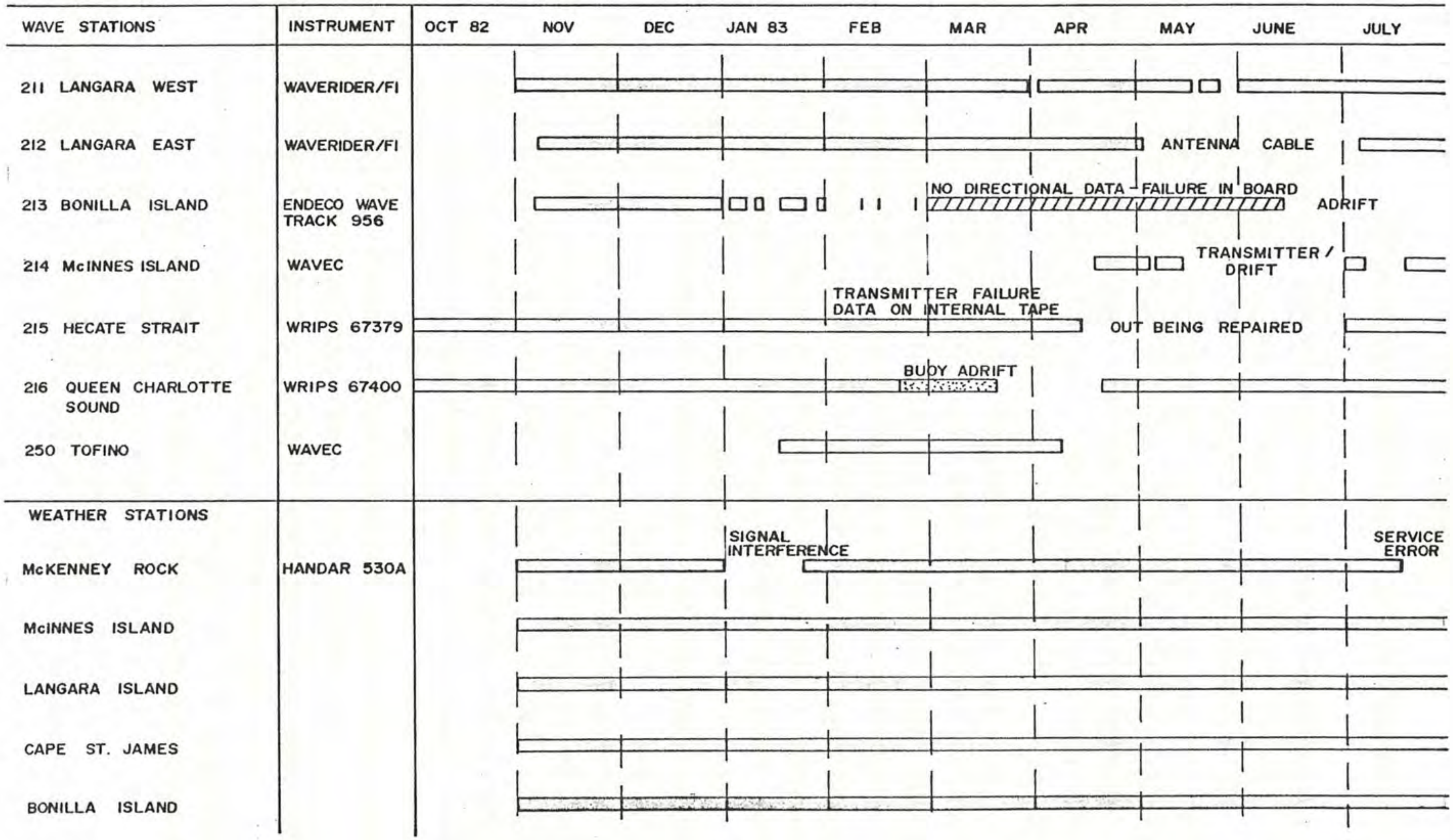


Figure 6.1 (a) Operational Record

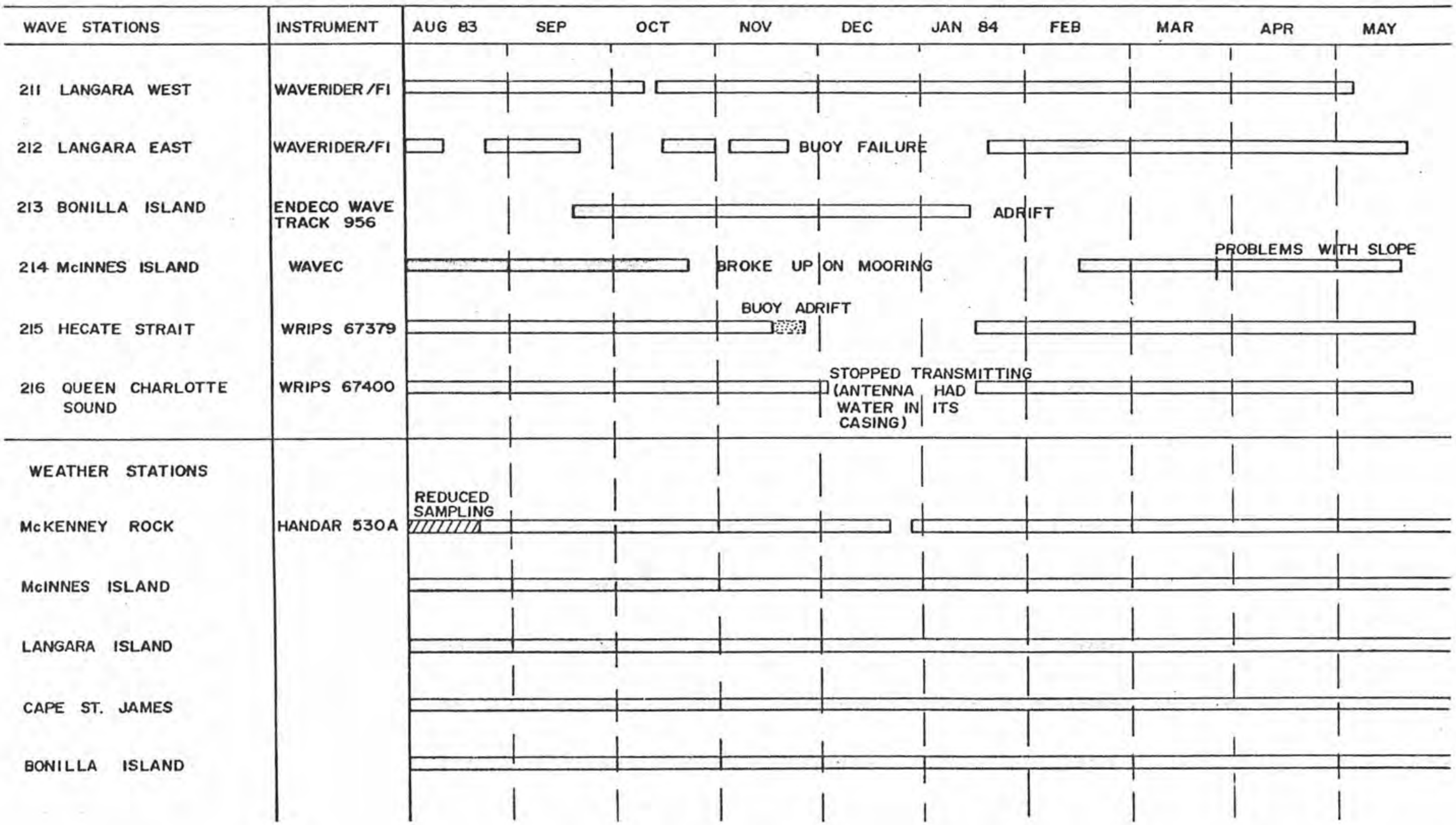


Figure 6.1(b) Operational Record

TABLE 6.1
PERCENTAGE WAVE DATA RETURN

No Brackets: data records/total possible data records during buoy operation

Brackets: data records/total possible data records during buoy deployment

	211 (Waverider)	212 (Waverider)	213 (Endeco Wave-Track)	214 (WAVEC)	215 (WRIPS)	216 (WRIPS)
Oct. 82	N/A	N/A	N/A	N/A	100 (100)	100 (100)
Nov. 82	79.0 (79.0)	98.4 (98.4)	91.8 (91.8)	N/A	100 (100)	99.6 (99.6
Sep. 83	96.1 (96.1)	75.8 (75.8)	97.9 (39.6)	99.2 (99.2)	100 (100)	100 (100)
Oct. 83	82.4 (82.4)	60.7 (60.7)	91.9 (91.9)	99.5 (78.2)	100 (100)	100 (100)
Nov. 83	94.2 (94.2)	88.8 (62.9)	92.1 (92.1)	- (0.0)	100 (53.3)	100 (100)
FALL	**87.9 (87.9)**	**78.8 (72.8)**	**92.7 (78.5)**	**99.3 (59.3)**	**100 (88.4)**	**99.9 (99.9)**
Dec. 82	91.9 (91.9)	98.8 (98.8)	83.1 (83.1)	N/A	99.6 (99.6)	100 (100)
Jan. 83	97.7 (99.7)	98.8 (98.8)	43.1 (43.1)	N/A	100 (100)	100 (100)
Feb. 83	98.4 (98.4)	98.7 (98.7)	4.5 (4.5)	N/A	100 (100)	100 (99.1
Dec. 83	99.6 (99.6)	- (0)	83.1 (83.1)	- (0.0)	- (0.0)	100 (6.0)
Jan. 84	89.0 (89.0)	13.1 (4.0)	37.5 (6.0)	- (0.0)	100 (61.3)	100 (62.1)
Feb. 84	96.8 (96.8)	85.3 (85.3)	N/A	98.6 (30.6)	100 (100)	99.6 (99.6
WINTER	**95.5 (95.5)**	**89.4 (63.5)**	**53.9 (44.7)**	**98.6 (9.7)**	**99.9 (76.2)**	**99.9 (73.5)**
Mar. 83	93.4 (93.4)	99.2 (99.2)	37.1 (37.1)	N/A	100 (100)	- (0.0)
Apr. 83	87.4 (87.4)	98.8 (98.8)	39.2 (39.2)	97.3 (97.3)	100 (65.4)	100 (36.3)
May 83	76.3 (76.3)	100 (4.0)	80.2 (80.2)	85.3 (37.5)	- (0.0)	100 (100)
Mar. 84	93.8 (93.8)	100 (100)	N/A	95.6 (95.6)	100 (100)	100 (100)
Apr. 84	99.7 (99.7)	98.8 (98.8)	N/A	90.4 (90.4)	100 (100)	100 (100)
May 84	100 (100)	97.3 (97.3)	N/A	100 (100)	100 (100)	100 (100)
SPRING	**90.3 (90.3)**	**98.9 (82.2)**	**52.3 (52.3)**	**93.4 (79.3)**	**100 (76.1)**	**100 (71.1)**
Jun. 83	97.6 (97.6)	- (0.0)	- (0.0)	- (0.0)	- (0.0)	99.6 (99.6)
Jul. 83	76.9 (76.9)	100 (77.)	- (0.0)	91.7 (53.6)	100 (95.6)	100 (100)
Aug. 83	95.8 (95.8)	56.5 (56.5)	- (0.0)	97.6 (97.6)	100 (100)	100 (100)
SUMMER	**90.0 (90.0)**	**75.4 (45.0)**	**- (0.0)**	**95.4 (51.0)**	**100 (65.9)**	**99.9 (99.9)**
OVERALL	91.5 (91.5)	88.2 (68.2)	65.6 (45.9)	95.6 (51.7)	100.0 (77.1)	99.9 (83.7)

Table 6.2
Summary of Mooring Failures

Station/Location		Date	Comments
216	Queen Charlotte Sound	February 22, 1983	Buoy adrift, tracked by ARGOS and recovered. Rubber cord cut. Presume mooring fouled by fishing vessel and cut free.
213	Bonilla Island	May - July, 1983 (date uncertain)	Buoy missing from station. Recovered near Ketchikan, Alaska. Mooring parted beneath subsurface buoy. No analysis possible as mooring and subsurface float were not recovered.
215	Hecate Strait	November 12, 1983	Buoy adrift. Tracked by ARGOS and recovered. Mooring parted in rubber cord section. Assume mooring fouled by fishing vessel and cut free.
213	Bonilla Island	February 10-16, 1983	Buoy missing from mooring. Recovered near Ketchikan, Alaska. Mooring parted approximately 5 m beneath subsurface buoy. No chafe marks on line. All strands at the parted end were the same length. Assume mooring fouled by fishing vessel and cut free.
211	Langara West	May 4, 1984	Mooring fouled and cut by fishing vessel. Mooring parted beneath subsurface buoys.

affected reception at Station 213. Data logging problems, possibly related to wear in the clutch mechanism of the take up and feed spool, affected data return for both Station 211 and 212.

The WAVEC buoy exhibited some prototype problems with the transmitter and receiver (signal drift) in May, 1983, and both were subsequently replaced. There were persistent problems, however, with the DIREC and Whisper-Writer terminal at the shore station, usually associated with power failures and changeover of generators. There were also a few records lost due to tape reading problems. It was found that different Columbia data loggers could not always read cartridges without error when written by another logger. This was attributed to slight differences in tape head alignment.

There were no major problems encountered during data processing. The time counters for Station 211 and 212 overflowed in October 1983 and September 1983, respectively, with the latter occurring during the period of tape problems. As a result, it was impossible to verify time assignments within 12 hours for Station 212 data from October 1 to November 7th. The DIREC receiver, for Station 214, did not account for the fact that 1984 was a leap year so that time headers in the data were off by one day from February 28 on. It also did not output a time header to the auxiliary port when recording continuously. In this case, times had to be estimated from the operator-logged times of cartridge replacement and by scan counting. Processing software modifications were able to handle these occurrences.

Although some problems were encountered with both the standard Waveriders and the WRIPS buoys, the data quality for the two Waveriders and two WRIPS buoys was very good throughout the study. Both the heave and directional data quality for the WAVEC buoy were good when the buoy was operational. From March 25 to May 15, 1984, large mean slopes were observed in the data as a result of the dislodgement of a couple of flotation pieces from their harness. This probably affected the surface following capabilities of the buoy in a frequency dependent manner, though the error introduced into the data is difficult to quantify. Another indication of this problem can be observed in the change in the buoy's response to averaged wave conditions before and after March 25 (Figures 6.2a and b). The dashed line on both these plots is the expected response given linear wave conditions. As the WAVEC buoy had previously broken up on its mooring, a possible design problem is indicated.

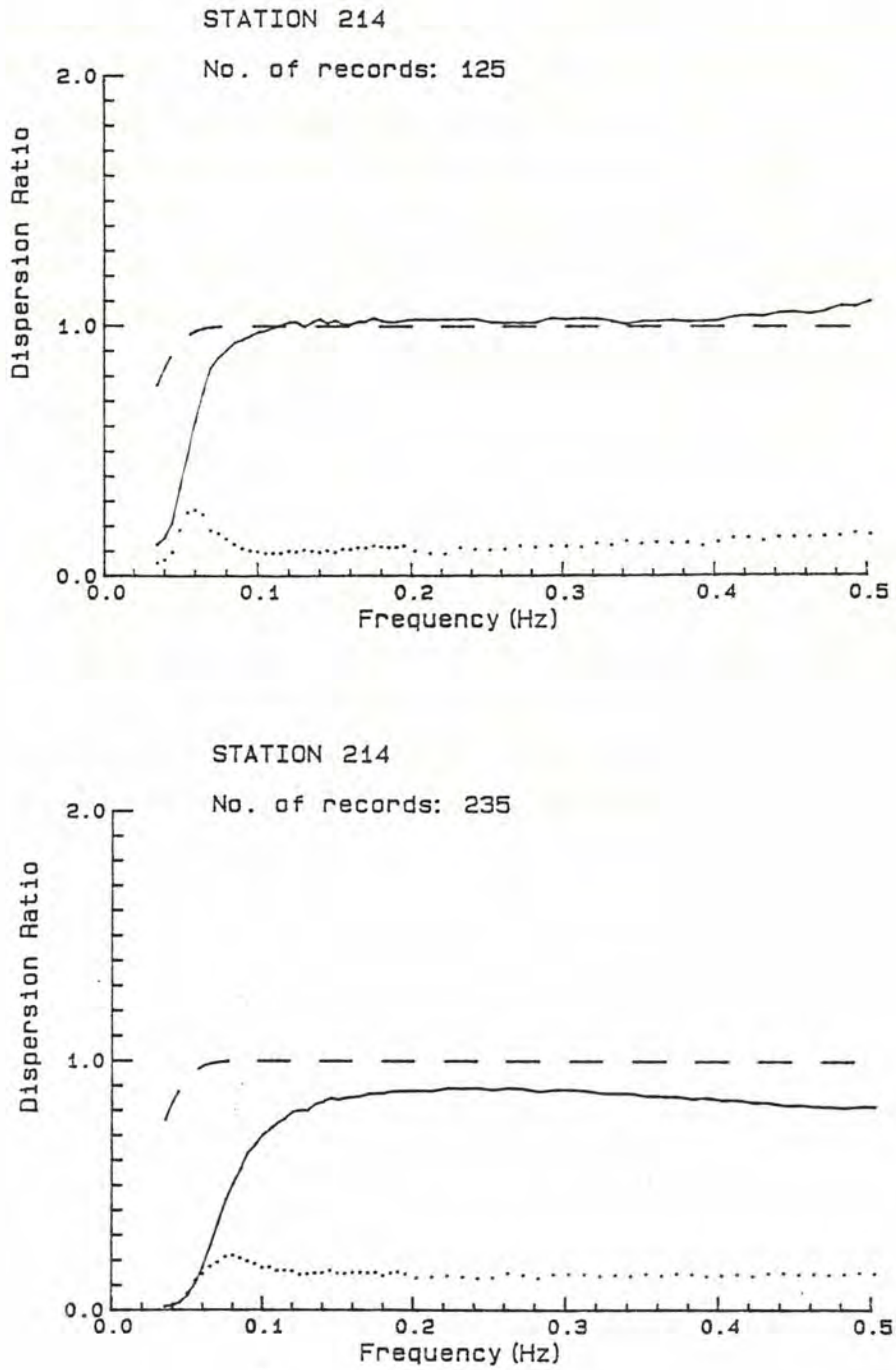


Figure 6.2 **(a)** (Upper) WAVEC buoy response before March 25, 1984
(b) (Lower) WAVEC buoy response after March 25, 1984
(dashed - theortical; solid - measured; dotted - standard deviation)

The heave data quality for the ENDECO buoy was generally poorer than for the other buoys due to the presence of significant amounts of spurious low frequency energy. The presence of this energy would lead to errors in the spectral statistics as well as in the directional calculations for these frequencies. The 10 frequency Band-Pass directional calculation was found to suffer from poor frequency resolution and the directions calculated were often inconsistent with expected wave propagation for the area (e.g. long period swell coming from the east). When compared with the Longuet-Higgins method used on WAVEC records, the Band-Pass approach does not lend itself to either verification of the buoy's response nor calculation of directional spectrum and directional spread as accepted in the literature. Assumptions of the directional distribution would have to be made in order to calculate a directional spectrum from the mean direction and standard deviation supplied by this wavecrest analysis.

Both the data return and quality from the five weather stations were good during the study. The McKenney Rock station did suffer from signal interference in January of 1983, while problems with excessive humidity stopped operation in the latter half of July and computer problems at NESDIS in Washington, D.C., resulted in some data loss in December 1983. Other than these disruptions, wind speed and direction and air pressure statistics are available for the entire study period.

7. METEOROLOGICAL CLIMATE

This study concentrated on the measurement and analysis of wave data, hence the accumulated wind data will only be examined here in order to assess general trends and to determine whether this study period was representative of the long term mean seasonal conditions. Volume 2 deals in greater detail with the interrelationship of the wind and wave data.

As mentioned in Section 2, the large scale meteorology is determined by the location and strength of the two pressure systems: the Aleutian Low and North Pacific High. Generally, strong south to southeasterly winds will predominate in the winter with weaker north to northwesterly winds in the summer. Winds measured at the weather stations, however, experience various influences, including large scale topographic wind steering along the mountainous coast and local topographic sheltering. As such, they may not always be representative of the local winds generating the sea condition, and especially offshore winds producing swell which propagates into the area. Due to the large scale topography, one would expect a predominance of SE-NW winds, with little cross-channel input, measured at Bonilla Island, McKenney Rock and McInnes Island (here referred to as "mainland stations"; see Figure 2.1). Of these three stations, McKenney Rock has the best local exposure. Bonilla Island has open ocean from SE through S to N and generally good exposure. The anemometer location on McInnes Island had been moved prior to this study, with the new site having improved readings for all directions except the NE quadrant. The weather station at Cape St. James is located on a very steep and narrow island at the southernmost tip of the Queen Charlotte Islands. The topography to the north influences wind measurements from this quadrant. It is open to all other directions though the steepness of the island could affect wind measurements by inducing vertical uplift and turbulence. Langara Island suffered from the poorest exposure with dense woods from to E and S to SW and steep shoreline slopes to the north.

Table 7.1 contains the summary of wind statistics measured over the study period, and, when available, a historical summary. Figures 7.1 and 7.2 graphically display the mean and maximum wind speed by direction and the percent occurrence of wind direction respectively. The largest mean and maximum wind speeds were generally measured during the winter. The maximums were associated with E to SE directions at the mainland stations, for all seasons. The wind speeds and directions measured at McKenney Rock and Bonilla Island were comparable given the

TABLE 7.1 SUMMARY WIND STATISTICS

Station	No. of Obs.	No. of Occurrences of Calm	Mean Speed (m/s)	Max. Speed (m/s)	STD. DEV. (m/s)	Dir. of Maximum Wind (°T)	Modal Direction	Historical Period	Mean Speed (m/s)	Max. Speed (m/s)	Dir. of Maximum Wind	Modal Direction
Langara I.												
Summer	595	68	3.28	15.44	2.58	315.	SW	1958 - 74[1]	5.3			W
Winter	1171	44	6.02	25.73	3.99	315.	SE	1958 - 74[1]	8.3			SE
Fall	772	43	4.95	15.44	3.26	45.	SE	1958 - 74[1]	7.3			SE
Spring	1067	37	4.71	15.44	2.90	90.	E	1958 - 74[1]	6.6			W variable
Bonilla I.												
Summer	626	10	6.29	21.62	3.64	135.	SE	1965 - 80[2]	6.4	22.7	SE	SE
Winter	1186	15	9.50	30.37	5.34	135.	SE	1965 - 80[2]	9.1	39.7	S	SE
Fall	834	17	7.89	28.82	4.94	135.	SE	1965 - 80[2]	8.4	35.0	SE	SE
Spring	1141	14	8.04	35.00	4.72	135.	SE	1965 - 80[2]	8.0	33.1	SE	SE
Cape St. James												
Summer	611	15	4.99	15.95	2.82	315.	NW	1955 - 80[2]	7.6	31.7	SSE	NW
Winter	1209	21	9.38	34.48	5.56	225.	SE	1955 - 80[2]	10.5	44.2	SE	NE
Fall	892	15	6.55	28.82	4.14	270	NW	1955 - 80[2]	9.4	49.2	SSE	NW
Spring	1204	5	6.74	26.76	3.93	225.	NW	1955 - 80[2]	9.2	44.2	NE	NW
McInnes I.												
Summer	591	13	4.41	18.01	3.18	135.	SE	1963 - 80[2]	3.4	22.2	S	MW
Winter	1129	23	6.87	29.85	5.09	135.	SE	1963 - 80[2]	6.2	33.1	SW	E
Fall	791	17	5.77	25.73	4.62	135.	SE	1963 - 80[2]	5.4	29.4	S	SE
Spring	1062	42	5.57	24.70	4.46	135.	SE	1963 - 80[2]	4.7	30.0	SE	NW variable
McKenney Rock												
Summer	1608	1	6.27	21.66	3.68	153.0	SE					
Winter	3361	15	9.93	35.62	5.27	149.0	SE					
Fall	2646	14	8.75	30.94	5.20	113.0	SE					
Spring	4227	62	7.78	27.33	4.88	149.0	SE					

1 From Petro-Canada "Initial Environmental Evaluation - Offshore Queen Charlotte Islands", 1983 prepared by Stuart and Krakeroski 1981 for period 1954-80.

2 Calculated from AES Climate Normals

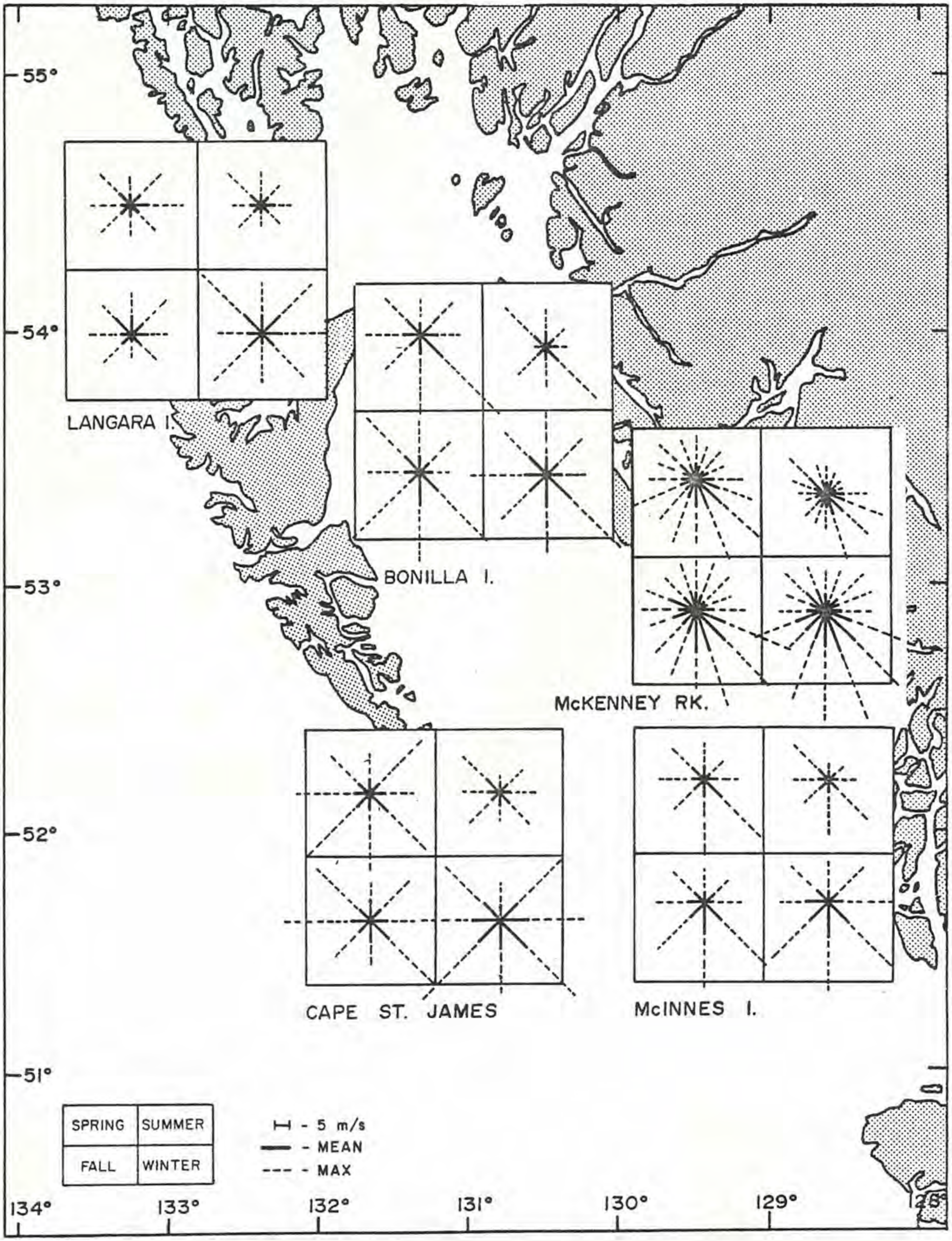


Figure 7.1 Seasonal mean and maximum wind speeds by direction

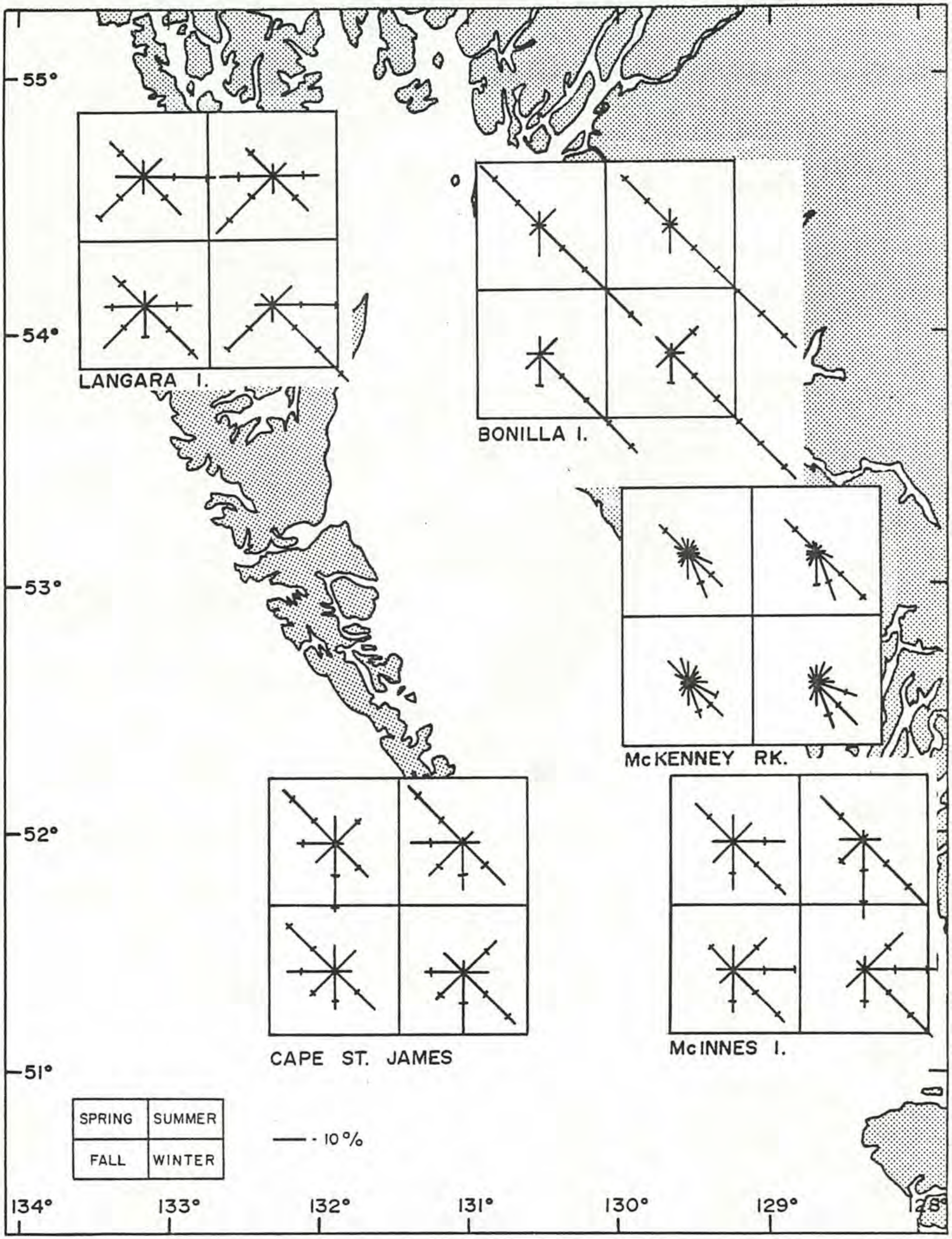


Figure 7.2 Seasonal wind direction distribution

differences in sampling interval and direction resolution. The direction distribution of winds at McInnes Island is also very similar though the velocities here are reduced. Wind speed and direction distributions at Cape St. James indicate partial sheltering from the north with the largest means associated with alongshore directions. There is a relatively greater contribution from other wind directions here than observed at the mainland stations. The Langara Island weather station recorded the lowest mean and maximum wind speeds presumably due to the sheltering land to the south. When compared with the other stations, there was a considerably larger percentage of occurrence of easterly winds. The seasonal distribution of wind directions, at all stations, showed a slight reduction in NW wind occurrences during the winter, which is to be expected.

Figure 7.3 contains the seasonal wind exceedances for each station. Similar geographical trends can be seen. In general, the exceedances for all seasons were lowest at Langara and highest at McKenney Rock. Both summer and winter wind speed exceedances at McKenney Rock and Bonilla Island were comparable, while only in winter was this true for Cape St. James. At both Cape St. James and Bonilla, the spring and fall curves were similar while at McKenney Rock distinctly larger exceedances were measured in the fall.

In order to assess whether or not the study period was representative of long term means, the summary wind statistics and direction distributions were compared against the climate normals, when available. The results are included in Table 7.1 and in Figure 7.4. With the exception of the McInnes Island and Bonilla Island mean wind speeds, and the maximum speeds at Bonilla, both the mean and maximum wind speeds were lower during the study period. The Bonilla Island means are comparable with the climate normals while the higher mean winds experienced at McInnes may reflect the location change of the anemometer after 1981. The low wind speeds are especially noticeable for Cape St. James considering that, historically, the means and maximums are larger here than at Bonilla while during the study they were generally lower. Although the modal directions are often quite similar, major differences in the occurrence of wind direction can be seen in Figure 7.4 which displays the percentage difference in occurrence, whether more or less than historical norms, for each compass point. At all stations, for all seasons, there were a greater number of occurrences of SE winds, generally to the detriment of N-NW winds in the summer. However, from the persistence analysis of direction at McKenney Rock (See Appendix 5), NW winds still have the largest maximum and

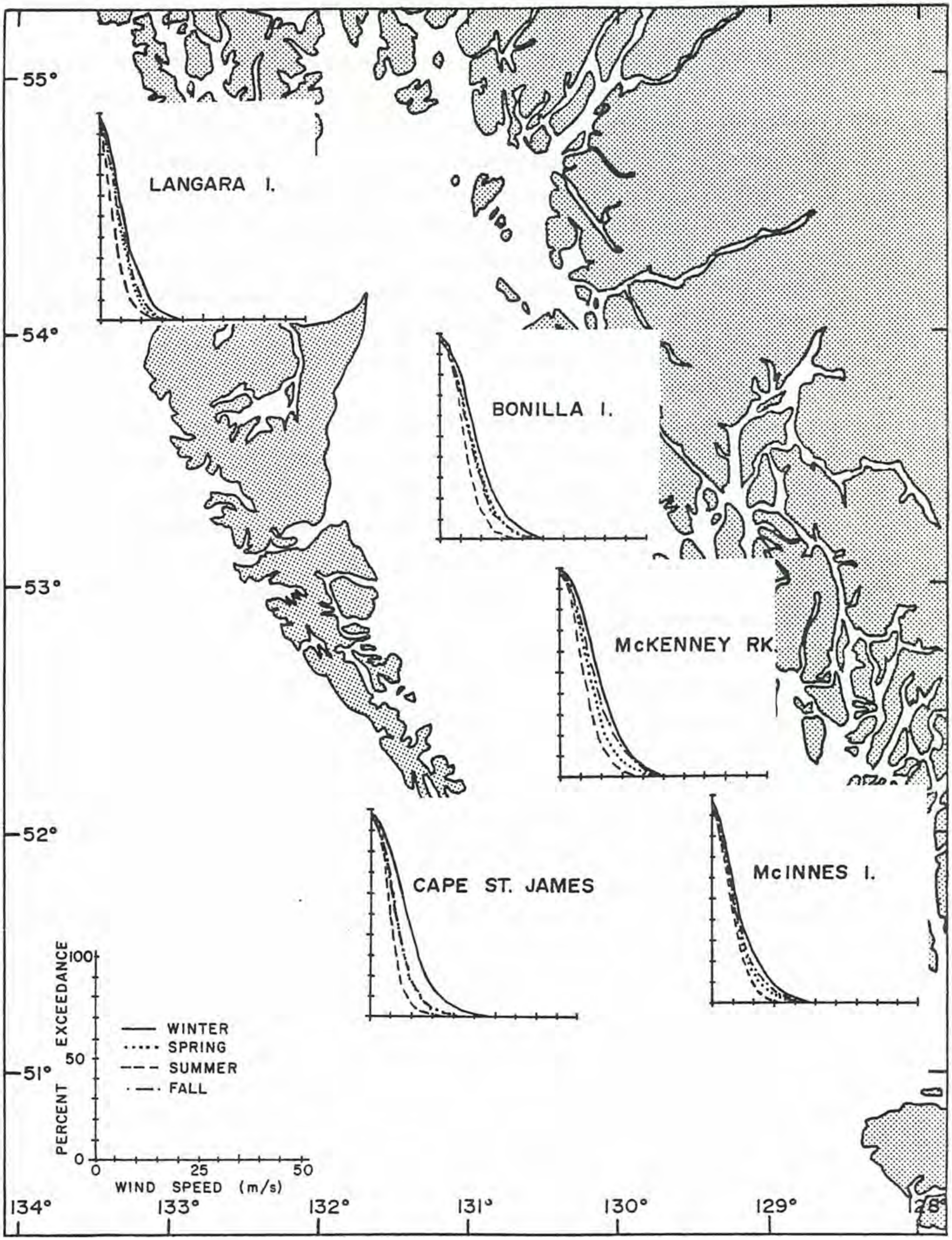


Figure 7.3 Seasonal percent exceedance of wind speed

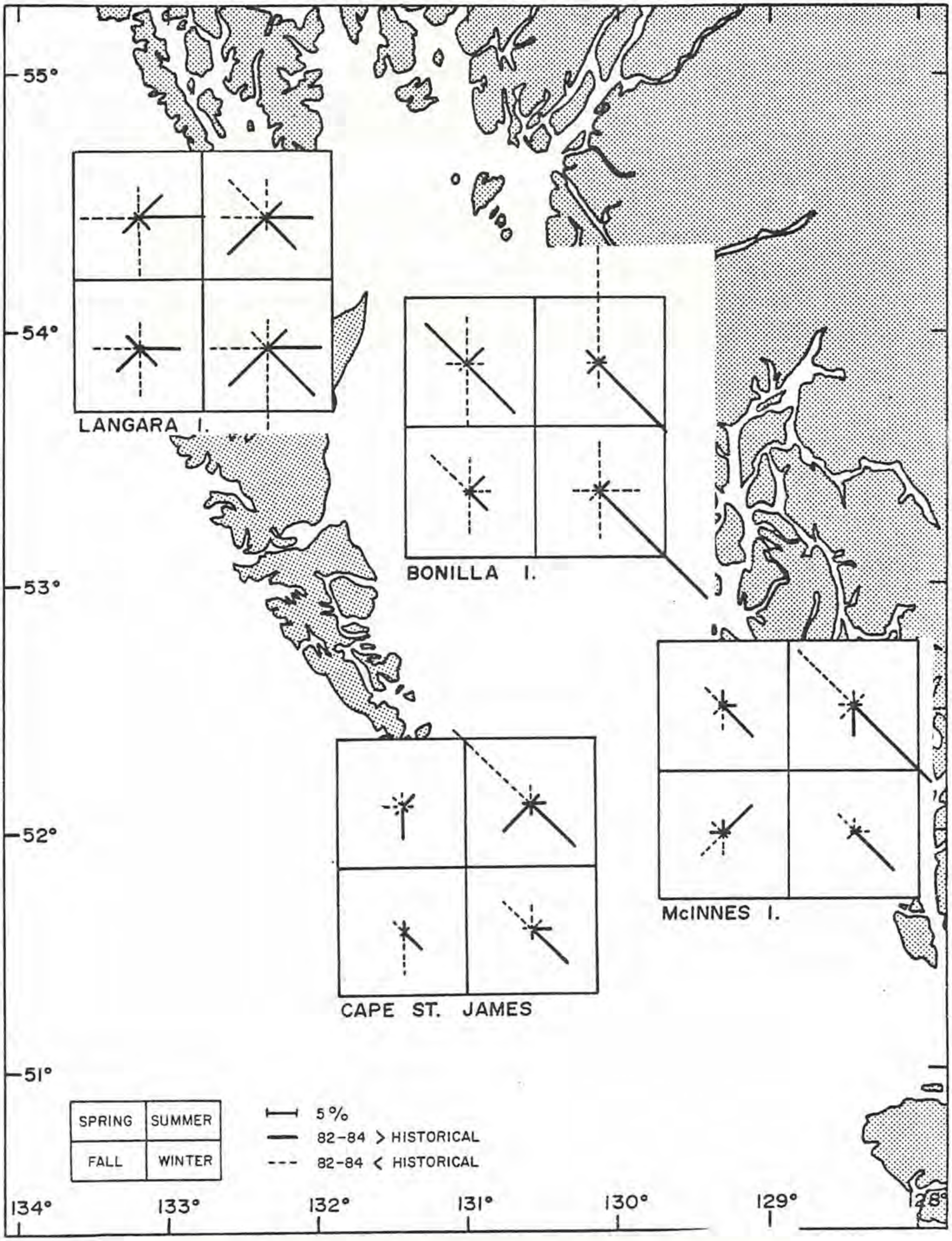


Figure 7.4 Seasonal wind direction distribution with respect to historical norms

mean persistence in direction for all seasons except winter. Both Bonilla and Langara show a large drop in occurrence of N and S winds for all seasons. Cross-channel wind occurrences at Bonilla were fewer while there was an increase in outflow winds through Dixon Entrance.

It is difficult to assess how representative this study data set is when considering inter-annual variability, as the wind direction distributions differed significantly from historical means. An examination of storm characteristics during the study period, in light of historical storm occurrences, would be required to properly categorize both the observed meteorological and wave climate.

8. WAVE CLIMATE

8.1 Observed Seasonal Wave Conditions

The wave conditions observed in the study area contain two components: long period swell (periods greater then 10 seconds) and shorter period sea. Whether or not swell energy is observed at a given buoy location will depend on both the exposure of the site and characteristics of the bathymetry along the route of wave travel. Shorter period energy will consist of locally produced waves and depend primarily on wind strength, duration and fetch. Given the observed wind strength and duration at McKenney Rock with a maximum local fetch of 150 nautical miles, wave conditions with significant wave heights of 3 - 6 m and significant periods of 7 - 9 seconds could be generated, under ideal conditions, within the study area. This fetch is associated with the complete length of Hecate Strait, and, for winds not blowing up or down the strait, the fetch is considerably reduced.

The significant wave heights measured at each buoy site represent the sum of the energy at all wave periods and include the influence of other factors such as wave steepening due to local bathymetry or currents, wave focusing as a result of refraction over shallow areas, as well as the specific interaction at each moment of time between winds and waves (i.e. active generation, active decay, etc.). Interpretation of the observed wave characteristics, prediction of extreme waves, and hindcast model verification all must take these factors into account.

Wave statistics, averaged over time are dependent on the data coverage: bias may be introduced by missing data. A common example used is wave height measurements from ships of opportunity, which can be biased low because ships actively try to avoid storm centres and extreme conditions. Bias in buoy data can result from periods of interrupted recording. If these interruptions are too extensive, the statistics become suspect. As such, winter measurements for McInnes Island (Stn. 214) and Bonilla Island (Stn. 213) are questionable. Other bias may be introduced due the buoy or the mooring design, or with the processing scheme used. The spurious, low frequency energy measured by the ENDECO WAVE-TRACK buoy, especially under more extreme wave conditions, could bias high the measurements of significant wave height. The large amount of band-averaging at higher frequencies in the satellite buoy spectral data will affect the various summary spectral statistics which are calculated from the higher moments of the heave spectrum.

Table 8.1 lists the summary wave statistics obtained over the study period. From these results, the following general comments can be made:

- The most extreme wave conditions were observed in Queen Charlotte Sound (216) in winter. This was to be expected given its exposure and seasonal weather patterns.

- Langara West (211) had the second highest mean significant wave heights (if one discounts the questionnable winter measurements at McInnes Island (214), November/83, December/83 and January/84), although the maximums were generally lower than those in Hecate Strait (215). It should be kept in mind that summer, winter and fall height values in Hecate Strait (215) may be biased low due to reduced data coverage compared with Langara West (211).

- There is a general reduction in wave energy between Langara West (211) and Langara East (212) as one travels eastward, though long period energy is still present.

- The relatively poor data coverage at Bonilla Island (213) and McInnes Island (214) makes it difficult to draw many conclusions. The wave energy, however, does seem to be shifted to shorter periods at Stn. 213, as one would expect, given its location.

The seasonal and geographic trends are more easily observed in Figs. 8.1 to 8.4. Fig. 8.1 displays the seasonal exceedance of significant wave height at each station. The largest exceedances were measured at Stn. 216 (Queen Charlotte Sound) and the lowest at Stn. 213 (Bonilla Island) for all seasons.

Exceedances at Langara West were always greater than those for waves measured at Langara East. In the summer, exceedances for Langara West (Stn. 211) were greater than those for Hecate Strait (Stn. 215), while for the other three seasons this was true only up to 4.0 meters, after which the roles reverse. A similar

Table 8.1

Summary Wave Statistics

Station	Number of Observations	Mean H_s (m)	Maximum H_s (m)	Standard Deviation, H_s (m)	Mean Peak Period (s)
Langara West (211)					
Summer	1991	1.55	4.25	0.564	9.48
Winter	4155	3.23	8.79	1.281	11.60
Fall	2556	2.63	8.99	1.174	10.71
Spring	3407	2.45	7.85	1.079	11.16
Langara East (212)					
Summer	331	1.21	3.46	0.506	8.20
Winter	919	2.90	7.35	1.024	12.09
Fall	671	2.23	6.74	.998	10.66
Spring	1172	2.10	6.94	.945	11.36
Bonilla Island (213)					
Winter	544	1.68	6.77	1.068	8.57
Fall	735	1.66	8.22	1.195	8.66
Spring	385	1.24	5.57	0.912	8.13
McInnes Island (214)					
Summer	374	1.10	3.81	0.470	11.20
Winter	133	3.90	6.79	1.515	11.53
Fall	432	1.68	6.75	1.090	9.71
Spring	788	2.44	7.32	1.565	11.00
Hecate Strait (215)					
Summer	485	1.06	3.66	0.528	12.54
Winter	1102	3.00	10.67	1.485	10.68
Fall	1104	1.94	9.21	1.371	10.74
Spring	1052	2.19	8.83	1.393	10.93
Queen Charlotte Sound (216)					
Summer	735	1.72	4.10	0.611	10.81
Winter	1118	3.95	11.39	1.522	12.27
Fall	1215	2.94	10.43	1.411	11.11
Spring	987	2.71	9.54	1.480	11.46

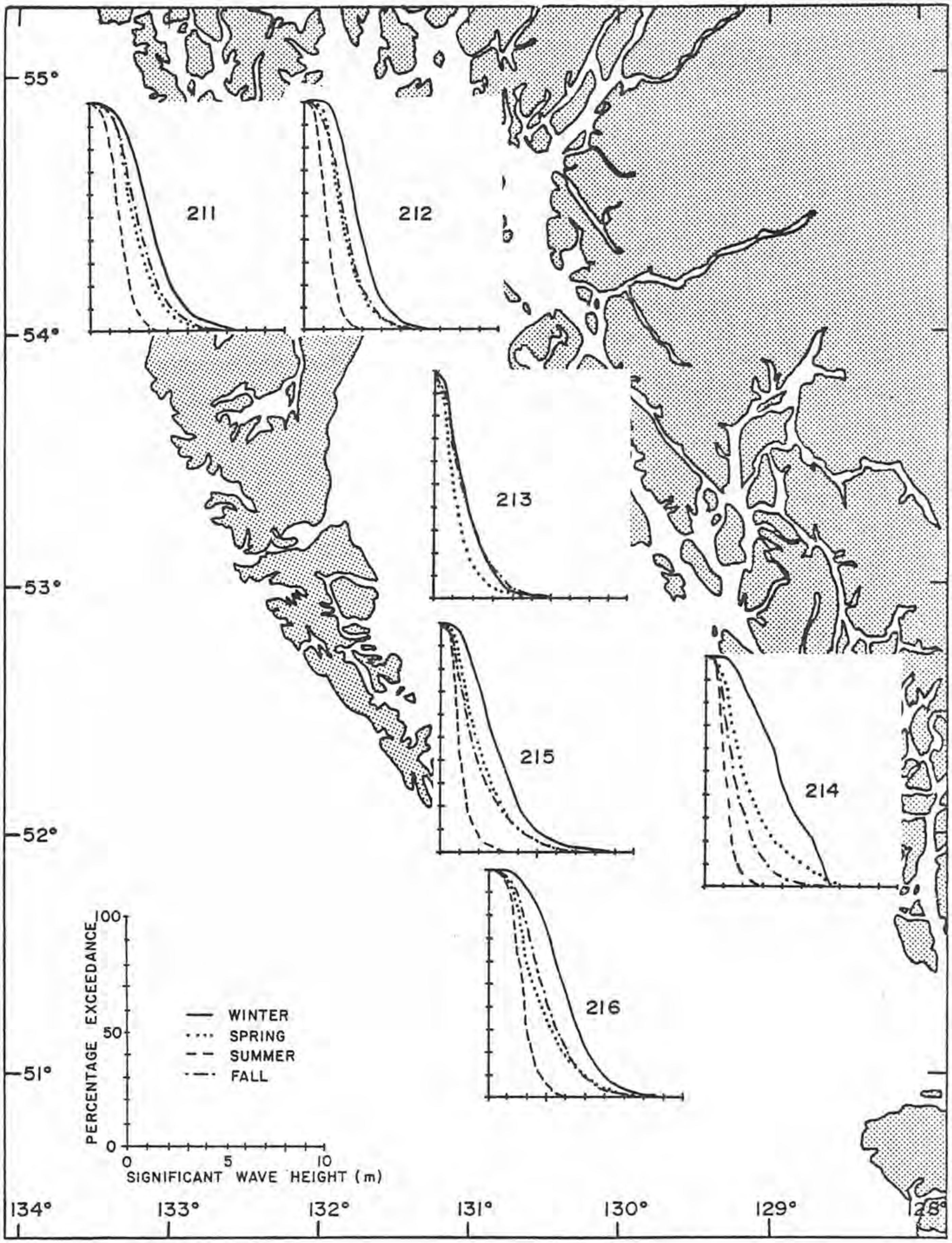


Figure 8.1 Seasonal percent exceedance of significant wave height

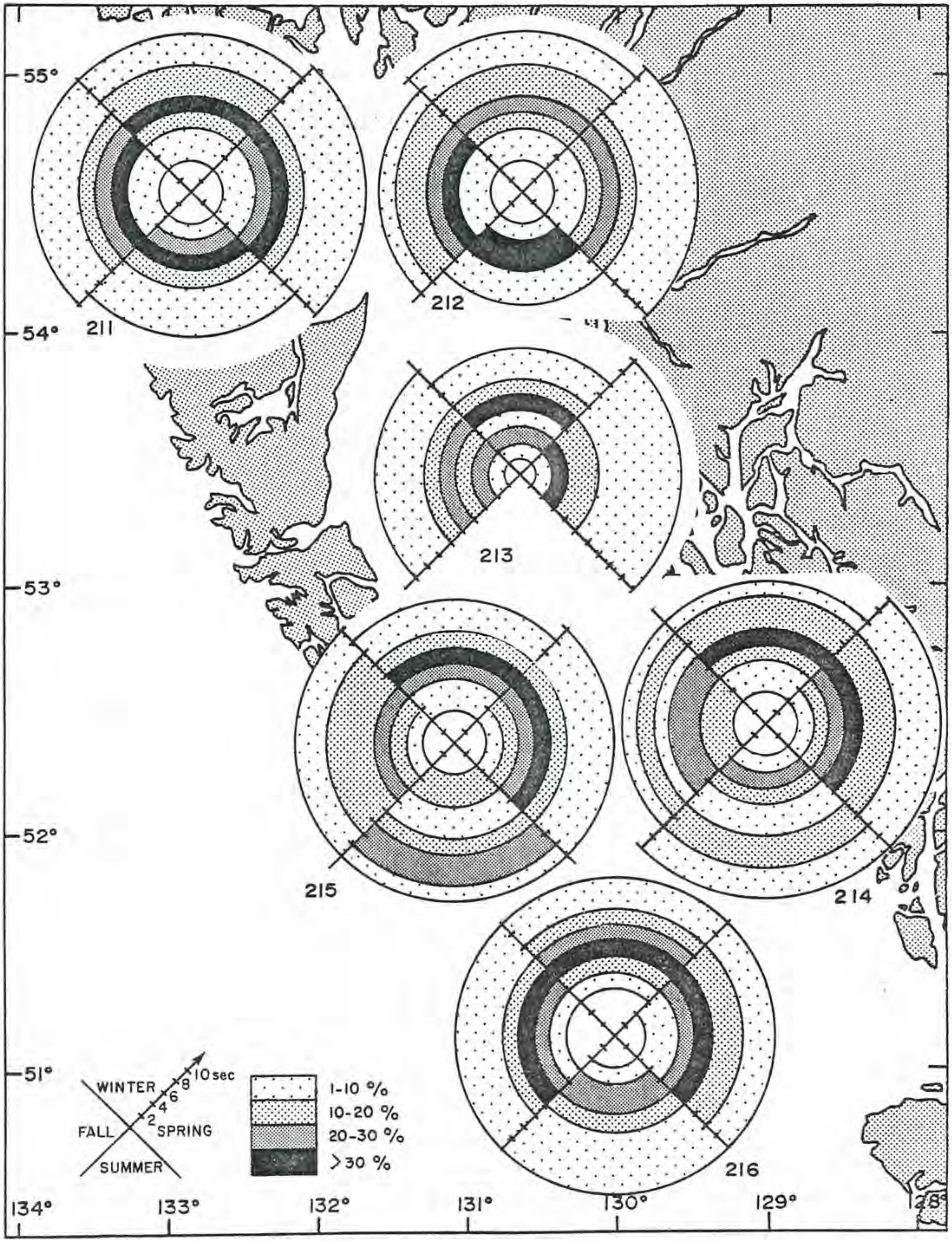


Figure 8.2 Seasonal percent occurrence of peak period

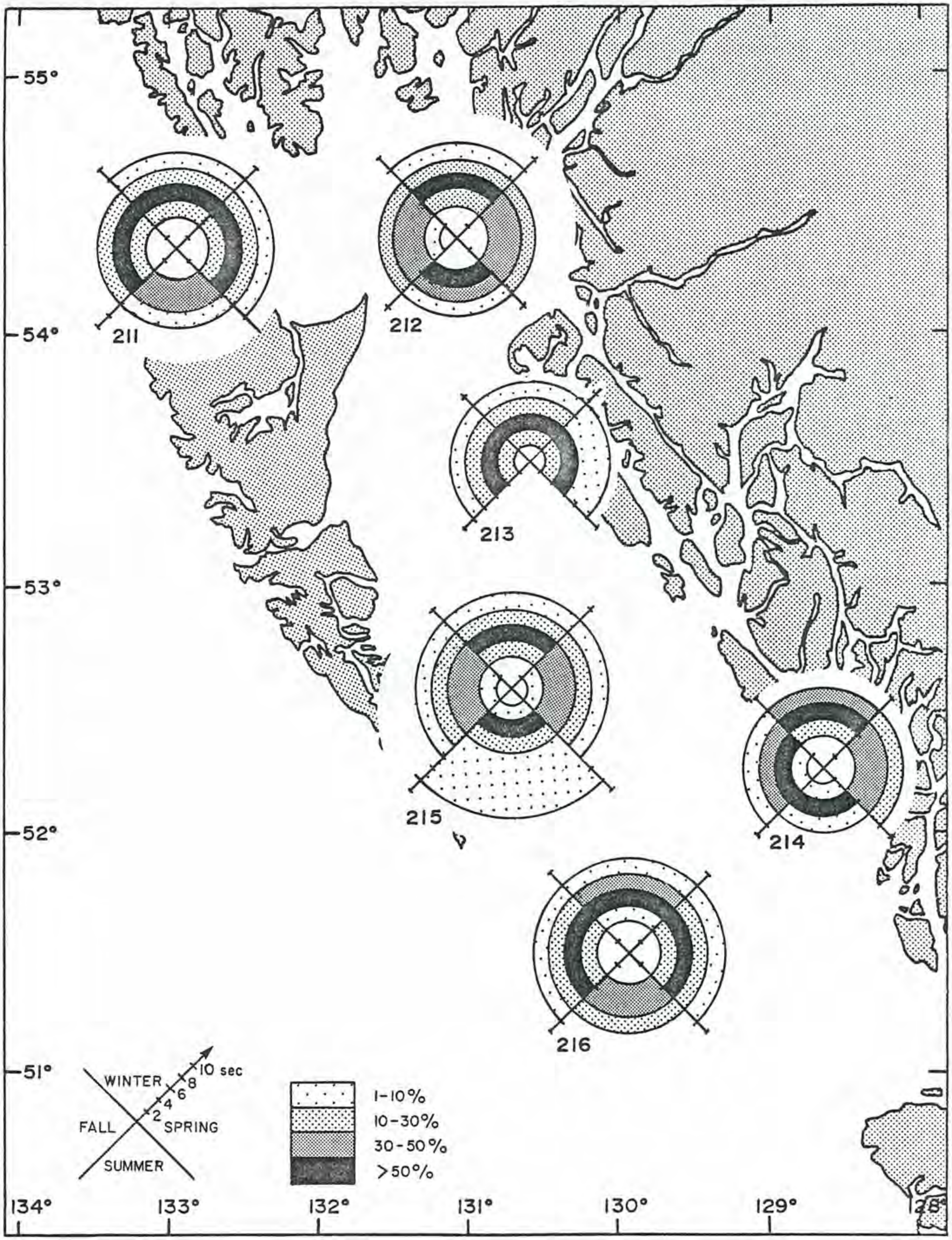


Figure 8.3 Seasonal percent occurrence of average apparent period

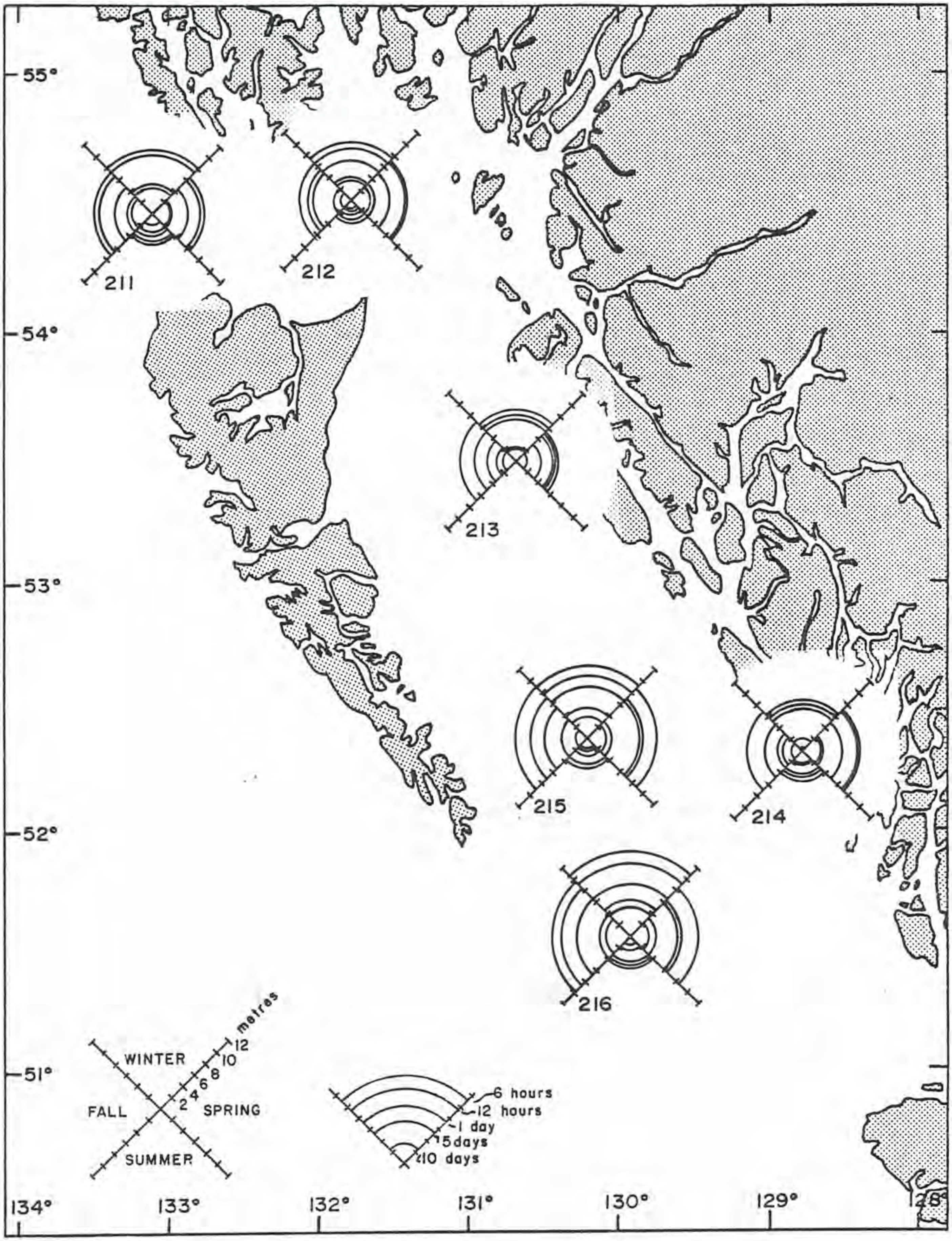


Figure 8.4 Seasonal maximum unfavourable persistence of significant wave height

situation occurred when comparing Langara East (Stn. 212) and Hecate Strait, except in this case the cutoff was between 2.0 and 3.0 meters in all seasons. These patterns were also evident in the cumulative exceedance values in Table 8.2, measured over the expected extreme wave period of November to March.

Table 8.2
Exceedances of Extreme Significant Wave Heights
(during November to March)

	Station	H_s >1.0 m	H_s >3.0 m	H_s >5.0 m	H_s >7.0 m	H_s > 9.0 m
211	Langara West	.989	.445	.069	.009	-
212	Langara East	.977	.270	.026	.003	-
213	Bonilla Island (quest.)	.697	.115	.016	.002	-
214	McInnes Island	(not included due to poor data coverage)				
215	Hecate Strait	.945	.371	.076	.012	.0015
216	Queen Charlotte Sound	.999	.663	.181	.029	.0049

This implies that the background wave conditions in Dixon Entrance are more energetic on average, probably due to swell entering the area, than in Hecate Strait. Extreme conditions associated with storms produce larger waves in Hecate Strait, possibly reflecting dominant storm tracks and/or larger local fetches in this area.

Figures 8.2 and 8.3 display the seasonal percent occurrence distribution of peak and average apparent period, respectively. The seasonal peak period distributions were similar between the two Langara stations, though in all cases there was a slight shift to shorter periods in the east. At Bonilla, there was a bimodal distribution at 4-6 and 8-10 seconds in fall and winter. Shorter periods associated with local generation predominated in the spring. Except in summer, the distribution at Stn. 215 and 216 were similar with a shift to longer periods at Stn. 216 (Queen Charlotte Sound) which is more open to swell propagating into the area. The summer measurements at Stn. 215 showed a bimodal distribution between local seas and long period swell while the site of Stn. 216 is more exposed for local wave generation. The wave peak period distribution at McInnes Island (Stn. 214) appeared to be in a somewhat intermediate position between those for the two WRIPS buoys. For all stations, the weight of the peak period distribution shifted up to longer periods from fall to winter and down in the spring, though the mode often stayed the same from winter to spring. This reflects the increased persistence, in the winter, of high winds allowing for longer period wave development locally, as well as the larger number of offshore storms generating swell. The larger up-shift in fall, then down-shift in spring, also follows the seasonal trend, described in Thomson (1981), of rapid storm buildup in fall with a more gradual drop in storm occurrence in spring. The increased onset and duration of storm conditions can also be seen in the seasonal maximum unfavourable persistence of significant wave height in Fig. 8.4. The more energetic extreme conditions in Queen Charlotte Sound and Hecate Strait are again implied by the persistences at the larger waveheights. These statistics are particularly affected by data quality and continuity, and should be considered in this light.

Figure 8.5 illustrates the seasonal distribution of mean wave direction, at the spectral peak, measured by the two directional buoys. Wave directions, like winds, should be considered as "from". Waves reaching McInnes Island are predominately from Queen Charlotte Sound and the Pacific Ocean and do not reflect, except possibly at high frequencies, the local wind directions. This is directly related to geographic influences on local fetches. Wave directions at Bonilla Island show scatter around the compass, though with some alignment along Hecate Strait as expected. How much of the scatter is real and how much is an artifact is difficult to determine because of problems with the direction measurement capabilities of the ENDECO WAVE-TRACK buoy.

8.2 Storms and Observed Extreme Waves

The measured significant wave heights for each station were examined for storm occurrences defined as periods of H_s greater than 5.0 meters. For the more severe conditions, the maximum waveheights were extracted from the amplitude-and phase-corrected time series. It should also be noted that the storm peak may have been missed due to the sampling schedule. The results are summarized in Table 8.3. Because of the low frequency energy and noise problems with the ENDECO WAVE-TRACK buoy, this analysis was not performed on Bonilla Island data. The largest

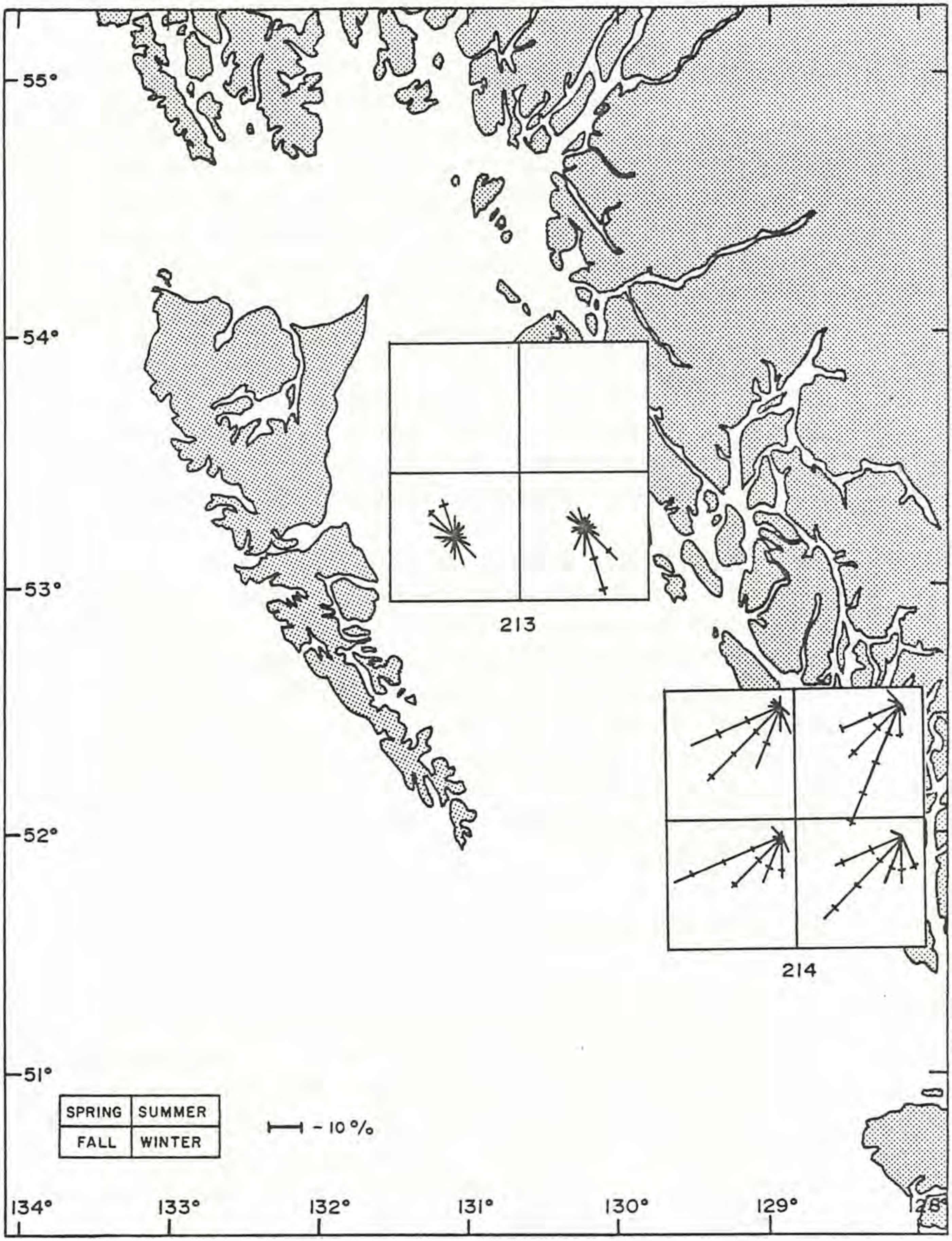


Figure 8.5 Seasonal percent occurrence of mean direction at the spectral peak

Table 8.3
Observed Extreme Waves

Record Station	Time	Significant Wave Height (m)	Peak Period (sec)	H_{MAX} (m)	H_{MAX}/H_{SIG}
Langara West	200/25/10/83	8.99	14.22	14.9	1.66
	300/25/10/83	8.68	14.22	12.9	1.49
	2100/4/1/84	8.19	14.22	15.24	1.86
	2300/4/1/84	8.79	16.0	14.2	1.62
	400/5/1/84	8.52	16.0	15.11	1.77
	400/31/1/84	8.53	16.0	11.87	1.39
	500/31/1/84	8.18	16.0	13.76	1.68
Langara East	0/9/1/83	7.35	14.22	13.03	1.77
	900/9/1/83	6.59	14.22	13.6	2.06
	304/23/10/83	6.74	14.22	12.4	1.84
	900/23/4/84	6.67	12.80	12.75	1.91
McInnes Island	600/25/10/83	6.79	14.29	12.2	1.8
	805/25/3/84	7.02	10.0	12.1	1.72
	1030/28/3/84	7.12	15.39	12.03	1.7
	1105/28/3/84	7.32	15.39	11.87	1.62
	600/7/4/84	6.54	12.5	12.43	1.90
	1930/9/4/84	6.78	11.77	11.37	1.68
Hecate Strait	1957/14/12/82	8.10	11.13	14.78	1.82
	1057/25/12/82	10.67	13.47	19.77	1.85
	1657/26/2/84	9.36	12.19	17.44	1.86
	1657/9/4/84	8.66	12.8	15.53	1.79
Queen Charlotte Sound	1110/25/12/82	11.39	14.22	18.52	1.63
	2310/25/1/83	10.41	13.47	15.84	1.52
	210/26/1/83	10.78	13.47	16.89	1.57
	810/6/11/83	10.43	12.80	17.12	1.64
	1710/9/4/84	9.54	11.64	15.57	1.63

single wave during the study period had a peak-to-trough height of 19.8 meters and was observed at Stn. 215 in Hecate Strait. The ratio of maximum wave height to significant wave height varied between 1.39 and 2.06 with an average of 1.78. There is an indication of a slight geographical variation in the ratio with lower values associated with Queen Charlotte Sound and, possibly, Langara West. Both have greater swell contributions and are deeper water stations compared with the others. Such a trend should be examined more carefully as it would affect both wave modelling of the area and extreme wave prediction. The maximum wave heights were not always associated with the largest significant wave height at a given station. Corresponding energy density spectra for the record of maximum significant wave height at each station are shown in Figure 8.6.

METOC charts were obtained from the METOC centre at CFB Esquimalt for many of the storms, to allow for a first order intercomparison of corresponding significant wave heights. The usefulness of these charts is extremely dependent on the number and areal coverage of visual observations from ships of opportunity or real-time transmitting wave buoys. Wave heights are contoured on both the basis of empirical as well as subjective determination. Unfortunately there are very few, and often no, reported observations from the study area and wave heights must be inferred from meteorological conditions as well as from offshore wave observations. Three charts were selected to illustrate different storm patterns and extreme wave conditions (Fig. 8.7 a, b, c). Table 8.4 compares wave heights from these, as well as other selected charts, against buoy data. Charts for some of the major storms (for example, December 25-26, 1982) were too poor for use in the comparison. It can be seen in Table 8.4 that the agreement is variable, with both over and under estimates in the chart values. These discrepancies are directly related to the paucity of real-time information as well as the averaging which goes into each chart as the charts are only produced every 12 hours. The severity of some of the under estimates does, however, indicate a need for an improved real-time reporting program for the study area.

8.3 Comparison with Other Areas

Remembering the limits of this wave data set, it is of interest to compare the severity of the wave climate along the northern coast of British Columbia, a

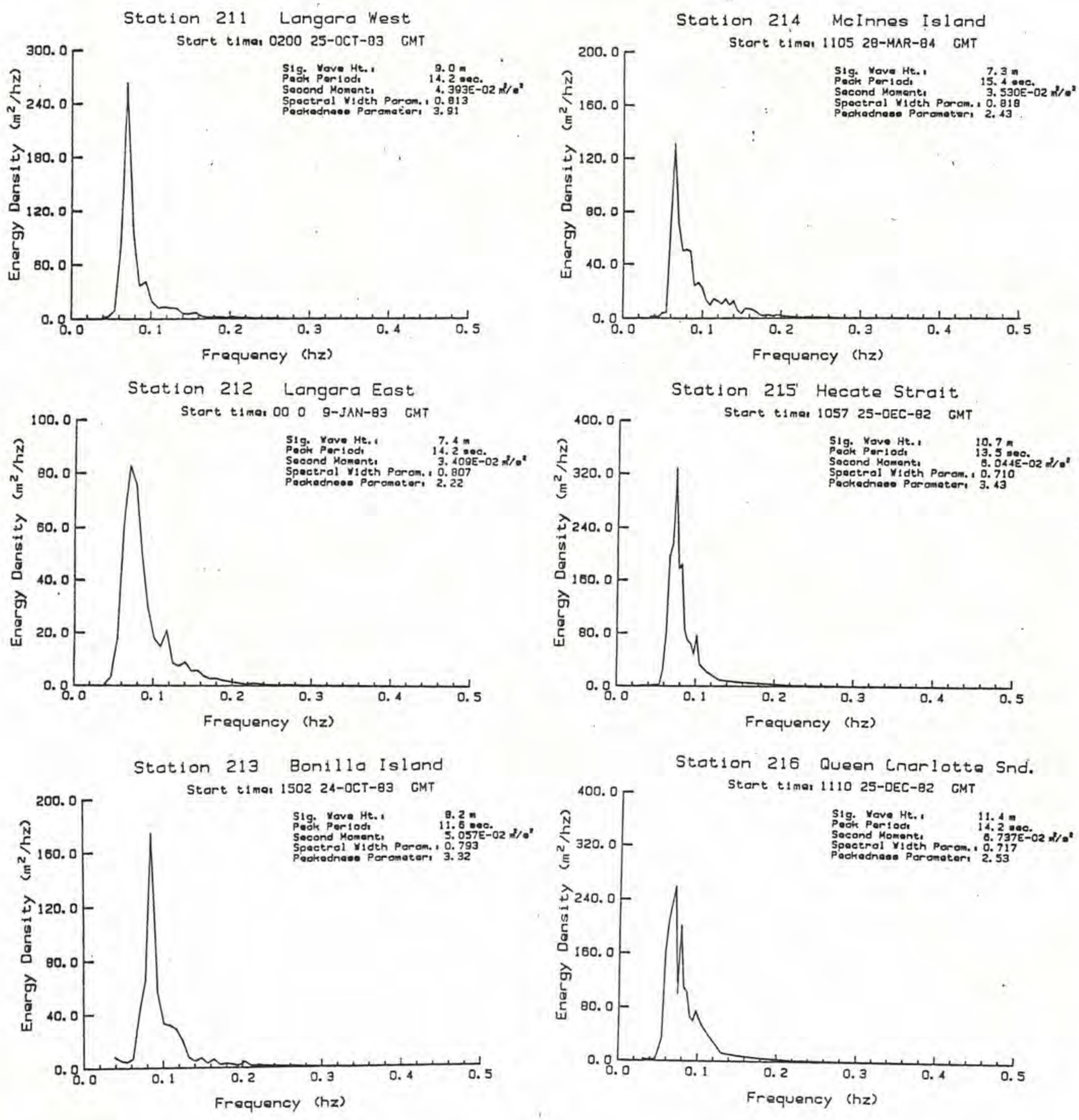


Figure 8.6 Energy density spectra for records of maximum significant wave height at each station.

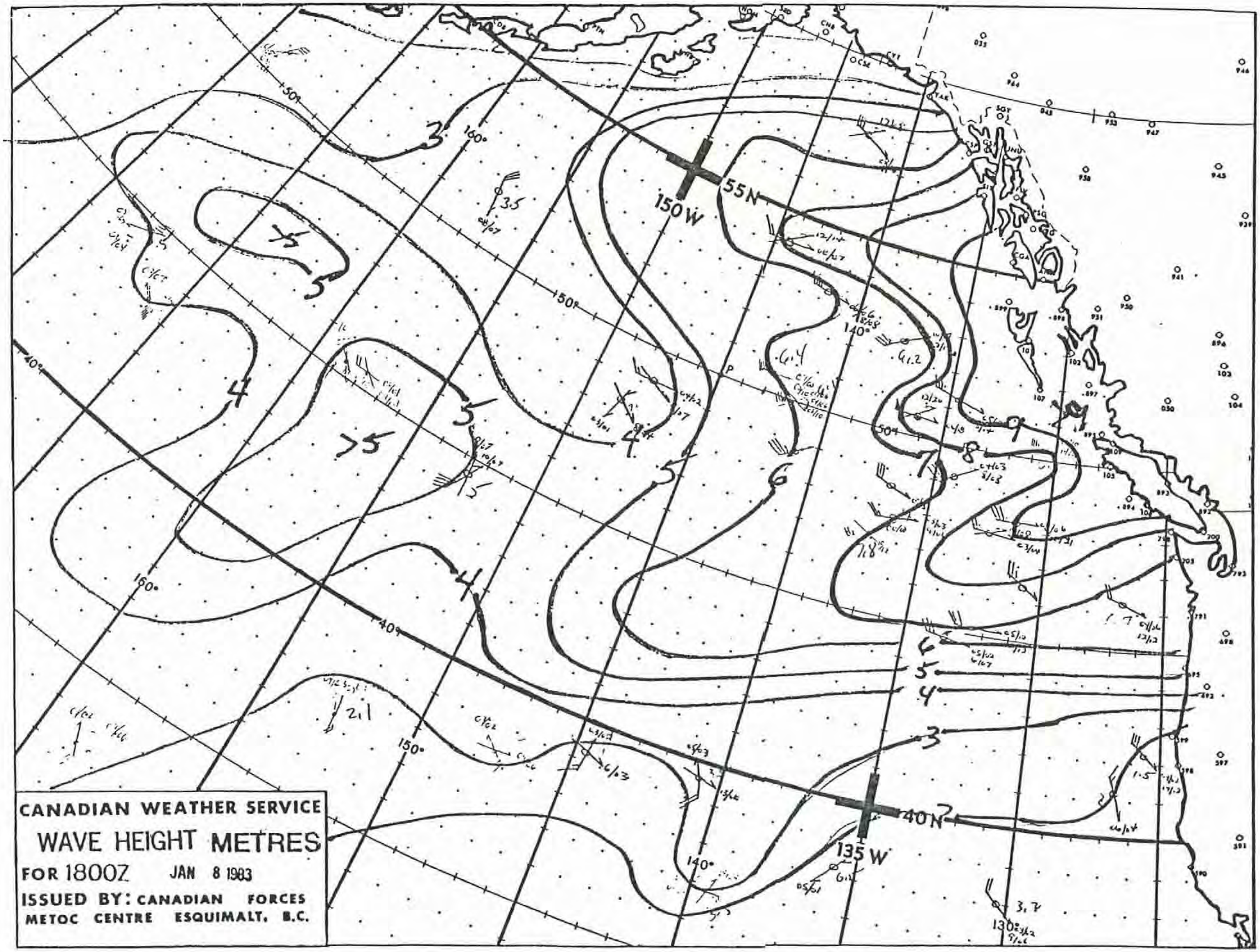


Figure 8.7(a) METOC chart for 1800z Jan 8, 1983

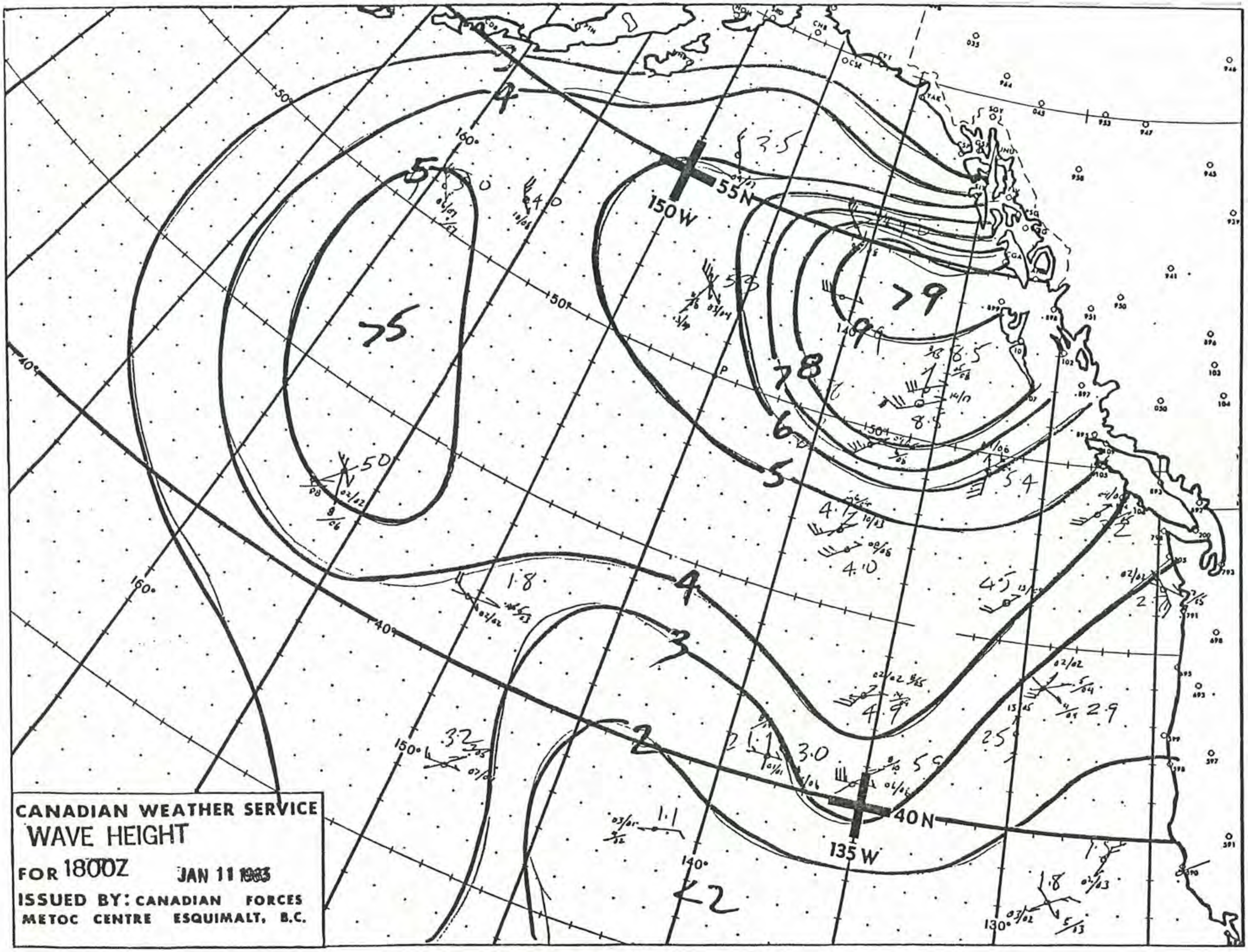


Figure 8.7(b) METOC chart for 1800z Jan 11, 1983

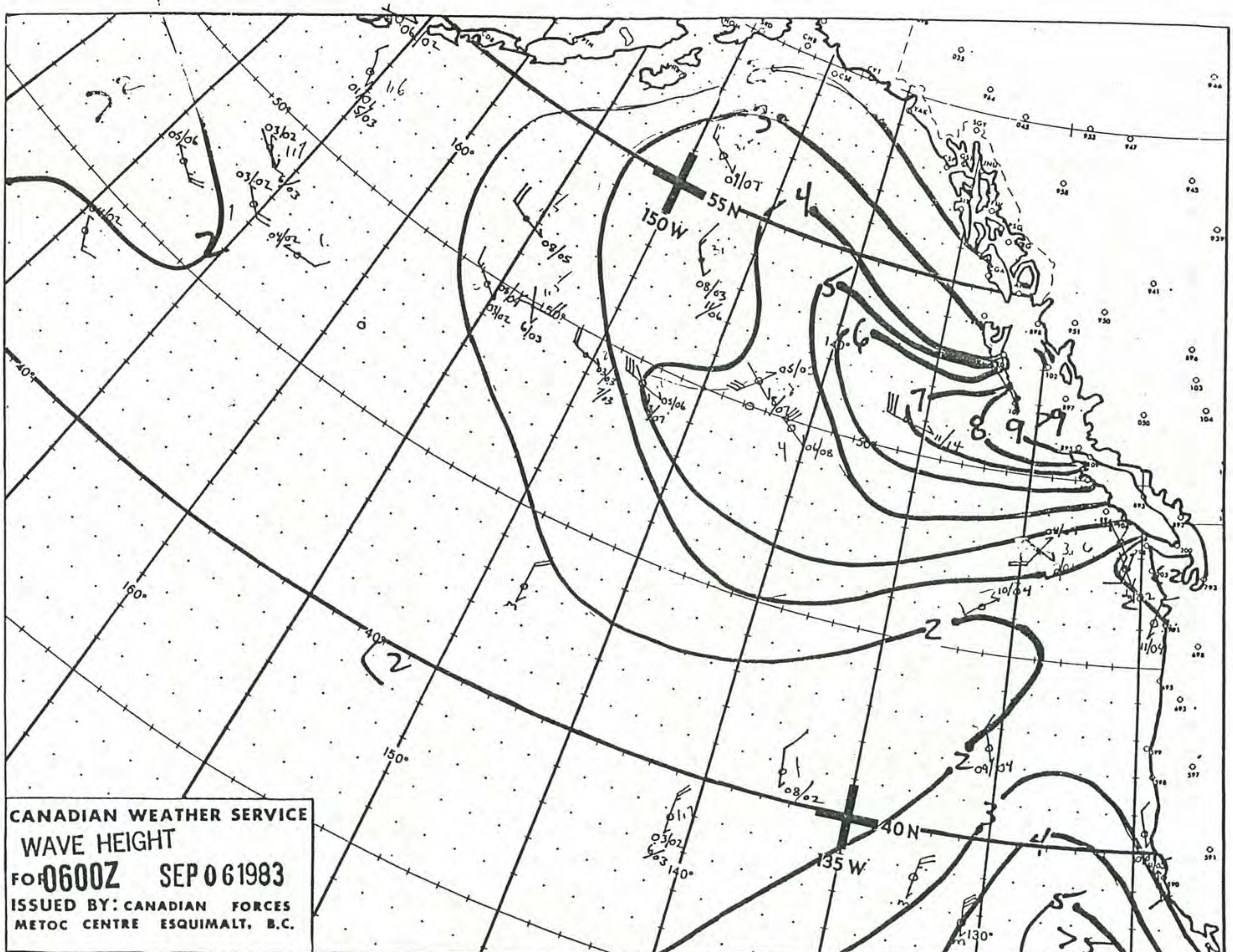


Figure 8.7(a) METOC chart for 0600z Sep 6 1983

Table 8.4

Comparison of Observations with METOC Charts of Largest Waves During Storms

Storm	METOC H_s (m) Langara	METOC H_s (m) Queen Charlotte Snd.	H_s (m) Measured 211	H_s (m) Measured 216	H_s (m) Measured 215	Locations of Maximum Wave Heights Indicated on METOC Charts
8-9/1/83	>9.0	>9.0	7.4	7.5	5.0	In study area
10-11/1/83	>9.0	6 - 8	8.4	7.1	6.0	Centre West of Dixon Entrance
6/9/83	2 - 3	>9.0	<5.0	8.9	<5.0	Centre in Queen Charlotte Sound
15/12/82	7 - 8	7 - 8	7.6	9.0	8.1	Centre just south of Alaska
25-26/1/83	7 - 8	7 - 8	5.6	10.8	8.95	Centre 40éN, 145éW
1-2/4/83	3 - 4	6 - 7	no data	no data	8.8	Major centre SW of Q. Ch. Snd. with 2 minor centres west of the area.
6/11/83	<4.0	3 - 7	9.2	10.4	9.2	Centre West of Vancouver Island
26/2/84	7 - 8	5 - 6	9.4	8.3	9.4	Three centres: one at Dixon Entrance (8m) and 2 further west (>4, >10m)
17-19/3/84	~5.0	5 - 6	5.0	5.3-7.9	5.0	1 centre west of Q. Ch. Is.(>9) other in Gulf of Alaska (<6)
28/3/84	2 - 3	6 - 7	5.6	8.4	6.9	Centre just west of Cape St. James (>8m)
7/4/84	5 - 6	5 - 6	5.6	8.1	7.5	Centre just west of Cape St. James (>9m)
10-11/4/84	>5	5 - 6	6.4	9.5	8.6	Centre west of Q. Ch. Snd. (>11 m)

potential petroleum exploration area, against currently active offshore drilling sites. The areas examined were the North Sea, Newfoundland Grand Banks (Hibernia) and Sable Island. The data sources included buoy, METOC, and hindcast model results. These data were not always available in the same format, they often had to be estimated from plots and they each also have their own limitations, so that only general comments can be made.

Table 8.5 lists the observed exceedances of significant wave height during expected extreme wave periods. The conditions in the Queen Charlotte Sound area were comparable with those at Hibernia and slightly more severe than in the central North Sea. Exceedances in Dixon Entrance and Hecate Strait were less than those at Hibernia and comparable with the Central North Sea, although greater background energy, associated with swell waves (2 - 3 m), is present in Dixon Entrance. Table 8.6 is included only for reference since available data from the northern coast of British Columbia is limited when examining predicted and observed extremes.

Table 8.7 lists the observed exceedances of peak period for the selected areas. Because exceedances at long periods are directly related to exposure and water depth, differences are to be expected. There is little preventing long period energy reaching Queen Charlotte Sound, Hecate Strait or Dixon Entrance from the Pacific. The North Sea, however, being semi-enclosed, does not allow long-period swell to develop locally, and swell is generally prevented access from the Atlantic due to the British Isles. Both the Hibernia and Sable Island sites, though fully exposed, are relatively shallow, and long period energy may be reduced due to refraction and/or wave breaking. With the exception of the southern North Sea, which is very sheltered, most of the wave energy lies in the 8 - 12 second range for all sites with a shift to the shorter periods (8 - 10 sec.) in the North Sea.

Table 8.5

Comparison of Winter Exceedances With Other Geographic Locations

Location	Type	Time Period	Significant Wave Height 2.0m	3.0m	4.0m	5.0m	6.0m	7.0m	8.0m	9.0m	Source
			%	%	%	%	%	%	%	%	
Queen Charlotte Snd. (Stn 216)	Buoy	Winter (Dec - Feb)	90	74	46	22	9	3	1	.5	This study
Hecate Strait (Stn 215)	Buoy	Winter (Dec - Feb)	72	44	22	9.5	4	1.7	.7	.2	This study
Dixon Entrance (Stn 211)	Buoy	Winter (Dec - Feb)	86	52	22	9	4	1.3	.3	-	This study
Hibernia	METOC	Winter Dec. to Feb. 11 year average	90 - 80	70 - 60	40 - 30	20 - 15	10 - 7	4	2	1 - .5	Neu (1982)
Queen Charlotte Snd. (Stn 216)	Buoy	Nov. to Mar.	86	66	40	18	7.2	2.9	1.4	.5	This study
Hecate Strait (Stn 215)	Buoy	Nov. to Mar.	63	37	17	7.6	3.2	1.2	.5	.15	This study
Dixon Entrance (Stn 211)	Buoy	Nov. to Mar.	80	45	18	6.9	2.8	.9	.1	-	This study
Central North Sea	Shipborne Wave Recorder	Nov. to Mar. 6 year average	65	35	18	8	3	1	< 1	-	Baird (1984)

Table 8.6

Observed and/or Predicted Extremes: Northern B.C. Coast and Other Areas

Location	Type	Time Period	Obs. Max H_s	Obs. H_{MAX}	H_s 50 yr.	H_{MAX} 50 yr.	H_s 100 yr.	H_{MAX} 100 yr.	Source
Queen Charlotte Snd. (216)	Buoy	Oct. 82 - May 84	11.4	18.5					
Queen Charlotte Snd.	Hindcast				17.7	31.7	19.8	35.7	Quayle and Fulbright (1975)
Hecate Strait (215)	Buoy	Oct. 82 - Nov. 84	10.7	19.8					
Hecate Strait	Visual		>20.0	30.0					James (1969)
Dixon Entrance (211)	Buoy	Nov. 82 - May 84	9.0	15.2					
Hibernia	METOC	1970 - 1980 Normal Year (for 11 yrs)	9.0 (12.3)	*16. *22			15-16	27-29	Neu (1982)
Hibernia	Buoy	1980 - 83	11-12	*20-22					Baird (1984)
Hibernia	WIS Hindcast	1956 - 75	>15				16-18	*29-32	Baird (1984)
Hibernia	SOWM Hindcast	1956 - 75					17-20	*31-36	Baird (1984)
Sable Island	METOC	1970 - 1980 Normal Year (Over 11 yrs)	8.7 (11.7)	*16 *21			15	26-27	Neu (1982)
Sable Island	Buoy	1981 - 83	8-9	*14-16					Baird (1984)
Sable Island	WIS Hindcast	1956 - 75	11-12	*20-22			15-16	*27-29	Baird (1984)
Sable Island	SOWM Hindcast	1956-75					17-18	*31-32	Baird (1984)
Labrador Shelf	METOC	1970 - 1980 Normal Yr. (over 11 years)	9.3 (12.5)	*17 *22.5			16-17	29	Neu (1982)
Northern North Sea	Buoy	1973 - 75	9-10	*16-18	*16-18	28-30			Baird (1984)
Central North Sea	Shipborne Wave Recorder	1969 - 76	11-12	*20-22	*11-14	20-25			Baird (1984)
Southern North Sea	Shipborne Wave Recorder	1970 - 79	6-7	*11-13	*9-11	17-20			Baird (1984)

* H_{MAX} calculated from H_s x 1.8, or vice versa and rounded.

Table 8.7

Comparison of Peak Period Exceedances: Northern B.C. Coast and Other Areas

Location	Type	Time Period	Peak Period (s) >4	6	8	10	12	14	16	18	Source
			%	%	%	%	%	%	%	%	
Queen Charlotte Snd. (216)	Buoy	year	100.0	99.0	85.8	60.8	35.8	20.4	9.5	2.3	
Hecate Strait (215)	Buoy	year	99.8	93.1	80.8	61.4	40.0	27.0	12.1	2.5	
Dixon Entrance (211)	Buoy	year	99.8	96.5	82.7	51.3	26.7	14.8	6.0	1.9	
Hibernia	Buoy	year	99	98	85	50	21	5	1	-	Baird (1984)[1]
Sable Island	Buoy	year	99	90	63	22	7	3	1	-	Baird (1984)[1]
Northern North Sea	Buoy	year	100	97	75	22	3	-	-	-	Baird (1984)[1]
Central North Sea	Shipborne Wave Recorder	year	100	98	81	32	7	<1	-	-	Baird (1984)[1]
Southern North Sea	Shipborne Wave Recorder	year	95	55	6	<1	-	-	-	-	Baird (1984)[1]

1 = Estimated from plots.

9. CONCLUSIONS AND RECOMMENDATIONS

9.1 Instrumentation and Field Work

9.1.1 Datawell Waverider Systems

The system is basically reliable. The receivers functioned very well with the only drawback being their large physical size. The Sea Data loggers were reliable, with few tape handling problems encountered by the operators. Battery power protected the electronics from spikes or other variations in AC power and decreased problems with the internal clock/counter. The loggers could be improved by adding an LCD display for the clock/counter which could be written down at the start and end of the tape by the operator. This would prevent ambiguities in time assignments when the counter is accidentally reset. Another improvement would be to modify the logger to allow for continuous recording during storm events.

9.1.2 ENDECO 956 WAVE-TRACK System

The small size of the buoy and its easy assembly and deployment proved to be very convenient at sea. The accelerometer and tilt sensors are fairly robust: they were still working after the buoy had grounded and rolled around the beach. However, the limited battery capacity is a serious handicap because the buoy cannot transmit continuously, being limited to 500 hours of transmission per battery pack. This causes problems in set-up and check-out of instruments, in buoy location by radio direction finder, and it prevents continuous recording of data during storms. The small size, with limited reserve buoyancy, and the high drag of the submerged staff and sensor assembly necessitates a large amount of subsurface buoyancy in the mooring. We favour a larger buoy, with both increased buoyancy and battery capacity, and provision for continuous recording. A switch away from lithium batteries is also desirable because they present problems in disposal. A bright flashing light is also needed: the buoy is extremely difficult to spot from a distance and this is probably why it was fouled twice.

The ENDECO receiver is small, light and easy to use. There were no apparent problems with power interruptions. The use of a Sea Data Logger is recommended, as the receiver does not supply adequate record and scan counters when providing digital output.

9.1.3 WRIPS Buoy

The WRIPS buoys were reliable and provided redundancy (satellite transmissions and internal recording) that resulted in little data loss. The two major drawbacks of these buoys are the inability to record continuously during storms, and the use of lithium batteries which are expensive and come under various transport and disposal restrictions. The two equipment problems encountered were a GOES transmitter failure and flooding of the transmit antenna housing.

The ARGOS system proved very helpful in tracking and recovering buoys that went adrift. To recover the buoy, an aircraft search was initiated from the most recent ARGOS position and a vessel directed to the buoy from the aircraft. There were some problems, however, in obtaining up-to-date ARGOS positions.

An Ocean Applied Research Model ADFS-335 Automatic Direction Finder System was tested from a research vessel as a means of "homing in" on the ARGOS transmissions. The device was found to be capable of providing accurate relative bearing information at distances up to 12 kms in smooth seas. This device should be modified and tested for aircraft use.

9.1.4 Datawell WAVEC

The relatively large size and weight of the buoy makes handling and deployment more difficult than the other buoys. Deployment is also complicated by the mooring cross suspended beneath the buoy. However, the large size makes it more visible and the resilient foam reduces potential damage during deployment and recovery operations. Anti-fouling paints do not adhere well to the foam or stainless steel and fouling could become a problem for long deployments. The major concern is the durability of the buoy design: on two occasions, during storms, the perimeter flotations either became dislodged or lost. The cause of the dislodgement is unknown but should be investigated further.

There were problems with the DIREC receiver during generator changeover at the shore station. This resulted in an inability to communicate with it using the terminal and prevented further trouble shooting since the terminal is essentially the only link to the unit. These problems occurred in spite of the installation of a voltage spike arrester and isolation transformer. A major improvement would be to add additional indicator lights, test points and a system reset switch on the receiver and to modify the system to operate from a DC rechargeable battery supply in case of power failures.

When the DIREC receiver was operational, it was found to be easy to use, it provided flexibility in programming, recording and displaying data, and allowed for monitoring of buoy battery voltage. The DIREC also supplied sufficient time, record and status indicators for later data processing. There were no problems with the telemetry aside from the initial receiver/transmitter frequency drift. A desirable further development of the system would be to allow for on-board processing, recording and GOES transmission of directional spectral information.

9.1.5 Weather Station

The satellite-transmitting weather station, supplied by Petro-Canada, proved to be reliable throughout most of the project. It has the distinct advantage over the Atmospheric Environment Service lighthouse weather stations in that it can be deployed in the most optimal position for good exposure. The instrument positions at the lighthouses are usually a compromise between accessibility and exposure.

9.2 Data Processing

At the onset of this project, the data processing scheme depicted in Figure 5.1 was established for the Waverider, WRIPS and WAVE-TRACK systems. It was designed to use common processing and display programs, whenever possible, which contained options for the different instrument types, thereby making it easier for the program user. However, as the complexity of the programs increased and the need to incorporate WAVEC data processing arose, it was found that the programs became too large for the capacity of the PDP-11/34 computer system, forcing numerous versions of a given program to be created. In retrospect, a series of smaller programs, specific to each instrument, but calling on a library of frequently used subroutines, would have proven more efficient and could have been made user-friendly through a set of command files. As the volume of data and time involved in processing increased with the onset of WAVEC data handling, a non-interactive processing scheme was also established and proved to be very efficient in both operator and computer time.

Both the data return and quality from the Waverider and WRIPS systems were excellent. The internal recording feature of the WRIPS buoys proved essential in providing missing records that resulted from buoy transmission failures or computer problems. The phone/computer link, established for transferring data from MEDS computer to Seakem, proved to be an efficient method and allowed for rapid troubleshooting of buoy problems.

The recording of digital data, using Sea Data Loggers for both the Waveriders and the ENDECO WAVE-TRACK buoy, virtually eliminated the many problems associated with analog recording. The ENDECO WAVE-TRACK receiver, although capable of transmitting 8-bit digital data to a standard data recorder (i.e., Techtran recorder) does not provide explicit time indicators, scan counters or quality codes. Experience with an ENDECO system using a Techtran data recorder and the numerous problems encountered with record time, as well as data block assignments, has indicated that the use of a Sea Data Logger (or equivalent) is highly desirable.

Numerous complications were encountered during the processing of the ENDECO WAVE-TRACK data. The 10 frequency Band-Pass directional wave analysis program had serious limitations. It provided poor frequency resolution, required large amounts of computer time, and did not allow for the calculation of a directional spectrum directly. Because it required complete, uninterrupted time series, there were fewer records that could be analyzed compared with the ensemble averaging approach of the Longuet-Higgins analysis on WAVEC data. The poor frequency resolution of the 10 frequency Band-Pass method forced a separate processing of the heave channel, through the same scheme as the Waveriders. An optional 28 frequency Band-Pass routine was available but its use proved to be prohibitive in computer time. ENDECO Inc. also supplied a program to perform a Longuet-Higgins analysis. Under recommendations of Seaconsult and the manufacurer, the 10 frequency Band-Pass method was retained. However, Dr. Lester Le Blanc (pers. comm.) who was involved in the initial design of the buoy, personally rejects the Band-Pass method and recommends a version of the Longuet-Higgins analysis using modified amplitude and phase transfer functions.

Upon examination of the heave spectrum of WAVE-TRACK records, the presence of spurious low frequency energy was observed. The height of this peak often rivalled that of the "normal" spectral peak. The cause of this energy is not clear. In order to correct for it, the manufacturer supplied two new versions of the spectral software. In both, the four lowest frequency bands were modified to eliminate this energy. Our concern was that the instrument amplitude and phase transfer functions, related to the electronics, were different from those originally supplied by the manufacturer (see Appendix 3). The presence of low-frequency energy and often noisy heave spectrum created other problems (related to the calculation of spectral statistics and the application of amplitude and phase corrections to the time series) by introducing long period oscillations into the data. If this spurious energy cannot be corrected in an acceptable manner the WAVE-TRACK buoy may have limited usefulness.

The DIREC receiver, used in the WAVEC system, was capable of providing time, record counters and quality codes. This was extremely useful in both time assignments and error checking. The Longuet-Higgins directional spectral analysis was applied to the data and appeared to describe the wave field well. Other directional distributions may be as valid, however, and should be tested. The data quality was good and there was good agreement with measurements taken by the nearby Waverider off Tofino during the initial trial. However, this test was too short and insufficiently rigorous for proper assessment.

9.3 Observed Wind and Wave Climate

Local winds measured during the study period showed the expected seasonal and geographic trends. However, the wind direction distribution was often different than historical means. How this relates to the measured wave field, in terms of 'normal' wave conditions, will have to be assessed.

Wave conditions generally agreed with those expected given mooring site exposure, except that wave peak directions measured at Bonilla Island were often confused and questionable, providing further criticism of the 10 frequency Band-Pass directional analysis.

Extreme conditions cannot be predicted into the future with confidence due to the relatively short duration of the study. Further monitoring is required to properly assess regional norms as well as extremes.

The conditions observed in the study area were similar to those measured at the currently active oil exploration sites of Hibernia and the Central North Sea. Peak periods extend to longer periods at our exposed sites than is the case for Hibernia, Sable Island and the North Sea.

10. ACKNOWLEDGEMENTS

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- IOS (Patricia Bay) personnel - Stan Huggett, Mike Woodward, Rick Thomson for advice and assistance during recovery and deployment operations.

- METOC personnel - Doug Bancroft and Mike Blake for providing wave charts.

- Datawell Staff - especially Mr. Peter Gerritzen for their advice and assistance in testing and operation of the WAVEC buoy.

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- Lighthouse keepers -Ted Ashe, Ken Brunn and Wayne Fullerton at Langara Point
  - Jean Beaudet at Bonilla Island
  - John Coldwell at McInnes Island.

  Without their avid interest and diligence, the data recovery would have been low and our problems numerous.

- Canadian Coast Guard Staff - Seal Cove - for assistance and advice, transport of equipment; especially Mr. Bruno Bomben, Mr. Nick Mansell, Mr. Rick Ogilvie and Ms. Vivian Skinner.

- Captain and crew of the CFPV Tanu for their efforts in the recovery of the WRIPS buoy off the west coast of Moresby Island in March, 1983.

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- The Captain and crew of CCGS George Darby for the recovery of the damaged WAVEC buoy in November, 1983.

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APPENDIX 1

DETAILED LOG OF EVENTS

LOG OF EVENTS: STATION 211 - LANGARA WEST

October 7, 1982	- Waverider/F1 (0.9 m diameter) S/N 67844-9 deployed (30.520 Mhz) LOCATION: 54°26.9'N 133°19.4'W LORAN-C: (5990) X - 11307.4 Z - 41619.9 WATER DEPTH: 293 metres (160 fathoms)
October 21, 1982	- WAREP Mk II S/N 2416 installed Sea Data Model 1236 S/N 02 installed - sampling initiated at 3 hour intervals - STATION FULLY OPERATIONAL AT 0000z October 22, 1984
November 6, 1982	- Sea Data Model 1236 S/N 02 removed (final recording at 1800z Nov. 6) - Sea Data Model 1236 S/N 01 installed - data recorded for 34 minutes every hour beginning at 0400z November 7, 1982.
July 5, 1983	- Waverider buoy S/N 67844-9 recovered from mooring (2145z). Batteries were replaced and the buoy serviced.
July 6, 1983	- Waverider buoy S/N 67844-9 redeployed (2120z) LOCATION: 54°26.9'N 133°19.7'W LORAN-C: (5990) X - 11307.1 Z - 41619.6 WATER DEPTH: 289 metres (158 fathoms)
May 4, 1984	- Waverider buoy S/N 67844-9 cut free from mooring and recovered by fishing vessel.
May 14, 1984	- Waverider buoy S/N 67844-9 picked up at Shearwater, B.C.

LOG OF EVENTS: STATION 212 - LANGARA EAST

October 7, 1982	- Waverider/F1 (0.9 m diameter) S/N 67843-9 deployed (30.320 Mhz) LOCATION: 54°26.2'N 132°48.3'W LORAN-C: (5990) X - 11340.1 Z - 41646.5 WATER DEPTH: 381 metres (208 fathoms)
October 21, 1982	- WAREP Mk II S/N 2415 installed - no data logger installed at this time.
November 6, 1982	- Sea Data Model 1236 S/N 02 installed on this system. Data recorded for 34 minutes (at 0000z, 0300z, etc.) every 3 hours. - STATION FULLY OPERATIONAL BEGINNING AT 2100z November 6, 1982.
May 3, 1983	- Buoy failure (due to broken antenna lead wire).
July 5, 1983	- Defective buoy S/N 67843-9 recovered at 1805z.
July 7, 1983	- Replacement Waverider/F1 S/N 67597 deployed (30.320 Mhz) LOCATION: 54°25.7'N 132°48.0'W LORAN-C (5990) X - 11342.6 Z - 41645.8 WATER DEPTH: 381 metres (208 fathoms)
November 22, 1983	- Waverider buoy S/N 67597 fails due to damaged accelerometer suspension.
January 22, 1984	- Defective Waverider buoy S/N 67597 removed from mooring and replaced with Waverider S/N 67843-9 (same frequency - 30.320 Mhz) (1200z)
May 25, 1984	- Waverider S/N 67843-9 recovered (0215z)

LOG OF EVENTS: STATION 213 - BONILLA ISLAND

October 2, 1982	- ENDECO WAVE-TRACK buoy S/N 9560110T deployed. Buoy transmitting at 0012-0030z, repeating every 3 hours. Transmission frequency = 30.420 Mhz. LOCATION: 53°21.2'N 130°46.7'W LORAN-C:(5990) X - 12153.3 Z - 41585.4 WATER DEPTH: 156 metres (85 fathoms)
November 4, 1982	- ENDECO WAVE-TRACK receiver S/N 9560110R installed. - Sea Data Model 1236 data logger S/N 03 installed. - STATION FULLY OPERATIONAL (1800z).
January, 1983	- Directional receiving antenna replaced with Kathrein antenna mounted on light tower.
January - May, 1983	- Heavy radio interference prevents data reception during January, February, March and April. - Failure in demultiplexing filter in receiver during January causes loss of data from one of the two tilt channels. No direction calculations possible for data collected January - May, 1983. Heave data only available at reduced frequency due to radio interference.
May 28, 1983	- 0028z - last good data recovered from ENDECO Buoy. Buoy went adrift sometime after this.
July 2, 1983	- Ship and aircraft search for ENDECO WAVE-TRACK buoy in vicinity of Bonilla Island.
July 19, 1983	- ENDECO WAVE-TRACK buoy recovered and delivered to Ketchikan, Alaska.
July 20 - 30, 1983	- Demobilize and check out ENDECO buoy. - Repair receiver filter - Send buoy to ENDECO for repairs.
September 18, 1983	- ENDECO WAVE-TRACK redeployed (1625z). LOCATION: 53°21.6'N 130°46.4'W LORAN-C: (5990) X - 12152.9 Z - 41585.1 WATER DEPTH: 154 metres (84 fathoms) - 2100z September 18, 1984 - data logging resumes.
January 5, 1983	- Failure of heave channel - receiver returned to Seakem for testing and adjustment.
February 10, 1984	- Returned to Bonilla Island - short (~5 seconds) transmissions from the buoy were observed.

February 16, 1984 - Buoy not found at mooring site.

March 15, 1984 - ENDECO WAVE-TRACK buoy recovered in Ketchikan, Alaska. Buoy heavily damaged.

LOG OF EVENTS: STATION 214 - McINNES ISLAND

April 19, 1983	- Datawell WAVEC buoy S/N 22003 deployed at 1650z. - Transmitting frequency = 30.120 Mhz LOCATION: 52°06.8'N 128°57.5'W LORAN-C: (5990) X - 13167.8 Z - 41427.0 WATER DEPTH: 189 metres (103 fathoms)
April 21, 1983	- Receiving station for WAVEC installed at McInnes Island. The receiving station consists of the following components: WAVEC receiver/processor (DIREC) - S/N 23001 3M Whisper Writer Teleprinter Model 1482 BA S/N 662035 with keyboard Model 1445 BC S/N 419166 Columbia Data Products 300D Recorder S/N D10386 Kathrein receiving antenna and associated cables. - SYSTEM FULLY OPERATIONAL AT 2100z.
May 14, 1983	- Data logging ceases due to transmitter/receiver frequency drift.
May 26, 1983	- Unsuccessful attempt to retune DIREC receiver at McInnes Island. DIREC, Whisper Writer and data recorder returned for servicing. Following consultation with manufacturer, the DIREC was returned to the manufacturer for repairs and modifications.
June 29, 1983	- WAVEC buoy S/N 22003 recovered at 1915z. The batteries were replaced and a replacement transmitter installed.
June 30, 1983	- Receiving station (DIREC S/N 22003, Columbia Data Products 300D Recorder S/N D10386, Whisper Writer printing terminal - Model 1482BA - S/N 662035 and Model 1445 BC - S/N 419166) reinstalled at 1700z. - WAVEC buoy S/N 22003 returned to existing mooring (1810z).
October 25, 1983	- WAVEC buoy S/N 22003 broke up on mooring (~600z)
November 26, 1983	- WAVEC instrument package plus top float recovered by the CCGS George Darby.
February 20, 1984	- WAVEC buoy S/N 22003 redeployed at 2124z. LOCATION: 52°07.4'N 128°57.0°W LORAN-C: (5990) X - 13165.3 Y - 30326.8 Z - 41430.0 WATER DEPTH: 190 metres (104 fathoms)
March 25, 1984	- WAVEC buoy S/N 22003 damaged in high seas. Large net buoy tilt results from displacement of a single flotation section.

May 15, 1984	- WAVEC buoy S/N 22003 recovered at 0330z.
May 16, 1984	- WAVEC receiving station equipment recovered from McInnes Island.

LOG OF EVENTS: STATION 215 - HECATE STRAIT

September 30, 1982 - WRIPS buoy S/N 67379 deployed.
(DCP 40402684 - frequency 401.728 GOES East)
- buoy transmitting at 0017 GMT repeated each 3 hours.
- Buoy acquiring data for 34 minutes beginning at 2257z and repeating every 3 hours.

LOCATION:	52°11.6'N 130°20.5'W		
LORAN-C: (5990)	X - 12738.3	Y - 30285.2	Z - 41349.3
WATER DEPTH:	370 metres (202 fathoms)		

- STATION FULLY OPERATIONAL.

January 20, 1983 - GOES transmissions fail after 0157z January 20, 1984.
- Data subsequently recovered from internal tape.

April 20, 1983 - WRIPS buoy S/N 67379 recovered and returned for repairs.

July 2, 1983 - WRIPS buoy S/N 67379 redeployed at this site (0230z).

LOCATION:	52°11.8'N 130°19.9'W	
LORAN-C: (5990)	X - 12738.7	Z - 41349.9
WATER DEPTH:	386 metres (211 fathoms)	

November 17, 1983 - WRIPS buoy S/N 67379 adrift from mooring.

November 24, 1983 - WRIPS buoy S/N 67379 recovered (2300z) by CFPV Kitimat II at 52°07.5'N 131°18.0'W.

January 12, 1984 - WRIPS buoy S/N 67379 redeployed at 2145 z.

LOCATION:	52°11.6'N 130°19.9'W		
LORAN-C: (5990)	X - 12743.3	Y -	Z - 41350.5
WATER DEPTH:	368 metres (201 fathoms)		

May 21, 1984 - WRIPS buoy S/N 67379 recovered (0130z).

LOG OF EVENTS: STATION 216 - QUEEN CHARLOTTE SOUND

September 29, 1982
- WRIPS buoy S/N 67400 deployed. (DCP 4040131E - frequency 401.7595 GOES West)
- Buoy transmitting at 0030 GMT repeating each 3 hours.
- Buoy acquiring data for 34 mins. at 2310z and repeating every 3 hours.

LOCATION:	51°18.5'N 129°57.6'W		
LORAN-C: (5990)	X - 13130.1	Y - 30098.3	Z -41157.9
WATER DEPTH:	270 metres (147 fathoms)		

- STATION FULLY OPERATIONAL.

February 22, 1983
- WRIPS buoy S/N 67400 adrift from mooring.

March 22, 1983
- WRIPS buoy S/N 67400 recovered (1853z) by CFPV TANU at 53°23'N 134°04'W.

April 20, 1983
- WRIPS buoy S/N 67400 redeployed at 0200z.

LOCATION:	51°18.5'N 129°57.6'W		
LORAN-C: (5990)	X - 13130.7		Z - 41147.9
WATER DEPTH:	270 metres (147 fathoms)		

November 5, 1983
- GOES and ARGOS transmissions stop from WRIPS buoy S/N 67400.

December 2, 1983
- WRIPS buoy S/N 67400 recovered from mooring by FV Jeannie Marie (under charter to Pacific Biological Station at Nanaimo, B.C.).
- Subsequent investigation revealed the presence of water in the antenna housing.

January 12, 1984
- WRIPS buoy S/N 67400 redeployed at 1645z.

LOCATION:	51°18.6'N 129°58.2'W		
LORAN-C: (5990)	X - 13130.7	Y - 30099.4	Z - 41158.9
WATER DEPTH:	249 metres (136 fathoms)		

May 21, 1984
- WRIPS buoy S/N 67400 recovered at 1320z.

LOG OF EVENTS: McKENNEY ROCK - WEATHER STATION

October 25 - November 1, 1982

- Installation of PetroCanada satellite transmitting weather station on McKenney Rock.
- Handar 530A DCP 4559E572 GOES East
- LOCATION: 52°39.1'N 129°28.3'W
  elevation (base) = 18 metres
- STATION FULLY OPERATIONAL (First GOES transmission) at 2100z November 1, 1982.

- Instrument package:

Wind speed	MET. ONE MET. ONE	Model 013 S/N 98-17-2 Model 014A S/N 497
Wind direction	MET. ONE MET. ONE	Model 023 S/N 104-3-2 Model 024A S/N 440
Air Temperature (two)	MET. ONE	060A-2 (no serial number)
Relative Humidity	PERNIX	50-30-50
Barometric Pressure	SOSTMAN	S/N 14539
Data Collection Platform (DCP)	HANDAR	Model 530 S/N 0298
Antenna	SYNERGETICS	Model 18B S/N 3881A00391
Solar Panel	SILONEX	Model NSL5622 S/N 072

December 29, 1982 - January 26, 1983

- GOES transmission not received. This problem was at least partially due to unauthorized DCP's competing for the time slot.

April, 1983

- Failure of secondary wind direction sensor.
- Remaining air temperature sensor giving erroneous values.

July 21, 1983

- Weather station serviced by Dwight Brymer. High humidity causes programming problems, with the result that only data collected at the synoptic hours (000z, 0300z, 0600z, 0900z, 1200z, 1500z, 1800z, 2100z) are available.

August 25, 1983

- Weather station serviced by Dwight Brymer. Programming problems resolved and hourly data available.

December, 1983	- Secondary wind direction sensor fails. - Missing data December 25 - 30, 1983, caused by computer problems at NESDIS in Washington, D.C.
May 16, 1984	- Weather station serviced by Dwight Brymer and Robin Brown.

APPENDIX 2

DETAILED SPECIFICATIONS OF EQUIPMENT

A2.1 Datawell Waverider buoy

A2.2 Datawell WAREP receiver

A2.3 ENDECO 956 WAVE-TRACK buoy

A2.4 ENDECO 956 WAVE-TRACK receiver

A2.5 Sea Data 1236 and 1236/3 Wave Recorder

A2.6 Datawell WAVEC buoy

A2.7 Datawell DIREC receiver/processor

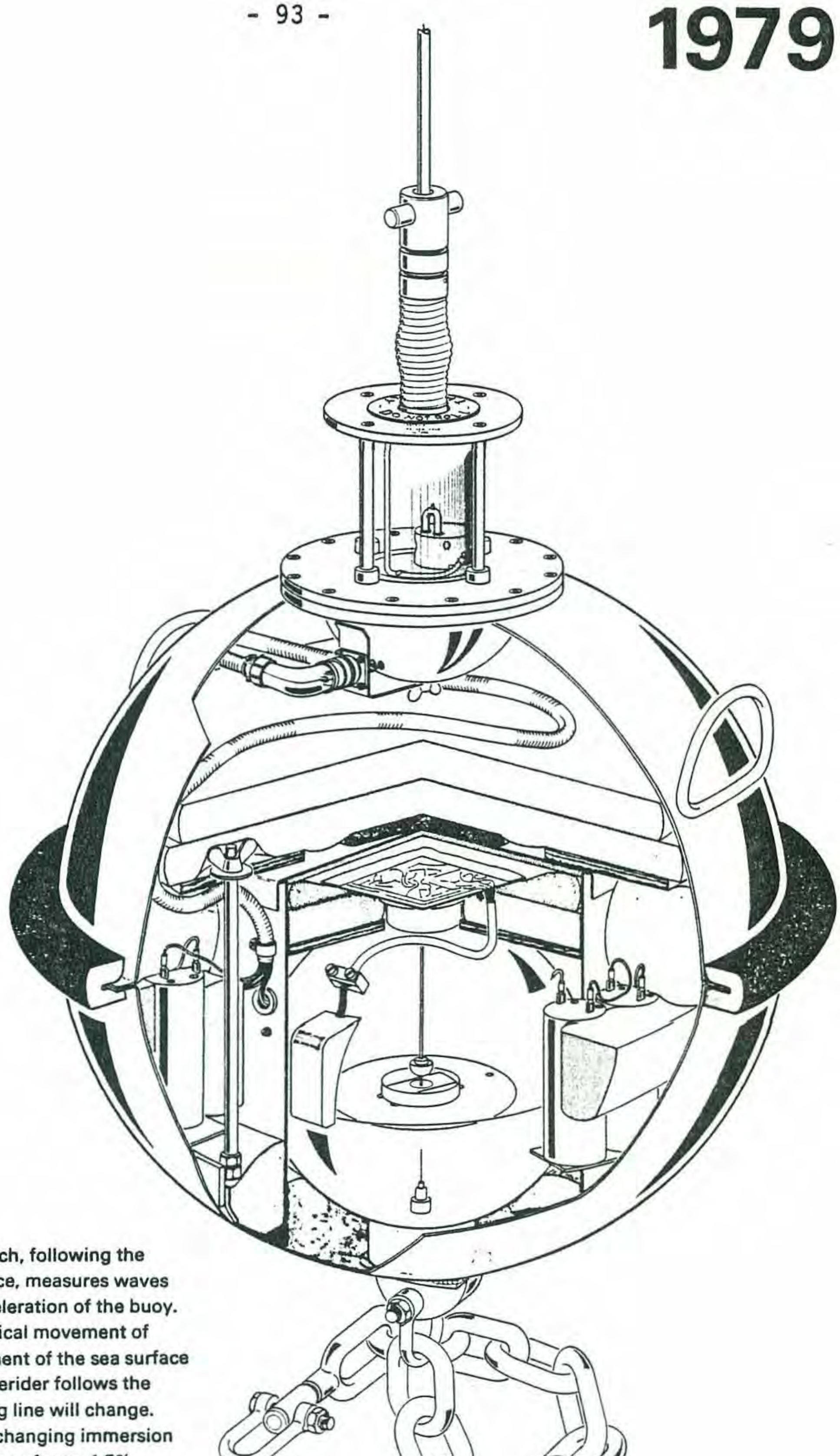
A2.8 Columbia Data products 300D Data Cartridge Recorder

Note: This information has been taken directly from the manuals provided by the manufacturer.

A2.1 Datawell Waverider Buoy

waverider fl

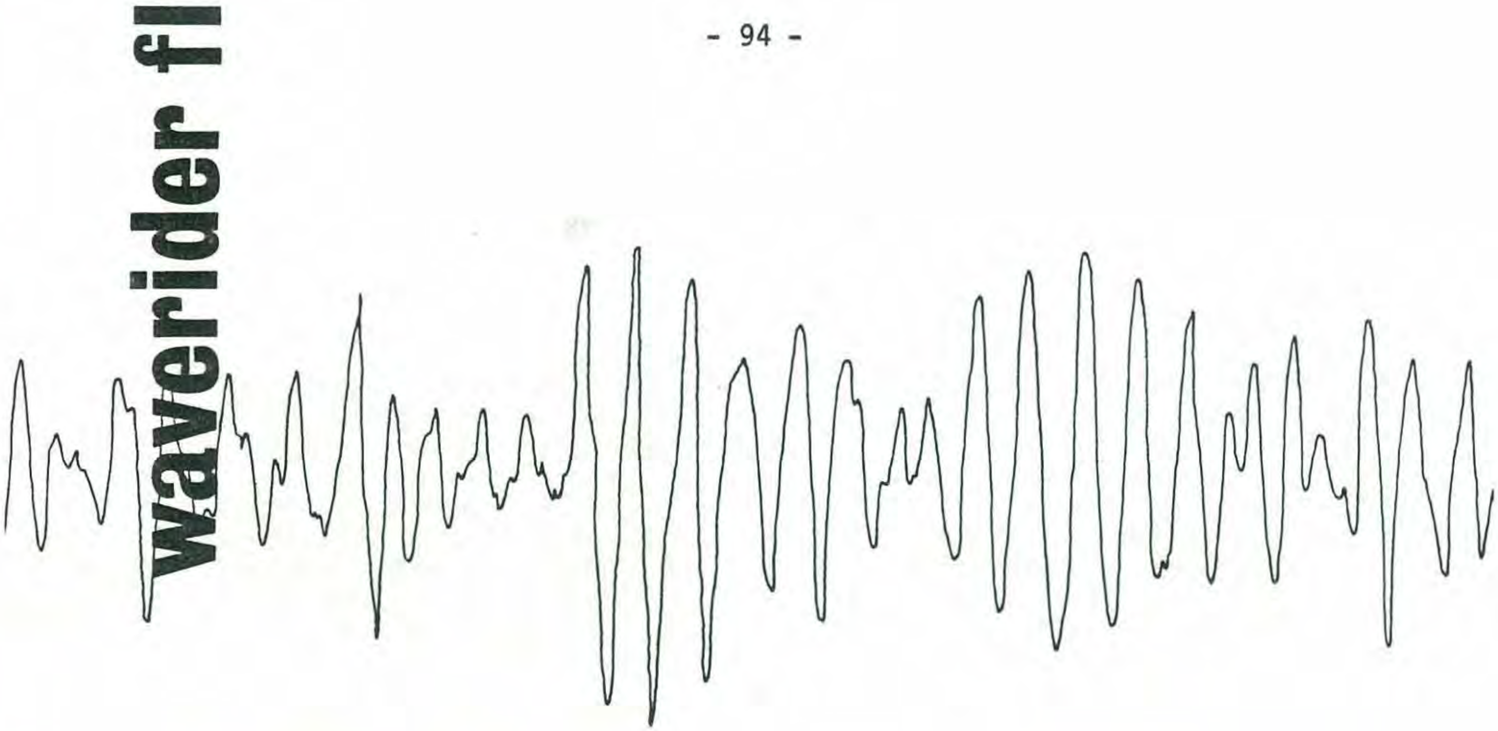
1979



The Waverider[1)] is a buoy which, following the movements of the water surface, measures waves by measuring the vertical acceleration of the buoy. The discrepancy between vertical movement of the Waverider and the movement of the sea surface is small. When a moored Waverider follows the waves the force of the mooring line will change. This force is produced by the changing immersion of the buoy, resulting in an error of max. 1.5%. With decreasing wavelength the buoy will not follow the wave amplitude if the wavelength is less than 5 m [waveperiod below 1.8 sec.]. If the wavelength is less than 2.5 m [waveperiod 1.25 sec.] the response of the buoy decreases fast with increasing wave frequency, see figure 1, part 2. The vertical mooring force on the buoy lies between zero [free floating] and 300 Newton = 30 kgf ≈ 65 lbs [current 2 knots, rubber cord at buoy end of mooring].

[1)] Registered trade mark

Datawell bv
laboratory for instrumentation
Zomerluststraat 4
2012 LM Haarlem - The Netherlands
tel. 023-316053
telex: 41415 datel nl



measurement of vertical acceleration

To avoid measurement of unwanted accelerations accompanying roll and pitch of the buoy, such as horizontal acceleration and decreasing effect of the gravitation, the sensitive axis of the accelerometer is mounted on a stabilised platform having a natural period of 40 seconds and a damping 0.8 of critical for amplitudes larger than 2°.

By this means the sensitive axis of the accelerometer is kept within a few degrees of the vertical, keeping the sensitivity for horizontal accelerations below 3%.

If the suspension of the platform is entangled, oscillations of the platform will occur, showing the zero line of the waverecord to be unstable with a period of 40 seconds. Such entanglement results if the accelerometer [Waverider] is spun more than 10 times [high speed] or faster than one turn in 10 seconds [continuous].

Contamination in acceleration measurement may also be caused by non-linearity of the accelerometer. Periodically changing accelerations with large amplitudes should be measured by the accelerometer in such a way that no change of average acceleration caused by non-linearity occurs [rectification]. For an amplitude of 6 m/sec^2 the accelerometer changes the average acceleration with less than 2.10^{-3}m/sec^2 [equivalent to 0.05 m].

integration of the accelerometer signal

In order to obtain vertical displacement the acceleration signal is integrated twice.

The integration process limits the response of the Waverider at low frequencies [see fig. 1, part 1], to prevent slow changes in the accelerometer output and electronics to appear on the wave record.

transmission of the wave signal

The d.c. signal analog with wave height is converted into an fm square wave signal at a scale of 1.86 Hz/m with zero wave height at 259 Hz.

This fm square wave modulates the transmitter [rise time 0.25 msec.]. The 100% am transmission frequency lies between 27 and 28 MHz.

At this frequency transmission by reflection against the ionized layers around the earth does not normally occur.

With the 80 mWatt power level and the phase-locked receiver dependable reception over 50 km [over sea] is obtained if the man-made noise level at the receiving site is low and the wave height below 10 m.

For wave heights above 10 m the transmitted e.m. waves are deflected by the sea waves, only by refraction can the signal reach the receiver, for example with a wave height of 25 m the range is lowered to 30 km. The transmission frequency is stabilised by means of a crystal type CR-77U.

The transmitted power is radiated from a quarter wavelength polyester glassfibre whip which, if broken, is easy to replace. Since its mounting on a spring allows bending over 90°, the whip will not easily break, however.

mooring

The Waverider is fitted with 5 kg chain ballast attached to the mooring eye.
This provides sufficient stability for use in free floating condition or moored is shallow water to prevent excessive pitch and roll.
To keep a moored Waverider from being pulled under by the passing waves a rubber cord is used as part of the mooring.
The low stiffness of this rubber cord allows the Waverider to follow waves up to 20 m, for higher waves two rubber cords should be used. Only if the mooring instructions as given in the Waverider manual are followed closely a reliable mooring can be assured. Its buoyancy [900 N] keeps the Waverider from submerging under the combined action of an 18 m wave height and a 1.0 m/sec. [2 knots] current. Submergence of the Waverider is indicated by the loss of phaselock in the receiver, which is an important help to check the behaviour of the Waverider in high waves.
Current velocities up to 3 m/sec. [6 knots] can be accepted with another mooring configuration together with a larger model having 2350 N buoyancy

collision risk

High shock accelerations are absorbed by the fluid surrounding the accelerometer and the shockproof mounting of the accelerometer housing, electronics and batteries.
The shell of the Waverider [AISI 316, thickness 2 mm] stays watertight even if largely deformed.
To reduce the risk of collision daymark (yellow topside) and light (group of 5 yellow flashes every 20 seconds) of the Waverider/fl[ash] are as specified for ODAS in the IALA buoyage system "A".

painting not yet introduced

The flashlight operates below a daylight level of 60 lux and has a visibility range of about 1 km.
The suspension of the stabilised platform in the Waverider will wind up when a ship passes so near that the buoy is set spinning.
A wound-up suspension increases the effect of mechanical coupling between the hull and the stabilised platform, exciting the platform in its natural frequency (period 40 seconds) when the Waverider follows the waves.
A triangle can be supplied, which - mounted around the equator of the buoy - will prevent spinning.

transferfunction Waverider

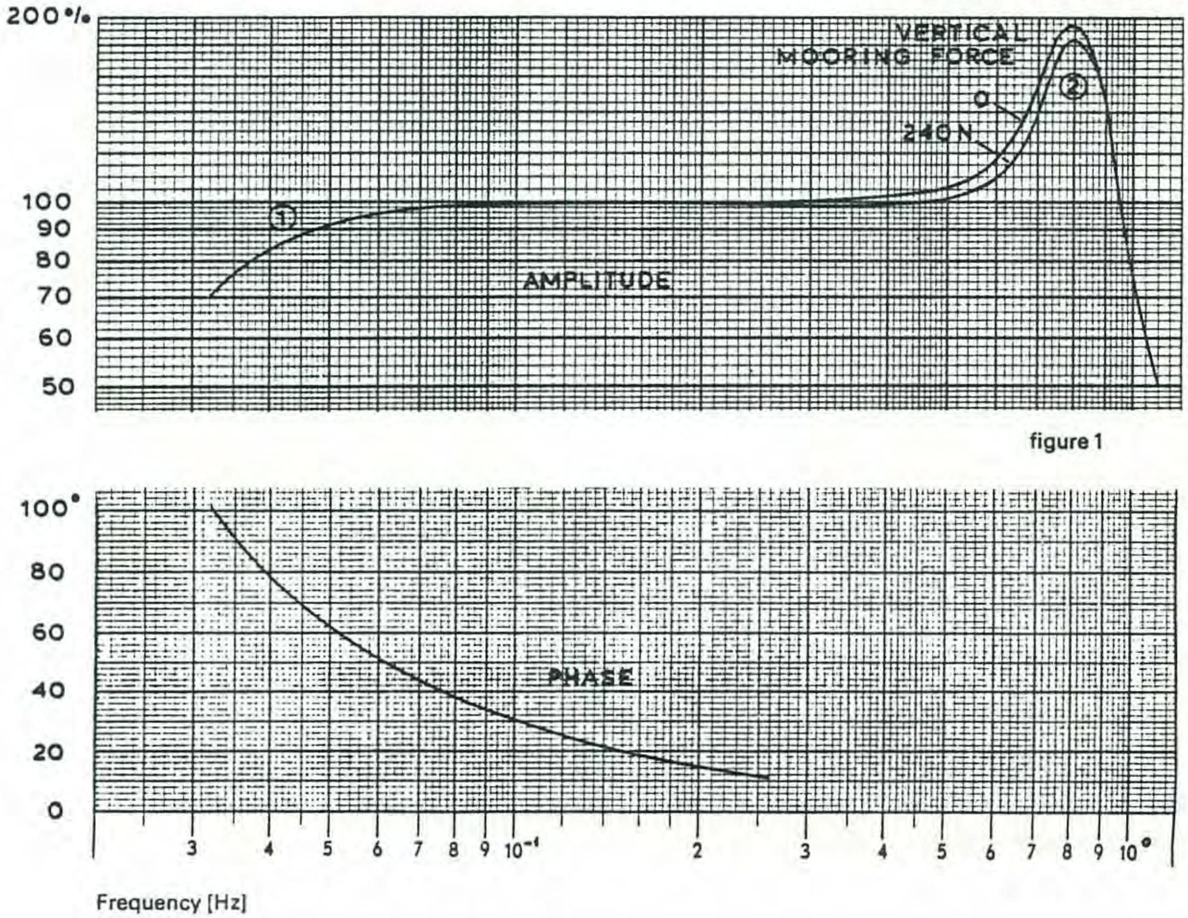


figure 1

specifications

Wave height

minimum: noise peak-peak [bandwidth 1 Hz]
eq. 0.02 m
maximum: twice max. amplitude 2 x 20 m

Wave frequency range

0.035 Hz-0.65 Hz [30%]
0.065 Hz-0.50 Hz [3%]
The wave amplitudes with frequencies between 0.065 and 0.03 Hz can be corrected within 3% of their true value from the frequency response given.

Accelerometer linearity

Non linearity rectification $< 2.10^{-3}$m/sec.^{2} for 6 m/sec.^{2} amplitude.

Horizontal sensitivity

< 3% of vertical sensitivity.

Transmitter frequencies for which crystals are kept in stock

Channel	1	– 27.505 MHz
	2	– 27.525 MHz
	3	– 27.545 MHz
	4	– 27.565 MHz
	5	– 27.595 MHz
	6	– 27.615 MHz
	7	– 27.655 MHz
	8	– 27.695 MHz
	9	– 27.715 MHz
	10	– 27.745 MHz

Radiated power

80 mWatt ± 20%

Battery life

>9 months

Maximum changes if temperature of surrounding water is between –5° and + 25°C

Zero	< 0.5 m
Sensitivity	< 3%
Carrier frequency	< 500 Hz

Extreme storage temperatures

–5°C and + 40°C.

Maximum changes during one year [20° C]

Sensitivity	1.0%
Zero	1.0 m
Platform angle	1°
Carrier frequency	300 Hz
Radiated power	20%

corrosion risk

A few unpainted 316 stainless steel Waverider shells show pitting after a few months, whereas fouling by marine growth is more common. Painting may protect against pitting, but the paint system has to be chosen carefully.
Waveriders can be supplied with Cunifer shells, which neither pit nor foul. Although this material can take large deformations, its breaking strength is half that of 316 stainless steel.

battery life

The Waverider is powered by 26 No. 6 cells [Leclanché].
The life of the cells is at least nine months assuming that the flash light operates 12 hours per day.
If stored cool, self-discharge of the cells is less than 20% per year. The end of cell life is indicated by large irregular excursions on the wave recorder. Discharged cells can be replaced through the hatchcover.

repair

Analysis for repair is given in the Waverider manual.
The repair is based on the use of a service kit containing an antenna power meter, breakout box, pulse switch and prints for replacement.

size and weight

The spherical shell has a diameter of 0.7 meter, diameter over fender 0.78 m, the height of the Waverider including mooring eye and antenna base is 1.10 m, including the antenna whip 3.10 m. Packing crate dimensions are:
height 1.50 m, width 0.78 m and depth 0.78 m.
The weight of a complete Waverider is 106 kg; with crate 148 kg.

warranty

Our products are guaranteed to operate within specifications during the warranty period.
Defects caused by transport are included, provided the instruments were handled in their original packing and with reasonable care.
Excluded from our warranty are the mooring system, pitting of parts exposed to seawater and mechanical damage caused by overloading.
The suspension of the accelerometer of the Waverider might be overloaded if:

a] the Waverider is spun more than 10 times [high speed] or faster than one turn in 10 seconds

b] the Waverider is subjected to large roll/pitch angles by improper mooring.

The warranty period is 12 months from the date of shipping or the period of battery life if shorter.
To decide whether a defect comes under our warranty, the instrument should be returned to Datawell free of charge. If it does come under our warranty, the instrument will be repaired and returned free of charge, by transport similar to that by which it arrived. If the repair does not come under our warranty, the costs of repair and transport will be charged to the buyer.

sales terms

Our products are sold only on the terms and conditions stated above. Notwithstanding any terms or conditions on buyer's order, our performance of any contract is expressly made conditional on buyer's agreement to our terms and conditions of sale unless otherwise specifically agreed by us in writing. In the absence of such agreement, commencement of performance and/or delivery shall be for the buyer's convenience only and shall not be deemed or constructed to imply our acceptance of the buyer's terms and/or conditions.

Patents:
To our knowledge no patent owned by others than ourselves is used in our instruments, but we cannot accept responsibility for this.

Packing: standard [0.1% failure with sea and air transport around the world].

Delivery: f.o.b. Schiphol [airfreight] or
f.o.b. Amsterdam or Rotterdam [surface freight].

Delivery time: from stock or in accordance with production planning.

Payment:
Is accepted only in Dutch guilders.

Discount:
quantity – 5% on the total purchases [based on listprices] if these exceed Dfl. 100.000/period of 12 months.
resale – no resale discount is given, direct contact with user is preferred.

Repair:
We will repair instruments up to 5 years after the production of that instrument has been discontinued.
Further liability is not accepted.

Inspection:
Should take place at destination to include any failure caused by transport.

Disputes shall be governed by the laws of the Netherlands.

Supplement to manual of Waverider for 0.9 m diameter (6000-9 series)

Hull diameter	0.9 m
Height including mooring eye and antenna spring	1.30 m
Weight buoy (incl.chain)	166 kg
Weight buoy in frame (incl.chain)	211 kg
Dimensions buoy in frame : height	1,68 m
width	1.00 m
depth	1.00 m
Static buoyancy	2350 N
Dynamic buoyancy	1760 N
Drag area C_D.A	0.4 m^2 (chapter 3.3)
Horizontal drag (V=1.1 m/sec)	240 N (chapter 3.1)
Line force (V=1.1 m/sec)	340 N (chapter 3.1)
Number of no. 6 cells	52
Battery life	>16 months (chapter 6.0)
Buoy wiring	drawing 690-35

Mooring (chapter 3) :

From Waverider no. 6943 on "chain coupling" and swivel are combined and delivered assembled to the buoy.
The chain is to be used at all times, also in moorings for depth more than 75 m.

A2.2 Datawell WAREP Receiver

FM output	: A frequency modulated signal is available at plug A between points F and D,with a center frequency of 259 Hz ± 5 Hz. The sensitivity is + 10.36 Hz frequency deviation for + 1 m vertical displacement of the buoy. Frequency going high for upward movement of buoy. Output voltage 10 V pp, ± 10% (square wave), loading resistance > 5 kohm. Linearity of the dc to frequency conversion better than 0.5% for 60% frequency deviation. Overall accuracy better than 3%. Deviation of center frequency with temperature 0.01% /^{0}C, with time < 0.25%/year. Bandwidth : The fm output is delivered by a slave VCO which is controlled by the analog output. So the fm modulation shows the same filtered characteristics as the analog output. (Fifth order filter with 0.6 Hz cut off frequency).
Recorder output accuracy	: < 4% within temperature range of buoy and Warep. Dead band : < 1% of f.s.d.
Bandwidth	: 0.5 Hz (0.1 dB)
Recorder scales	: 5-0-5 or 10-0-10 (in m) vertical buoy displacement corresponds with 5-0-5 (in cm) on recorder. The scale is selected by a switch on the frontpanel. Deflection to the left corresponds to upward motion of the buoy.
Recordingpaper dimensions	: Recording width: 10 cm, length: 16 m.
Paper speeds	: 600, 1800 and 3600 mm/hr ± 1.5%.
Weight	: 28 kg (62 lbs).
Programming clock	: Max. 12 starts per day. Min. distance between two starts is 1 hour.
Timer	: Measuring period: 5, 10, 20 or 40 (± 10%) minutes.
Auxiliary contact	: Plug A between points B and C, closed during measuring periods of program. The mercury wetted contact does not work properly if the Warep is tilted more than 30^0. The contact is shunted with a capacitance of 0.022 uF in series with a 68 Ω resistance for contact protection (max. 0.5 A - 300 V - 100 VA resistive load). For heavier- or inductive load see documentation "Clare relais".

Specifications

Temperature range	: 0^{o} - 40 ^{o}C.
Supply	: 100 - 300 V ac, 40 Hz - 2 kHz, < 15 VA or 10 - 30 V dc, 4.4 W.
Receiver	: Crystal stabilized, crystal type CR-77U available channels: 1 27.505 MHz 6 27.615 MHz 2 27.525 MHz 7 27.655 MHz 3 27.545 MHz 8 27.695 MHz 4 27.565 MHz 9 27.715 MHz 5 27.595 MHz 10 27.745 MHz
Sensitivity	: With the receiving antenna at least 100 m from traffic, a maximum receiving distance over sea water of 50 km (30 miles) is possible with 0.08 W transmitter.
Antenna	: λ/4, end fed, omnidirectional, wind rating (without ice) 150 km/h (80 knots).
Bandwidth	: Input am demodulator : 2.4 kHz (6 dB) Output phaselock filter: 3 Hz (3 dB) Output recorder : 0.8 Hz (0.4 dB)
Analog output	: The output of the phaselock filter is filtered again (fifth order Butterworth filter, cut off frequency 0.6 Hz). This filtered output is available between points E and D of plug A. Sensitivity : 1.0 V/m Min. loading resistance: 10 kΩ Output is going positive at E for upward movement of buoy. Linearity: fm demodulator < 0.4%. Overall linearity (including Waverider): within 0.4% Bandwidth: 0.6 Hz 3 dB (fifth order filter) 0.3 Hz < 0.1 dB (< 1% down) Overall scale accuracy: During life within temperature range of Waverider and Warep: < 3.5%.

Introduction

The receiving equipment has been designed for the reception and recording of wave height measurements provided by the Waverider.
The Waverider transmits wave height on a carrier signal at a frequency between 27.50 and 27.75 MHz (see available channels).
The choice out of 6 channels is made either manually by the switch "receiving channel" on front panel or "remote" by short circuiting one out of 6 plugpoints to -10 V (plugpoint G of plug B).
The carrier signal is amplitude-modulated by an auxiliary carrier with a mean frequency of 259 Hz.
The instanteneous frequency of the auxiliary carrier varies in proportion to the wave height.
The low-frequency signal from the receiver (259 Hz) is demodulated by a phaselock system and subsequently fed to a recorder.
Available are two analog outputs (penwritten record and electrical), further a frequency modulated output.
The receiving equipment is provided with a programming unit, consisting of a program clock to start measurements and a period timer setting the measurement period.
An auxiliary contact is available for external use (e.g. tape-recorder).
The equipment can be supplied with any supply voltage between 100 and 300 V. 40 Hz - 2 kHz 15 VA or between 10 and 30 V dc 4.4 Watt.
The low power consumption makes battery supply practical.

Use in tropical climate

The electronic circuit boards in Wareps Mark II-F are protected against moisture- and fungus by acrylic coating.
This will keep the Warep functioning normally under high humidity, inclusive condensation, but offers no protection against corrosion of clock and recorder metal parts or chassis metalwork.
For short periods the clock can be protected by placing dry silicagel inside the housing. Provided the door is kept closed 200 gram of silicagel will last for two weeks.
To prevent metal corrosion relative humidity should be kept below 80%.

A2.3 ENDECO 956 WAVE-TRACK Buoy

I. DESCRIPTION AND SPECIFICATIONS

A. General Description

The Type 956 WAVE-TRACK Buoy is an orbital following wave buoy, reporting wave direction in addition to wave height and period. It is a lightweight data buoy that is inherently stable and cannot be capsized. The WAVE-TRACK Buoy is designed for applications in severe open ocean and coastal environments.

When used in conjunction with the ENDECO Type 956 WAVE-TRACK receiver, it is a complete data acquisition system providing three channels of simultaneous, real-time data.

The "Inverted Pendulum" configuration houses the electronics and battery power supply in a spherical surface buoy. A submerged sensor assembly is located in a pressure case at the "fulcrum" of the system. The mooring cable attaches at the hydrodynamic balance point between the spherical buoy and "fulcrum" of the inverted pendulum. This hydrodynamic design allows the buoy to move with the orbital motions of the local wave field and effectively filter out high frequency noise.

Wave height and period are determined by the double integration of acceleration as measured by an accelerometer located in the sub-surface sensor housing. The single axis, vertically orientated accelerometer is stabilized by a rugged suspension system that completely eliminates any problems with "hang-up" or "entanglement". The suspension system also permits the accelerometer to remain vertically oriented even during severe wave conditions.

Wave direction is determined from the direction and magnitude of buoy tilt when the buoy is at the point of maximum heave (i.e. the wave "crest".) The buoy tilt is derived by the coordinate resolver circuit which converts the outputs of the tilt sensors in conjunction with compass data to "NS" and "EW" components of tilt. The capacitive inclinometers, located in the subsurface sensor housing, are infinite life-span, high resolution devices, utilizing mercury (Hg) as the level sensor. The differential capacitive design effectively eliminates errors due to temperature coefficients. The inclinometer associated electronics are located on a printed circuit board within the sensor housing. The flux-gate magnetometer, also located in the subsurface sensor housing, is a gimballed, highly sensitive, solid state heading sensor that accurately measures the angle between the earth's magnetic field and the WAVE-TRACK buoy's reference point. This directional information is utilized by the coordinate resolver circuit board to "rotate" the indicated X & Y coordinates of tilt into a NS/EW plane of reference.

The outputs of the coordinate resolver circuits and the output of the double integrator are supplied to discreet voltage-to-frequency converters before being combined at the 3-channel multiplexer and applied at the audio input of the FM transmitter module (see Block Diagram, Figure 1).

The entire sensor housing is oil-filled with synthetic oil which provides temperature stability between sensors as well as dynamic damping for the gimballed compass and the accelerometer suspension.

The Standard Type 956 system configuration consists of a transmitting buoy and mooring assembly, and a multi-purpose receiver circuit. The buoy contains a programmable crystal timer, accelerometer, double integrator, X and Y inclinometers, magnetometer, coordinate resolver, self-contained lithium battery pack, and an FM transmitter, all housed in a reinforced fiberglass, foam-filled buoy. The receiving unit provides analog, digital (RS-232-C) outputs and an integral strip chart recorder.

B. Specifications

Wave Height Range:	15.24m (50 ft.) crest to trough or 30.48m (100 ft.) crest to trough (optional)
Wave Height Resolution:	5.95cm (2.34 in.) on 15.24m Range 11.9cm (4.69 in.) on 30.48m Range for 8 bit digitization
Wave Period:	2-30 seconds
Accelerometer:	
Linearity:	Better than ±0.2 percent
Hysterisis:	Less than ±0.2 percent
Resolution:	±0.001 percent
Temperature Coefficient:	+0.01 percent/degree C (±0.02 percent/degree F)
Horizontal Sensitivity:	Less than 3% of vertical
Wave Direction:	0-360° Conventional Wave Direction
Wave Direction Resolution:	1.4 Degrees (8 Bits)
Wave Direction Accuracy:	±10.0 Degrees
Buoy Tilt Range:	±45° per axis
Buoy Tilt Resolution:	0.35 Degrees
Buoy Tilt Accuracy:	±4.0 Degrees
Transmitting Frequency:	30 to 175 MHz FM (crystal controlled, to be specified by user)
Transmitting Power:	100 Milliwatts (Nominal)
Data Signals:	
Chan. One (Heave)	2300 ±150 Hz
Chan. Two (NS)	1300 ± 50 Hz
Chan. Three (EW)	730 ± 50 Hz
Programmable Crystal Timer	
Basic Accuracy:	±2.0 seconds/day
Transmitting Interval Range:	2 min. - 68 hrs. (selectable)
Transmitting Duration Range:	1 min. - 4 hrs. (selectable), or continuous

Battery Pack

Type:	Lithium/thionyl-chloride
Number:	21-DD Size
Fuses:	Four 3AG - 1/4 amp Fast Blow One 3AG - 1/2 amp Fast Blow
Storage Life:	Up to 10 years
Operating:	6 months based upon (8) 18 minute transmissions per day at a transmitting power level of 100 mw.

Beacon Lamp

Visibility:	1 mile
Flash Rate:	4 seconds
Flash Duration:	125 ms

Operating Environment

Operating Medium:	Salt, fresh, or polluted water
Operating Water Temperature:	-5° to +45°C (23° to 113°F)
Storage Temperature Range:	-34° to +65°C (-29° to +149°F)
Maximum Submergence Depth:	10M (33 ft.)

Instrument Housing

Materials:	Hard-coated aluminum, reinforced fiberglass and PVC plastic
Finish:	Subsurface PVC plastic treated for resistance to marine growth.
Hardware:	300 series stainless steel and plastic
Dimensions:	0.76M (2.5 ft.) diameter x 2.44m (8 ft.) long plus antenna
Weight in Air:	68 kg (150 lb.)

Shipping Crate Dimensions
and Weight

(1) 0.84 meter cube (33" cube) wgt 60 kg (130 lbs.)
[sphere]

(1) 0.43M x 0.53M x 2.13M (17" x 21" x 84") wgt 40 kg
(88 lbs.) [staff and shroud]

(1) 0.25M x 0.30M x 0.36M (10" x 12" x 14") wgt 7.0 kg
15 lbs.) [battery pack surface shipment]

or

(1) 0.46M dia. x 0.61M high (18" dia. x 24" high) steel
drum for air shipment of battery pack

A2.4 ENDECO 956 WAVE-TRACK Receiver

I. DESCRIPTION AND SPECIFICATIONS

A. General Description

The ENDECO Type 956 WAVE-TRACK Buoy System is a complete data acquisition system that utilizes a wave orbital following buoy for accurate and reliable measurement of wave height, period, and direction. The ENDECO Type 956 WAVE-TRACK Receiver is a compact unit designed to receive multiplexed FM signals from the WAVE-TRACK Buoy unit. This receiver unit operates on standard 115VAC power and provides direct interface capabilities for both analog and digital outputs in addition to a self-contained strip chart recorder.

B. Specifications

1. RF Receiver

Frequency Range:	30 to 175 MHz FM crystal controlled
RF Input Impedance:	50 ohms
Sensitivity:	<0.25 μv
Adjacent Channel Rejection:	70 db
Modulation Acceptance:	± 7 KHz
Audio Response:	30-3000 Hz
Audio Output Power:	500 mw

2. Strip Chart Recorder

Type:	Galvanometric
Chart Speed:	305 cm/hr (120"/hr.)
Chart Paper:	50 Divisions
	5.9 cm (2.3") wide x 19.2m (63 ft.) long, pressure sensitive
Recording Duration:	6.3 hours/roll (continuous)
Sensitivity: Heave:	1 Division = .15m (.5 ft.) [15.2m crest to trough range (50 ft.)]

3. Analog Outputs

Heave:	0-5 Volts 1000 ohm output impedance
North/South Tilt:	0-5 Volts 1000 ohm output impedance
East/West Tilt:	0-5 Volts 1000 ohm output impedance

4. Digital Output

Serial Output to EIA Standard RS-232-C 8 bit resolution

Sampling Rate:	Selectable - 0.5, 1,2,4 second intervals (all 3 channels sampled simultaneously)
Frame Interval:	Selectable - 128, 256, 512 1024 3-word samples

5. Carrier Detect Output:	0-5 Volt TTL 5000 ohm output impedance Relay contacts SPDT 2 amp 115 VAC
6. Power Input:	115 VAC 50 to 440 Hz @ 1/4 amp
7. Operating Temperature:	-5° to +45°C (23°F to 113°F)
8. Storage Temperature:	-34°C to +65°C (-29°F to 149°F)

9. Deck Unit

Material:	corrosion resistant Formica case
Hardware:	stainless steel and chrome plated brass
Dimensions:	33 cm W x 24.1 cm D x 20.3 cm H (13 in. x 9.5 in. x 8 in.)
Shipping Box Dimensions:	40.6 cm cube (16 in. cube)
Weight:	7.4 kg (16.5 lbs.)
Shipping Weight:	10 kg (22 lbs.)

A2.5 Sea Data 1236 and 1236/3 Wave Recorder

Sea Data 1236 and 1236/3 Wave Recorder

General

The Sea Data 1236 and 1236/3 Wave Recorders are high capacity data recorders designed to digitize and record the output from wave buoy receivers. The Sea Data 1236 Wave Recorder is designed to digitize and record the analog output of the heave signal from a Datawell Waverider/WAREP system. The Sea Data 1236/3 Wave Recorder is designed to digitize and record 3 channels (heave, N/S tilt, E/W tilt) from an ENDECO 956 WAVE-TRACK system. The devices are very similar (except for the three channel recording capability).

The recorder contains an internal clock/counter and this (along with the recorder switch settings) is recorded with the digitized wave signals.

Specifications

1)	Recording Medium	- standard digital certified, 300 or 450' cassette tapes.
2)	Recording Capacity	- 10 megabits on 300 foot cassette.
3)	Sample Interval	- 0.25, 0.5, 1.0, 2.0 seconds (switch selectable)
4)	Operating Modes	- continuous scan or burst operating mode.
5.	Burst Interval	- 0.5, 1.0, 1.5, 2.0, 3, 4, 6, 8, 12, 16, 24 hours (switch selectable).
6)	Wave Samples per Burst	- 32, 1024, 1280, 2048, 2560, 4096, 5120, 8192 (switch selectable).
7)	Station ID/Record Header	- 3 digits - set with thumbwell switches
8)	Internal Clock	- Special cut 9.194304 Mhz quartz crystal - Stable to +/- 2 ppm over +10°C to +40°C. - correctable to +/- 1 ppm over -20°C to +65°C - counter advances 1 bit each sample interval - recorded as a 20 bit value.
9)	Power	- internal rechargeable 12v lead-acid battery with external charger - optional 20 A hr battery holder in lid for "D" cells

10) Signal Input

1236	- +/- 15 volts (equivalent to +15 to -15 metres surface elevation from Datawell Waverider/ WAREP system)
1236/3	- 0-5 volts (all channels)

For signal output from ENDECO 956 WAVE-TRACK System:

Channel 1	- -50 to +50 feet (-15.2 m to +15.24 m) surface elevations
Channel 2	- +45° to +45° tilt (magnetic N/S)
Channel 3	- -45° to +45° tilt (magnetic E/W)

11) Analog to Digital Conversion

1236	- 11 bit (heave channel) equivalent surface elevation resolution (with Datawell Waverider/WAREP system) = 1.5 cm
1236/3	- Channel 1 (heave) 11 bit - equivalent surface elevation resolution (with ENDECO 956 WAVE-TRACK System) = 1.5 cm
	- Channel 2 - N/S tilt = 8 bit, equivalent tilt resolution 0.35°
	- Channel 3 - E/W tilt = 8 bit, equivalent tilt resolution 0.35°

12) Size - 30.5 cm L x 35.6 cm W x 25.4 cm H

13) Weight - 9 kg (more with optional 20 Ahr battery pack in lid).

A2.6 Datawell WAVEC Buoy

WAVEC Buoy

Physical Dimensions

Instrument Cylinder:

Diameter (including eyes)	0.80 m
Height (including antenna base)	0.87 m
Weight	274 kg

Assembled Buoy

Diameter	2.5 m
Overall height (excluding antenna)	1.7 m
Weight:	
instrument cyclinder (1)	274 kg
wings (4)	148 kg
top float (1)	60 kg
segments (4)	160 kg
mooring cross (1)	62 kg
Total	704 kg

I Principle of Wave direction and height measurement

The Wavec buoy follows the movements of the water surface and measures its own vertical acceleration, pitch and roll angles and the magnetic field components.
The elevation of the water surface and the slope of the water surface in North and West direction are derived from these measurements.
The co- and quadrature spectra of the heave and slope signals are calculated by the microprocessor in the Wavec receiver (Direc).
The Direc receiver is only provided with a RS232C serial port.
No keyboard, display and plotting/printing facilities are implemented.
If a flexible self contained wave direction system is required a HP85 with serial interface 82939A option 001 and I/O ROM 00085-15003 or equivalent must be considered as an essential part of the system.
The HP85 calculator can be adapted by a set of available programs (on cassette) to derive from the co- and quadrature spectra characteristic figures of angular and frequency distribution of wave energy.

Transformation formulae

For obtaining directional data, the slope of the water surface should be known besides the heave signal.

The signals which are transmitted from the buoy are:

Heave	=	double integrated vertical acceleration
Pitch	=	sine of angle between neg. x axis and horizontal plane
Roll	=	sine of angle between y axis and horizontal plane
H_x	=	magnetic field component in x direction
H_y	=	magnetic field component in y direction
H_z	=	magnetic field component perpendicular x and y (downwards)

The transformation formulae are as follows:

Absolute value of magnetic field: $|H| = \sqrt{H_x{}^2 + H_y{}^2 + H_z{}^2}$

Inclination angle of earth magnetic field ϕ: $\phi = \text{arc tg } (H_v/H_h)$ in which

$$H_v = (pH_x - rH_y + H_z \sqrt{1 - p^2 - r^2}$$

$$H_h = \sqrt{H_x{}^2+H_y{}^2+H_z{}^2-(pH_x-rH_y+H_z(\sqrt{1-p^2-r^2})^2}$$

Compass angle of Wavec buoy = ψ : $\sin\psi = \left[H_y+rH_z+r\,\dfrac{pH_x - rH_y}{1+\sqrt{1-p^2-r^2}}\right]\Big/ H_h$
(Orientation)

$$\cos\psi = \left[H_x-pH_z+p\,\frac{rH_y - pH_x}{1+\sqrt{1-p^2-r^2}}\right]\Big/ H_h$$

Slope of water surface
South $\longrightarrow$ North

$$: \delta h/\delta u = \frac{-\left[(pH_x-rH_y)\sqrt{1-p^2-r^2}-H_z(p^2+r^2)\right]}{H_h\,\sqrt{1-p^2-r^2}}$$

Slope of water surface
East $\longrightarrow$ West

$$: \delta h/\delta v = \frac{rH_x + pH_y}{H_h\,\sqrt{1-p^2-r^2}}$$

The calculations are performed by the micro computer in the Wavec receiver (Direc). All these signals are available on line at the output ports of the Wavec receiver.

Data flow at receiver side

Receiver 1. The received bits are collected in a block of 128 bits containing the sampled values of roll, pitch, heave H_x, H_y and H_z.

2. Error detection c.q. correction.
3. Calculation from data of slope North, slope West, and compass angle of Wavec buoy and inclination and absolute value of earth magnetic field.
4. Storage of 256 samples of received heave and calculated slope data (= 200 sec of data).
   The first 32 samples and last 32 samples are tapered.
5. Calculation of Fourier components $c_n = a_n + ib_n$ from the collected heave and slope data.
6. Formation of the co- and quadrature spectra from the Fourier comp.

C(vv)	C(nn)	C(ww)	v = heave
C(vn)	C(vw)	C(nw)	n = slope North
Q(vn)	Q(vw)	Q(nw)	w = slope West

The spectra obtained from max. 9 consecutive time series of 200 sec are averaged and corrected for the transfer of the Heave signal and the anti-aliasing filters.

Hippy Sensor:

Position

The position of the sensor in the can is immaterial, only the relative position of compass block and Hippy sensor is of importance.
For purpose of checking however, a frontside is indicated on flange and inner side of can (red dot).
The roll axis is defined through center of can and frontside.

Outputs

pitch (p):

Measures sine of angle γ_1 between roll axis and horizontal plane.
p (in volts) = $10 \sin \gamma_1$
Output is positive if rear side of buoy is lifted.

roll (r):

Measures sine of angle γ_2 between pitch axis and horizontal plane.
r (in volts) = $10 \sin \gamma_2$
Output is positive if port side (left side) is lifted.

The mast angle α (equal to angle between base plane and horizontal plane) can be derived from both outputs according to $\sin^2\alpha = p^2 + r^2$ (see fig. 7)
Angle β between pitch axis and horizontal rotation axis is equal to β = arc tg r/p (see fig. 7)

Heave and acceleration

The Hippy delivers heave in the frequency range of 1/30 - 1 Hz.
An output giving acceleration from dc - 1 Hz is available.

High pass filter for heave measurement

The heave is obtained by double integrating the acceleration.
Temporary offset of the platform caused by horizontal acceleration leads to false acceleration outputs; in order to minimise the resulting false heave outputs a high pass filter is used.
The resulting transfer of high pass filter is
$1/((1 - i\sqrt{2}.a - a^2)(1 - ib))$ $a = T/30.8$ $b = T/170$ T = period time
Resulting amplitude transfer and phase shift is given under the specifications for some frequencies.

Three axis fluxgate magnetic meter.

The three fluxgate magnetic meters are placed in an aluminum cube which is carefully aligned with the axis of the pitch roll measuring system.

This aluminum block shields the fluxgates from the varying magnetic fields of the pitch roll system to prevent interference with the switching frequencies of the fluxgate elements.

The resulting time delay in the field measurements caused by induced current in aluminum block and can is approx. 25 m/sec.

Specifications:

Supply from dc-dc converter on Hippy pcb:	-13½ V - 0 - +13½ V	1 mA
	- 5 V - 0 - +5 V	1 mA
Sensitivity	: 200 mV/A/m ± 1%	
The three channels correspond to each other within	: 0.2%	
Zero offset	: < 0.05 A/m	
Alignment of axis	: < 0.5°	
Bandwidth	: 30 A/m	
Time delay in passband	: 0.06 sec	

Filters

7° order Butterworth filter.

All analog outputs are filtered to prevent aliasing errors.

Supply from dc-dc converter on Hippy pcb:		-13½ V - 0 - +13½ V	1 mA
Transfer		: -0.5 (± 0.2%)	
Cut off frequency		: 0.6 Hz	
Attenuation at 1.28 Hz		: 200 x	
Time delay on passband		: 1.468 sec	
Time delay of the 6 channels are equal to each other within		: 10 msec	
Sensitivity at output	Heave	: -250 mV/m	
	Pitch	: -87.3 mV/°	
	Roll	: -87.3 mV/°	
	H_x	: -100 mV/A/m	
	H_y	: -100 mV/A/m	
	H_z	: -100 mV/A/m	

The output range is ± 5 V for all channels.

Heave

Scale	: 0.5 V/m, maximum range ± 20 m Output positive going for upward movement of the sensor.
Position of accelerometer	: Approx. 30 cm above bottom plate in centre of cylinder. The heave (acceleration) of this point is measured.
Accuracy	: Better than 2% of measured value.
Zero offset	: Below 30 cm (300 mV), typically 3 cm.
Noise	: Below 1 cm peak.
Frequency response	: See table below and descr. of high pass filter.

Period	Ampl. transfer	Phase shift
30 sec	- 28.6%	+ 98^0
20 sec	- 8.5%	+ 64.5^0
15 sec	- 3.0%	+ 47^0
10 sec	- 0.7%	+ 30.5^0
5 sec	-	+ 15^0
2½ sec	-	+ 7.5^0

The wave amplitudes with frequencies between 0.067 and 0.033 Hz can be corrected within 3% of the true value from the frequency response, table above.

Acceleration

Scale	: 0.5 V/m/sec , max. range ± 10 m/sec^2 Output is positive for upward acceleration.
Bandwidth	: Low pass third order filter; up to 1 Hz: linear phase shift equal to 0.06 sec up to 5 Hz: within 6 dB
Accuracy	: Better than 2% of measured value.

A2.7 Datawell DIREC Receiver/Processor

Wavec Receiver (DIREC)

1. General

The DIREC contains a radio receiver, a microcomputer, a real time clock/timer and a communication interface.
The radio receiver delivers encoded digital data to the microcomputer.
Decoding, data quality check and error correction are done by the microcomputer.
From the microcomputer three types of data will be available:

1. Monitor data.
   This contains all data as from each separate buoy channel.
2. Real time data.
   This contains the original Heave and the Slope north, Slope west data from the axis transformation.
3. Co- and Quadrature spectra, as averaged from good blocks of 256 data samples over a half hour period.

The DIREC has two RS232 ports, the Main- and Auxiliary port.
The Main port is used for independent data monitoring and to program the system. Data transfer over the Main port is initiated by sending proper commands.
The Auxiliary port is used for data transfer only. Which data will be sent depends on programming through the Main port.
After Power up, the baud rate(s) (jumper selectable) are initialised and the system starts automatically in the Standard or in a previous Programmed mode which was saved in the Back-up memory, depending on a setting of WE jumper.
A system selftest is performed at Power up or Master Reset and the results may be called by sending an ERRORØ command.
After ± 3.3 minutes the system has calculated comparison data for quality checks.
In the Standard mode the Auxiliary port continues sending the Real time data.
The data rate depends on the sample rate of the buoy.
If Monitor or Real is programmed for the Auxiliary port a Time message is sent before data transfer at the Auxiliary port starts.
When the axis transformation is performed the microcomputer also calculates the buoy's Orientation, Inclination of magnetic field vector and the absolute magnetic field vector (Habs). They may also be displayed upon request.
The results are checked to fall within limits. The outcome of these checks are reflected in the status character and in the Log message for monitoring the data quality and overall behaviour.

The results of the axis transformation are collected in files of 256 samples (= 200 sec) and further processed to get the co- and quadrature spectra.

Cvv	Cnn	Cww	v = heave
Cvn	Cvw	Cnw	n = slope north
Qvn	Qvw	Qnw	w = slope west

Each half hour the summed results are normalised and corrected for tapering, anti-aliasing- and heave filter errors.

1.1 Specifications

Power requirements	: 180 to 250 V (installed) 87 to 120 V (option) see page 7 48 - 62 Hz 100 Watts (max.)
Fuses	: Two F.S.F. 1A 20x5 mm
Back-up battery	: 9 V PP7 BEREC or equivalent
Power consumption from battery	: Main Power on - Main Power off 15 mW
Accuracy clock	: 1 minute per month
Temperature range	: 0 - 50 ^{0}C operating
Humidity	: Internal parts in hermetic enclosure external parts (junction board) RH 95% non condensing.
Humidity indicator (blue)	: Desiccant type VG 95239-100-45 Hermann. Replace desiccant if it has a pink colour.
Common return	: All I/O lines at the junction panel have a common return which is floating to GND(case).
Common leakage to GND	: < 1 μA at 300 V
Input/Output protection	: All lines are protected against transients. Outputs are short circuit proof. Current 5 A peak for a sinusoidal current of 8.3 msec 70 mA continuous at damp voltage of $\pm$ 25 V max.
EMI filtering	: All lines at the junction panel including the Power lines are filtered to GND.
Jumper selectable baud rates	: 300, 600, 1200, 1800, 2400, 3600, 4800 and 9600 baud (see table for jumper settings).
Parity Sending	: even
Receiving	: ignored
Stopbit	: One
Interface connectors	: RS232C compatible. Main port is directly compatible with HP85 serial interface option 001.
Data string or message termination	: CRLF
Buoy's sampling time	: 0.78125 sec.
Software	: Exchangeable (8 EPROMS).

Data formats	
for MONITOR and REAL	: Decimal offset range 0 to 9999 zero ≡ 5000 Signed decimal range -9999 to 9999
for CO QUAD	: Scientific format Signed mantissa fixed 5 decades Signed exponent fixed 2 decades e.g. - 7 6 5 4 3 E +2 1
Monitor character	: First character of a MONITOR or REAL data string (standard). ASCII 0-9 cyclic repeating for line numbering. A - (> 2D) is displayed if there were more than 9 missing lines.
Status character	: Second character of a MONITOR or REAL data string (standard), reflecting the results from data quality checks per sample (see table 3.4.1).
Set-up time	: ± 3.3 minutes after Power up or Master reset until status character is not equal 4.
Jumpers	: For baud rate selection and system set-up.
Standard installed jumpers	: JM, JA, ICCON, BRA0 and BRA1.

A2.8 Columbia Data Products 300D Recorder

SECTION 1: INTRODUCTION

1.1 General

The 300D is a stand alone Data Cartridge Recorder designed for data logging applications. The unit utilizes the highly respected 3M type Data Cartridges, which are available in 300 and 450 foot lengths. Its high performance, long life and storage capacity far exceed those of other low cost recording media, such as floppy disks and cassettes.

The 300D is ideal for connecting to bulk data generating devices, (i.e. Commercial Data Loggers). The unit may be controlled manually with the front panel switches, or remotely, using ASCII Control Codes. Remote operation has been simplified by the inclusion of an ACK/NAK programming protocol, allowing greater control with less software overhead. A character search function enhances data retrieval by automatically scanning the tape for a user supplied identifier. The high storage capacity enables the 300D to collect data over a long period of time, making it ideal for remotely located installations. Its Power Fail/Restart capability also provides for complete unattended operation. This feature insures continued operation when power is restored.

An Auto Answer feature enables the 300D to be polled, enabling data recorded at a remote site to be sent back to the data center via Modem.

The 300D is also a very convenient program loader. Its high speed, up to 19,200 baud, enables the user to load programs at a fraction of the time required by other media. The Transparency Mode allows the 300D to write and read 8 bit binary data with full control of the unit handled by front panel pushbutton switches.

The internal design of the 300D facilitates custom modifications. In many applications a minor change to the 300D firmware can greatly simplify a particular design task.

As can be seen from above, the 300D provides the user with many different cost effective uses. Its high data reliability and long life will provide many hours of trouble free operation.

1.2 Variable Block Read And Write

The 300D is designed to read and write variable length blocks. Incoming data is temporarily stored in a 2048 character buffer. (See Figure 2-1 "System Configuration"). If this buffer becomes full, the data is written onto a tape creating a maximum 2048 character block. Two of these buffers are provided, enabling one to receive characters while the other is being "dumped." This permits a continuous data flow at the maximum baud rate.

When the 300D receives a Stop Write command, a block will be created equal in length to the number of characters currently in the buffer. For example, Issuing a Start Write command followed by 256 characters of data and a Stop Write Command would create a block with 256 characters.

During Read, data is handled in a similar fashion, only in the reverse order. A block of data is read from tape and is temporarily stored in a buffer for transmission. As the buffer is being transmitted, the other buffer is being filled from the tape. The buffer receives only the number of characters contained in one (1) block, up to a maximum of 2048. This enables the 300D to Read any block length up to 2048 characters.

SECTION 2: PRODUCT DESCRIPTION

2.1 General

The Model 300D Data Cartridge Recorder is a desk-top unit housed in an aluminum-alloy cabinet measuring 5 1/2 inches by 7 inches by 14 inches. Weighing 13 pounds, it consists of two Printed Circuit Boards (Figure 2-2).

The 300D designed for ease of operation, has a simple external front panel layout consisting of the transparency switch and tape control pushbuttons. The back panel consists of the ON/OFF power switch, and DB25S Terminal and Modem/CPU connectors.

The cartridge drive guarantees that all cartridges will be interchangeable regardless of manufacturer, allowing data interchange from recorder to recorder. The precision drive system with the cartridge assures constant tape tension throughout start/stop and run modes. Its high performance, long life and storage capacity far exceed those of other low-cost recording media.

The cartridge contains 1/4 inch computer grade magnetic tape certified error free by the tape manufacturer. The cartridge assembly consists of a high impact plastic cover mated to a metal case. Protection of the tape head is afforded by a plastic door that closes over the tape head opening when the cartridge is removed from the drive. (Figure 2-3)

Table A-1. Specification Summary

Physical	
Dimensions	
Height	5.2 inches (13.1 cm)
Width	7.0 inches (17.5 cm)
Depth	14.0 inches (35 cm)
Weight	13 pounds (5.9 Kilograms)
Power Requirements	110 VAC +10% 50-400 Hz 220 VAC +10% 50-400 Hz
Environmental	
Operating Temperature	40 degrees to 115 degrees F
Relative Humidity	20%to 80% non-condensing
Cartridge Assemblies	
Media	
Cartridge	300 Ft/450 Ft ANSI Compatible Data
Storage Capacity	2.57 Mbytes/3.86 Mbytes
Tracks	4
Recording	
Read/Write Speed	30 ips
Rewind Speed	75 ips
Format	PE 1600 bpi
Record Length	1 to 2048 character length
BOT/EOT Sensing	Automatic with LED sensor
Bit Error Rate	1 in 10^8 soft errors
Communications	
Interfaces	
Serial	Two standard RS232C ports
Parity	Selectable odd, even or no parity
Transmission Mode	Full or half duplex, asynchronous
Serial Transmission Rates	Switch selectable 75, 110, 300 1200, 2400, 4800, 9600 or 19,200 baud
Options	Transparency through Remote Control

Recommended Data Cartridges

3M-DC-300	Verbatim-TC 2000
DC-300 XL	TC 2450

APPENDIX 3

DATA PROCESSING

A3.1 INSTRUMENT TRANSFER FUNCTIONS

Datawell Waverider

Waverider Correction for Low Frequencies:

$$A = 1 / (1 - ip\sqrt{2} - p^2) \ * \ 1 / (1 - iq)^3$$

where $p = T/30.8$
$q = T/460.$
T = period
$i = \sqrt{-1}$
A = complex transfer functions

WAREP correction for High Frequencies:

$$A = 1 / \sqrt{1 + (\frac{f}{f_o})^{10}}$$

where $f_o = 0.6\ H_z$

Phase Shift: constant time delay of 0.877 seconds up to 0.6 Hz.

WRIPS Satellite Transmitting Buoy:

Same low frequency correction as above. No high frequency correction.

Datawell WAVEC

Heave Correction for Low Frequencies:

$H = 1 / (R + I)$ where R is real and I is imaginary part

$R = 1 - p^2 + pq\sqrt{2}$
$I = p^2q - q - p\sqrt{2}$

where $p = T/30.8$
$q = T/170$
T = period

Heave and Slope Correction for High Frequencies:

$$R = 1 / \sqrt{1 + \left(\frac{f}{f_o}\right)^{14}}$$

where $f_o = 0.6$ Hz

Phase Correction: constant time delay of 0.877 seconds up to 0.6 Hz.

ENDECO Wave-Track

Heave Correction:

Original Documentation: The amplitude and phase corrections were calculated from the look up table reproduced as Table A3.1.

Subsequent Documentation: Values given in Table A3.2.

Tilt Correction:

Original Documentation: Constant time delay of 0.4 seconds, no amplitude correction.

Subsequent Documentation: Time delay changed to 0.74 seconds

Table A3.1

Frequency	.033	.035	.039	.042	.045	.050	.055	.061	.069	.083
Amplitude	1.55	1.22	1.176	1.09	1.05	1.01	1.01	1.	1.01	1.026
Phase	197.9	178.7	160.1	149.9	137.2	126.6	109.9	87.8	74.5	60.0
Frequency	.100	.110	.124	.143	.165	.200	.250	.333	.478	.5
Amplitude	1.	1.022	1.02	1.02	1.005	1.01	1.09	1.06	1.32	1.33
Phase	46.8	39.7	26.8	10.3	5.9	0.0	-18.0	-24.0	-51.6	-54.0

Table A3.2

Frequency	.033	.038	.044	.051	.058	.067	.078	.090	.104	.120
Amplitude	1.46	1.20	1.08	1.02	1.	.99	.99	1.	1.	1.01
Phase	217.3	182.9	152.7	127.0	105.3	86.9	71.1	57.4	45.3	34.3
Frequency	.138	.159	.184	.212	.245	.282	.326	.376	.433	.5
Ampltitude	1.01	1.01	1.01	1.01	1.02	1.03	1.05	1.1	1.18	1.33
Phase	24.1	14.5	5.1	-4.4	-14.3	-24.8	-36.3	-49.0	-62.7	-77.1

A3.2 STATISTICS AVAILABLE FOR DISPLAY

Data Quality Flag:	0 - 8 acceptable for plotting, etc. 9 - 99 unacceptable
Spectral Moments M_0, M_1, M_2, M_4:	$M_n = \sum_{i=a}^{b} f_i^n \, P(f_i) \quad f_i$ where f_i = frequency $P(f_i)$ = spectral density at f_i a,b = limits of range of frequencies
Significant Wave Height:	$H_s = 4 \; (M_0)^{1/2}$
Spectral Maximum:	maximum value of P (f)
Peakedness Parameter:	$Q_p = 2 \sum_{i=a}^{b} f_i P^2 (f_i) \quad f_i / M_o^2$
Spectral Width Parameter:	$\epsilon = (1 - M_2^2 / \; (M_0 - M_4\,)\,)^{1/2}$
Spectral Narrowness Parameter:	$\gamma = ((M_2 * M_0 - M_1^2) / \; M_1\,)^{1/2}$
Mean Direction at Spectral Peak	(WAVEC and ENDECO WAVE-TRACK only)
Peak period:	Period associated with spectral maximum
Average period:	$TM_{01} = M_0 \,/\, M_1$
Average Apparent Period:	$TM_{02} = (M_0 \,/\, M_2\,)^{1/2}$
Apparent Crest Period:	$TM_{24} = (M_2 \,/\, M_4)^{1/2}$

Additional Statistics Available from WRIPS DATA:

Memory Test: 0 - OK, 1 - failure

Battery Voltage

Mean Wave Height (of OFF- and ON - SYNOPTIC Data)

Average Period (of OFF- and ON-SYNOPTIC Data):
half the number of zero crossings divided by the record length (in seconds)

Variance (of OFF- and ON-SYNOPTIC Data): M_0

Maximum Amplitude (of OFF- and ON-SYNOPTIC Data): uncorrected for buoy response

On-Synoptic = data collected, processed and transmitted every three hours

Off-Synoptic = data collected halfway between transmission periods (i.e. one-and-a-half hours into recording cycle).

A3.3 SOFTWARE DESCRIPTION

A large amount of software had to be developed during the course of this study in order to handle the different instrument types, data formats and various displays. Brief description of the programs and samples of non-routine data products follow.

WAVE CLIMATE STUDY PROGRAMS

DATA TRANSFER--

1)FROM CASSETTE OR CARTRIDGE:

RCOLUM--accesses Columbia data logger and transfers data from cartridge to a file on the PDP11.
SEARD---accesses Sea Data Logger and transfers data from cassette to a file on the PDP11.

2)FROM EXTERNAL COMPUTERS:

ARGOS---contacts the computer in Maryland to obtain ARGOS satellite data.
ARGKIL--ensures that modem hangs up after ARGOS has been run.
DELTEMP-program to delete all temporary data files left on the MEDS computer system by the program GOES.
GOES----program to transfer satellite data form the MEDS computer in Ottawa, automatically, at a scheduled time to a disk file.
GOSKIL--ensures that the modem hangs up after GOES has been run.
REDO----program to allow the re-copying of a temporary file created by GOES from the MEDS computer to the Seakem computer.

READING--

GOESEX--reads a WRIPS buoy internal tape, extracts the GOES message from it and writes it to a new file. The output files are of the same format as the GOES message received from Ottawa.
RDWAVE3-reads the data that has been transferred from cassette using SEARD, checks for missing data, bad characters and pads these values. The data is output in Wave Climate Study raw data format.
RWAVEC2-reads the data that had been transferred off of cartridge using RCOLUM, checks for bad or missing data and pads these values. The data is output in Wave Climate Study raw data format.
SATRAW--extracts the raw time series from internal WRIPS tapes, pads any missing or bad data, and writes it into a file with Wave Climate Study raw data format.
TRNWEA--reads Petro-Canada or AES weather data and reformats it into standard time series format.

CALIBRATION--

CUTUP---extracts desired records from a Wave Climate Study calibrated data file and writes it, in similar format, to another file.
CWAVEC--calibrates WAVEC raw time series, checks for spikes and interpolates,when necessary, any missing data values.
SATCAL--calibrates raw time series data obtained from WRIPS internal tapes, checks for spikes, interpolates missing data and writes the records to a file in Wave Climate

Study calibrated file format.

UNFMT---formats unformatted data files to allow for printout or terminal display.

UNFMT2--formats unformatted calibrated files and rewrites the file using fixed record lengths to allow for the files to be written to unlabelled tapes.

WAVCAL--calibrates ENDECO and WAVERIDER data, despikes and interpolates missing data.

WHDFIX--used to change information contained in the main file header of an unformatted Wave Climate Study file.

SPECTRAL PROGRAMS---

DIRCAL--calculates mean direction and spread factors from the co- and quad-estimates calculated in SPCTRA2 on WAVEC data and Wave-Track data.

ENDNEW--performs directional spectral analysis on ENDECO data using Longuet-Higgins approach(no longer used).

ENDSPC--performs directional spectral analysis on ENDECO data using band-pass method.

INVERS1-performs inverse spectral analysis on waverider and WRIPs calibrated time series in order to apply complex transfer functions and to calculate the maximum waveheights.

INVERS2-as INVERS1 except for ENDECO and WAVEC data.

SPCTRA--performs spectral analysis on waverider and ENDECO heave data.

SPCTRA2-performs directional spectral analysis on WAVEC and Wave-Trackdata.

SORTING--

PRELIM--allows for extraction of specific statistics from individual record headers for later manipulation.

REFORM--reformats spectral data obtained from MEDS to Seakem's Wave Climate Study spectral file format.

SATSRT--sorts satellite spectral data into monthly files.

WAVSRT--sorts Waverider, Wavec and Endeco spectral files into monthly files.

WAVSRT2-like WAVSRT but handles Endeco directional spectral files output from DIRCAL.

WNDHD---extracts pertinent wind speed and direction from a wind data file and inserts it into the individual record header of a Wave Climate Study monthly spectral file.

DISPLAY--

The documentation on display programs is divided into four groups:

1) General displays:

CALPLT--time series plots of raw or calibrated heave (and tilt or slope)in unformatted files.

EXCEED--draws exceedance plots of significant wave height. (on output of PRELIM-limited use)

HISTO---draws histograms of spectral properties in the individual record headers of monthly sorted Wave Climate Study spectral files

PERS1---draws persistence of significant wave height (on output of PRELIM-limited use)

PERS2---draws persistence of peak period or peak direction

(on output of PRELIM-limited use)

POWCON--monthly contoured energy plots by frequency and time(3 versions)

SPCPLT--draws time series plots and scatterplots of spectral properties in individual record headers of monthly sorted spectral files; draws energy density spectra and can be used for data quality check of the spectral records.

SPCPRN--produces a table of summary values of RMS waveheight by frequency band for a month of spectral records.

SPCVAL--produces a printout of the values in a spectral record.

2) DIRECTIONAL specific displays:

DIRCON1-produces contoured energy density by frequency and direction for a chosen WAVEC record.

DIRCON3-same as DIRCON1 but for Wave-Track records calculated using SPCTRA2 and DIRCAL

DIREN---produces a table of energy density by frequency and direction for a chosen WAVEC(or Wave-Track) directional record

DSTAT---calculates bulk statistics on time series of heave and slope including: RMS elevation, RMS slope, Hsig, theta(atan(slope 2/slope 1)), normalized slope and normalized elevation. Scatterplots of normalized slope vs normalized elevation and angle theta vs normalized elevation are produced.

PLDIR---produces a spectral density plot as well as a plot of mean direction and angular spread by frequency for a directional record in a monthly sorted file. Also handles Endeco directional data calculated from ENDSPC. The program is also used for quality checking of WAVEC spectral records.

PLDIR2--like PLDIR but modified to handle Endeco data calculated using SPCTRA2 and DIRCAL.

3) ENDECO specific displays:

ENDHD---used to extract the mean direction at the spectral maximum from the directional spectral files and insert it into the individual record headers of a monthly sorted heave spectral file.

STIKPL--used to draw stick plots at given frequencies against time

4) Extended displays:

LINEAR--calculates a "dispersion ratio" to determine the linearity of the wave field or to see effects of improper mooring design, icing of buoy, sensor problems etc.

5) Wind data:

DIRPER--persistence of wind direction

PLTWEA--time series plots of wind speed and direction

RDWPET--reads Petro-Canada weather data

WEAPLT--time series of weather information

WNDEXC--exceedance of wind speeds

WNDPER--persistence of wind speeds

WNDSCT--scatterplot of wind speed by direction

WNDSTAT-summary wind statistics
WNDST2--summary wind statistics by direction

A3.4 FILE AND TAPE DOCUMENTATION

The following files have been archived at Seakem as part of the standard data processing scheme:

Wave Data:

1) Raw data files - unedited, un-calibrated, formatted.

2) Calibrated data files - calibrated and despiked time series
   - stored unformated

3) Spectral files - formatted

4) Directional Spectral files - formatted (directional buoys only)

5) Monthly checked spectral files - quality controlled spectral data; formatted

The raw wave data, monthly checked spectral files and the wind data have been supplied to MEDS.

Times associated with each raw data file and documentation of the raw data file and spectral file formats follow.

STATION 211 - LANGARA WEST
INFORMATION ON RAW DATA FILES

TAPE #	ZERO COUNTER TIME	TIME OF FIRST	TIME OF LAST RECORD	COMMENTS
	JULIAN DAY,YEAR	HR(GMT)/JDAY/YR	HR(GMT)/JDAY/YR	
1				TEST TAPE
2	308.250, 82	2000/310/82	2100/310/82	
3	!!	400/311/82	1600/316/82	
4	!!	1800/316/82	500/322/82	
5	!!	700/322/82	300/328/82	
6	!!	600/328/82	200/334/82	
7	!!	400/334/82	200/340/82	
8A	!!	400/340/82	500/346/82	
8B	!!	1534/347/82	1100/352/82	PROBLEMS WITH FIRST COUPLE OF BURSTS
9	!!	1300/352/82	1100/358/82	
10	!!	1300/358/82	100/364/82	
11	!!	300/364/82	2200/ 4/83	
12	!!	0/ 5/83	2100/ 10/83	
13	!!	2300/ 10/83	2300/ 16/83	
14	!!	0/ 17/83	300/ 23/83	
15	!!	500/ 23/83	900/ 29/83	
16	!!	1300/ 29/83	1600/ 35/83	
17	!!	1800/ 35/83	1500/ 41/83	
18	!!	1700/ 41/83	1100/ 47/83	
19	!!	1300/ 47/83	1200/ 53/83	
20	!!	1300/ 53/83	1300/ 59/83	
21	!!	1500/ 59/83	1400/ 65/83	
22	!!	1500/ 65/83	1700/ 71/83	
23	!!	2100/ 71/83	1600/ 77/83	
24	!!	1700/ 77/83	1200/ 83/83	
25	!!	1300/ 83/83	1200/ 89/83	
26	!!	1300/ 89/83	200/ 96/83	MOST OF TAPE UNREADABLE
27	!!	600/ 96/83	600/102/83	
28	!!	700/102/83	500/108/83	
29	308.250, 82	600/108/83	900/114/83	
30	!!	1300/114/83	1200/120/83	
31	!!	1300/120/83	1200/128/83	
32	!!	600/130/83	1000/136/83	
33	!!	2100/137/83	1600/143/83	
34	!!	1500/148/83	500/154/83	MISSING DATA UNTIL MAY 28
35	!!	600/154/83	2300/159/83	
36	!!	0/160/83	1900/165/83	
37	!!	2000/165/83	1900/171/83	
38	!!	2000/171/83	2000/177/83	
39	!!	2100/177/83	2000/183/83	
40	!!	1400/190/83	1700/194/83	MISSING DATA AT BEGINNING OF TAPE
41	!!	1800/194/83	2300/200/83	
42	!!	200/201/83	100/207/83	
43	!!	200/207/83	100/213/83	
44	!!	200/213/83	200/219/83	
45	!!	300/219/83	500/225/83	
46	!!	600/225/83	500/231/83	
47	!!	600/231/83	500/236/83	
48	!!	700/236/83	500/241/83	
49	!!	700/241/83	500/246/83	
50	!!	*800/246/83	1700/251/83	*1ST GOOD RECORD
51	!!	1800/251/83	2000/256/83	

52	!!	2200/256/83	500/262/83	
53	!!	700/262/83	500/268/83	
54	!!	700/268/83	500/274/83	
55	!!	600/274/83	1400/282/83	
56	284.583, 83	1300/286/83	500/291/83	PROBLEMS WITH FIRST PART OF TAPE DURING WHICH THE COUNTER WRAP-AROUND OCCURED
57	!!	600/291/83	500/297/83	
58	!!	600/297/83	500/302/83	
59	!!	600/302/83	2100/306/83	
60	!!	2200/306/83	1600/311/83	
61	!!	1700/311/83	200/317/83	
62	!!	300/317/83	2300/321/83	
63	!!	0/322/83	1700/327/83	
64	!!	1800/327/83	1700/332/83	
65	!!	1800/332/83	1700/337/83	
66	337.750, 83	1900/337/83	100/343/83	COUNTER RESET
67	!!	200/343/83	2000/347/83	
68	!!	2100/347/83	200/353/83	
69	!!	300/353/83	500/358/83	
70	!!	600/358/83	500/363/83	
71	!!	600/363/83	500/ 3/84	
72	!!	600/ 3/84	500/ 8/84	
73	!!	600/ 8/84	500/ 13/84	
74	!!	600/ 13/84	2000/ 17/84	
75	!!	1900/ 18/84	1800/ 23/84	
76	!!	1900/ 23/84	1400/ 25/84	PROBLEMS IN MIDDLE OF TAPE
76B	!!	1600/ 26/84	2000/ 28/84	
77	!!	2100/ 28/84	1700/ 31/84	MISSING DATA AT END OF TAPE
78	!!	1200/ 32/84	500/ 36/84	
79	!!	600/ 36/84	1800/ 36/84	PROBLEMS DURING READING
79B	!!	0/ 37/84	500/ 40/84	
80	!!	705/ 40/84	500/ 44/84	
81	!!	708/ 44/84	2300/ 47/84	
82	!!	0/ 48/84	500/ 52/84	
83	!!	600/ 52/84	500/ 56/84	
84	!!	600/ 56/84	500/ 60/84	
85	!!	600/ 60/84	1700/ 63/84	
86	!!	1800/ 63/84	2300/ 67/84	
87	!!	0/ 68/84	500/ 73/84	
88	!!	600/ 73/84	2300/ 78/84	
89	!!	0/ 79/84	500/ 84/84	
90	!!	1800/ 85/84	1700/ 91/84	RECORDER LEFT ON STANDBY FOR 1.5 DAYS
91	!!	1900/ 91/84	1700/ 96/84	PROBLEM WITH FIRST 10000 SCANS
92	!!	1900/ 96/84	500/102/84	
93	!!	600/102/84	2300/107/84	
94	!!	0/108/84	2300/113/84	
95	!!	0/114/84	2000/119/84	
96	!!	2100/119/84	500/125/84	
97	!!	600/125/84	2100/125/84	

STATION 212 - LANGARA EAST
INFORMATION ON RAW DATA FILES

*Sampling every three hours

TAPE #	ZERO COUNTER TIME	TIME OF FIRST	TIME OF LAST RECORD	COMMENTS
	JULIAN DAY, YEAR	HR(GMT)/JDAY/YR	HR(GMT)/JDAY/YR	
1	294.125, 82	2205/310/82	105/328/82	
2	!!	705/328/82	405/346/82	
3	!!	900/346/82	2100/363/82	
4	!!	300/364/82	1500/ 13/83	
5	!!	2100/ 13/83	900/ 31/83	
6	!!	1500/ 31/83	900/ 47/83	
7	!!	1500/ 47/83	900/ 65/83	
8	!!	1500/ 65/83	1500/ 82/83	
9	!!	1800/ 82/83	300/100/83	
10	!!	600/100/83	1200/118/83	
11	!!	1500/118/83	*300/123/83	*LAST GOOD RECORD
				TAPE EXTENDS TO 1500/145/83
				PROBLEM WITH ANTENNAE CABLE
12	!!	0/189/83	1200/205/83	
13	!!	1500/205/83	300/222/83	
14	!!	*1500/235/83	300/237/83	*FIRST GOOD RECORD
				MOST OF TAPE UNREADABLE
				EXPECTED 1ST REC. 600/222/83
15	!!	900/237/83	1500/249/83	
16	!!	1800/249/83	1500/266/83	
17	270.461, 83	1516/286/83	304/297/83	PROBLEMS IN FIRST HALF OF TAPE
				COUNTER WRAP-AROUND OCCURRED
				AT SAME TIME.
				THE ZERO COUNTER TIME WAS
				CALCULATED FROM EXPECTED RECORD TIMES
				IN TAPE 19.
				TIMES FOR TAPE 17 AND 18 ARE
				QUESTIONABLE.
18	!!	604/297/83	1434/311/83	
19	!!	1734/311/83	534/321/83	
20	!!	834/327/83	2304/278/83	*NO GOOD DATA
				BUOY FAILURE
21	21.875, 84	0/ 22/84	300/ 38/84	FIRST GOOD RECORD AFTER
				DEPLOYMENT AT 1200/22
22	!!	600/ 38/84	1500/ 53/84	
23	!!	1800/ 53/84	2100/ 67/84	
24	!!	0/ 68/84	300/ 84/84	
25	!!	600/ 84/84	1800/ 99/84	
26	!!	0/100/84	1500/115/84	
27	!!	1800/115/84	900/130/84	
28	!!	1200/130/84	2100/145/84	BUOY OUT OF WATER
				AT 1:15 MAY 25

STATION 213 - BONILLA ISLAND
INFORMATION ON RAW DATA FILES

TAPE #	ZERO COUNTER TIME	TIME OF FIRST	TIME OF LAST RECORD	COMMENTS
	JULIAN DAY, YEAR	HR(GMT)/JDAY/YR	HR(GMT)/JDAY/YR	
1				TEST TAPE
2	308.250, 82	014/309/82	015/321/82	
3	!!	*015/322/82	1515/335/82	*FIRST GOOD RECORD
4	!!	015/336/82	1516/350/82	
5	!!	2126/350/82	1818/365/82	
6	!!	018/ 1/83	1819/ 15/83	
7	!!	019/ 16/83	*320/ 31/83	*LAST GOOD RECORD QUALITY OF DATA VERY POOR
8	!!	?2137/ 31/83	1537/ 41/83	QUALITY VERY BAD
9	!!	2135/ 56/83	1522/ 61/83	FIRST 2/3 OF TAPE UNREADABLE VERY POOR DATA QUALITY UNTIL MARCH
10	!!	2122/ 61/83	1223/ 74/83	FOR TAPE 10 TO TAPE 18 TILT VALUES ARE BAD
11A	!!	2123/ 75/83	1524/ 87/83	BREAK IN TAPE
11B	!!	924/ 88/83	1224/ 91/83	
12	!!	1825/ 91/83	1225/106/83	
13	!!	1825/106/83	1226/121/83	
14	!!	1826/121/83	1527/136/83	
15	!!	027/137/83	*1228/148/83	*LAST GOOD RECORD PROBLEMS BY END OF TAPE
16	!!			NO DATA - BUOY ADRIFT
17	!!			NO DATA - BUOY ADRIFT
18	261.125, 83	2100/261/83		ONLY ONE RECORD
19	!!	0/262/83	1501/274/83	
20	!!	1801/274/83	1502/289/83	
21	!!	1802/289/83	1503/305/83	
22	!!	1803/305/83	1504/320/83	
23	!!	1804/320/83	1205/335/83	
24	!!	1505/335/83	1506/350/83	
25	!!	1806/350/83	1508/ 1/84	
26	!!	2108/ 1/84	1208/ 16/84	MOST OF TAPE IS BAD DATA BUOY ADRIFT

STATION 214 - MCINNES ISLAND
INFORMATION ON RAW DATA FILES

TAPE #	TIME OF FIRST RECORD	TIME OF LAST RECORD	COMMENTS
	HR(GMT)/DAY/MON/YR	HR(GMT)/DAY/MON/YR	
1A	2100/21/ 4/83	900/26/ 4/83	NUMEROUS PROBLEMS WITH READING RAW DATA CARTRIDGE FILE HAD TO BE BROKEN UP INTO SMALL PARTS
1B	1200/26/ 4/83		ONLY ONE RECORD(SHORT)
1C	1200/26/ 4/83	1500/27/ 4/83	
1D	1800/27/ 4/83	1500/30/ 4/83	
2A	2100/30/ 4/83	600/ 5/ 5/83	NUMEROUS PROBLEMS WITH READING RAW DATA CARTRIDGE
2C	2100/ 6/ 5/83	300/ 9/ 5/83	
3	600/ 9/ 5/83	000/11/ 5/83	
3C	600/11/ 5/83	1200/14/ 5/83	PROBLEMS WITH DATA. LAST READABLE RECORD AT 900/14/5/83
4	2101/30/ 6/83	1801/ 5/ 7/83	
5	2101/18/ 7/83	2101/28/ 7/83	
6	301/29/ 7/83	601/ 3/ 8/83	
7	301/ 4/ 8/83	301/13/ 8/83	
8	901/13/ 8/83	1801/22/ 8/83	
9	2101/22/ 8/83	2101/31/ 8/83	
10	001/ 1/ 9/83	1501/10/ 9/83	
11	1801/10/ 9/83	900/18/ 9/83	
11B	900/18/ 9/83	1200/20/ 9/83	
12	1500/20/ 9/83	00/ 1/10/83	
13	600/ 1/10/83	1500/11/10/83	
14	1800/11/10/83	2100/17/10/83	
15	0/18/10/83	1500/26/10/83	BUOY BROKE UP ON MOORING LAST GOOD RECORD AT 600/25/10/83 BEFORE TRANSMISSION LOSS

FROM TAPE 16 ON, WAVEC RECORDED CONTINUOUSLY IF THE RMS WAVEHEIGHT WAS GREATER THAN 1.0M

16	601/17/ 2/84	0001/25/ 2/84	
17	301/25/ 2/84	2305/27/ 2/84	ON CONTINUOUSLY MOST OF TAPE
18	2331/27/ 2/84	1501/ 6/ 3/84	

FROM TAPE 18 ON, DAYS IN RECORD HEADERS ARE OFF BY 1 AS THE RECEIVER MISSED FEBRUARY 29 AND SET IT TO MARCH 1.

19	1801/ 6/ 3/84	1501/15/ 3/84	
20	601/16/ 3/84	430/24/ 3/84	NUMEROUS TRANSMISSION AND TAPE PROBLEMS

FROM TAPE 21 ON, PROBLEMS IN THE SLOPE DATA AS THERE WAS A LARGE MEAN.
BUOY FLOTATION PIECES SLIPPED OUT OF HARNESS

21	601/24/ 3/84	400/29/ 3/84	
22	601/29/ 3/84	529/ 7/ 4/84	
23	600/ 7/ 4/84	1801/10/ 4/84	
24	2345/10/ 4/84	0001/19/ 4/84	
25	301/19/ 4/84	1501/26/ 4/84	
26	1801/26/ 4/84	635/ 5/ 5/84	
27	601/ 5/ 5/84	1630/13/ 5/84	
28	1801/13/ 5/84	*1501/15/ 5/84	*AFTER THIS RECORD, TIME HEADERS HAVE BOTH WRONG TIMES AND DATES. THE PROPER TIMES ARE UNKNOWN.

STATION 215 - HECATE STRAIT
INFORMATION ON RAW INTERNAL WRIPS TAPES

TAPE #	PLATFORM ID	INITIAL COUNTER TIME	TIME OF 1ST	TIME OF LAST RECORD	COMMENTS
		JULIAN DAY, YEAR	HR(GMT)/JDAY/YR	HR(GMT)/JDAY/YR	
1	40402684	268.331, 82	* 457/271/82	* 157/114/83	* OF TIME SERIES RECORDED
			**2257/274/82	** 157/108/83	**OF GOOD TIME SERIES
2	"	173.956, 83	* 157/174/83	*2257/331/83	* OF TIME SERIES RECORDED
			**1957/185/83	** 457/327/83	**TIMES OF GOOD RECORDS
3	"	4.332, 84	* 457/ 7/84	*1357/152/84	* TIMES OF RECORDED TIME SERIES
			** 457/ 13/84	**1357/140/84	**TIMES OF GOOD RECORDS BUOY RECOVERED AT 2300 MAY 20

STATION 216 - QUEEN CHARLOTTE SOUND

TAPE #	PLATFORM ID	INITIAL COUNTER TIME	TIME OF 1ST	TIME OF LAST RECORD	COMMENTS
		JULIAN DAY, YEAR	HR(GMT)/JDAY/YR	HR(GMT)/JDAY/YR	
1	4040131E	268.215, 82	* 210/271/82	* 210/ 88/83	* TIMES OF RECORDED TIME SERIES
			** 210/274/82	** 210/ 79/83	**TIMES OF GOOD RECORDS
2	"	103.965, 83	*2010/106/83	*2010/354/83	* TIMES OF RECORDED TIME SERIES
			**2010/112/83	**1110/335/83	**TIMES OF GOOD RECORDS MOORED AFTER 500 APR 20/83 ON BOARD SHIP AFTER 2010 DEC. 2/83
3	"	4.340, 84	* 510/ 7/84	* 210/150/84	* TIMES OF RECORDED TIME SERIES
			** 510/ 13/84	** 210/141/84	**TIMES OF GOOD DATA BUOY MOORED AFTER 2000 JAN 10. BUOY RECOVERED AFTER 1200 MAY 21

WEATHER DATA FILE DOCUMENTATION

TAPENAME = WEATHR
ANSI LABELLED
1600 BPI
BLOCKSIZE = 5120.

PETRO-CANADA SUPPLIED WEATHER DATA FOR McKENNEY ROCK

Applies to all files named *****.PET
The data are written in columns with the following format:

COLUMN	VARIABLE	FORMAT
1	BLANK	
2-9	STATION ID	A9
10-11	MONTH	I2
12-13	DAY	I2
14-15	HOUR	I2
16-19	YEAR	I4
20-22	JULIAN DAY	I3
23-29	PRESSURE (PRIMARY SENSOR)	F7.2
30-36	AIR TEMPERATURE (PRIMARY SENSOR)	F7.1
37-43	DEW POINT TEMPERATURE	F7.1
44-50	RELATIVE HUMIDITY	I7
51-57	WIND DIRECTION (PRIMARY SENSOR)	I7
58-64	WIND SPEED (PRIMARY SENSOR)	F7.1
65-71	BATTERY VOLTAGE	F7.1
72-78	INTERIOR TEMPERATURE	F7.1
79-85	WIND DIRECTION (SECONDARY SENSOR)	I7
86-92	WIND SPEED (SECONDARY SENSOR)	F7.1
93-99	AIR TEMPERATURE (SECONDARY SENSOR)	F7.1

Note: - All times are in GMT
- All directions are True.
- Any missing data is replaced by 9999.99,9999999, or 99999.9 according to the proper data format

---

MCKENNEY ROCK DATA(REFORMATTED PETRO-CANADA DATA FILES)

Applies to all data files named *****.MCK

Note. For completeness, one should work with the original Petro-Canada files described above whenever possible.

File Format:

1) 12 Header lines

LINE 1: COMMENT,START TIME(YEAR,MONTH,DAY,HOUR,MINUTE),
END TIME(YEAR,MONTH,DAY,HOUR,MINUTE),NO. OF DATA COLUMNS,
SAMPLING INTERVAL(TO BE IGNORED IN THIS CASE),
LATITUDE(DEG,MIN,SEC) AND LONGITUDE(DEG,MIN,SEC)

FORMAT = 28A1,5I2,5I2,I2,F6.2,I3,2I2,I3,2I2

LINE 2: STATION NAME
FORMAT = 30A1

LINE 3 TO 5: COMMENTS

LINE 6 TO 12: DESCRIPTION OF EACH DATA COLUMN SUCH THAT
LINE 6 DESCRIBES COLUMN 1, LINE 7 DESCRIBES COLUMN 2 ETC.

EACH LINE : PARAMETER CODE,SCALE,COLUMN TITLE
FORMAT : I2, E8.0 , 30A1

The scale is used to convert the respective data value
to an integer for storage.

2) LINE 13 ON : DATA LINES WRITTEN AS NI5 WHERE N IS THE NO. OF COLUMNS.
(IE. 7I5 : JULIAN DAY,HOUR,SPEED,DIRECTION,PRESSURE,TEMPERATURE
AND RELATIVE HUMIDITY)

Times are in GMT and Directions are all True.
Any missing data are replaced by -9999.

AES WEATHER STATION DATA

Applies to all data files named *****.BON, *****.LAN, *****.CSJ, or *****.MCI

The format for these data files are very similar to that for McKenney
Rock reformatted data.

File Format:

1) 9 Header lines

LINES 1 TO 5: (as above)
LINES 6 TO 9: DESCRIPTION OF DATA COLUMNS (ONLY 4)(as above)
2) LINES 10 ON : DATA LINES WRITTES AS 4I5 (JULIAN DAY,TIME,SPEED,DIRECTION)

DATA FORMAT DOCUMENTATION

WAVERIDER DATA - STN. 211,212

Data cassette read using a Sea Data Reader, either by CCIW or Seakem.

Each data line consists of 62 characters, with counters and data values in Hex.

```
IE. *CCTTTTTSSSND D D D D D .............D  D  D  VQ
                  1 1 1 2 2 2             16 16 16
```

where

* - Indicator for the start of a scan(CCIW).This is replaced by a space in data read at Seakem.

CC - Scan counter cycling from Hex values 80 to BF (ie. 128 to 191) then starting back at 80 (ie. a total of 64 scans). The last scan in a record should have counter value C0(ie. 192) and there is a corresponding jump in time in the following scan.

TTTTT - Time counter which increments by one every 1/128 hours. To obtain the time of a record, convert TTTTT from the first scan to decimal, divide by 128 to obtain the number of hours passed since the recorder was turned on, and add this value to the logged initial counter time (ie. the time associated with counter value 1). These initial time values are supplied in the tape documentation.

SSS - Station number, not in Hex.

N - instrument code

DDD - 16 data values each written with 3 Hex digits.

V - variable, not used

Q - quality code for scan. = 0 (CCIW) or G (Seakem) if scan is good. other quality codes include S for short and P for parity error.

To convert heave data values to SI units in meters:

1) first subtract 2048 from the decimal value. If the output(IX) is less than 2048 this would indicate that the reader was unlocked and no data was being received.

2) X in meters = ((IX-HZERO)/BITS)*RANGE

Where,

	211	212
HZERO:	1026.509	1026.837
RANGE:	29.997	29.953
BITS:	2047.0	2047.0

ENDECO WAVE-TRACK DATA STN. 213

Data cartridges read using a Sea Data Reader.
The scan format for counters, time indicators and quality flags are the same as those for the waveriders.
Each line, however, is now 70 charaters long.

```
IE. *CCTTTTTSSSNH H H TN TN TE TE H H H TN TN TE TE .......H H H TN TN TE TE VQ
                  1 1 1  1  1  1  1 2 2 2  2  2  2  2       8 8 8  8  8  8  8
```

There are 8 sets of heave(3 Hex digits), north-south tilt(2 Hex digits) and east-west tilt(2 Hex digits) values.

To convert these raw values to SI units, the following should be used:

X = ((Xraw - HZERO)/BITS)*RANGE
Xeng = X*VAL1-VAL2

Where:

	HEAVE	TILT
HZERO:	-0.4094	-0.2794
RANGE:	4.8460	4.8021
BITS :	2047.0000	127.0000
VAL1 :	6.0960	18.0000
VAL2 :	15.2400	45.0000

WAVEC DATA - STN. 214

Data cartridge translation performed at Seakem.

At the start of each new transmission, a time indicator is written of the form:

*YYYY MM-DD HH:MM (MM HH HH)
ie. *Year Month-Day Hour:Minute (sampling period, repeat time, start hour)
Ex. *1983 09-29 15:00 (34 03 12)

The times are in GMT.

This is then followed by approx. 2600 lines (or scans) of data, each having the form:

MS,HHHH,SSSS,SSSS
ie. MonitorStatus,Heave,North-South slope,East-West slope

where M = monitor character consisting of a sequential number from 0 to 9 used as an indicator for any missing data scans. If more than 9 scans are missing, M takes on a value of 'A'.

S = status character with a value of 0 to 9 increasing with increasing error severity. Any data having a status greater than 2 should be rejected.

Each heave and slope value consists of 4 decimal values,in signed or unsigned format, and to convert to SI units:

HEAVE(m)= (HEAVE(raw)-IOFF)/100
SLOPE = (SLOPE(raw)-IOFF)/2000

where IOFF equals 0 if signed format, and 5000 if unsigned format is used. Most of the Wave Climate Study data is in unsigned format. Problems with the receiver at the beginning of the study caused a default to signed format in the first tape.

The WAVEC buoy measures positive slope up towards the North and up towards the West.

NB. If the receiver is set to continuous recording, time header lines may not be written out. They are only written if data transmission is interrupted. In February 1984, the DIREC receiver forgot that 1984 was a leap year, and all the header times following February 28 are offset by one day.

SATELLITE INTERNAL WRIPS TAPES

When data cassette translation is performed by MEDS, the data format is as described on the attached sheets. When read at Seakem, the format is very similar with the following differences:

Quality Control: G - OK
S - SHORT
P - PARITY ERROR

The MEDS data records consist of 197 characters per line. In Seakem records each data record is written over three lines instead with 73, 72 and 52 characters on each. Otherwise, formats and interpretation are the same.

The times of the records are given by a synoptic counter which increments by 1 every three hours. The times of the time series records are given by that of the GOES message immediately following. The second and third characters is a counter indicating whether the record is a GOES message(if it is even valued) or a time series line(if it is odd valued).

HEADER DOCUMENTATION

The following gives details of Wave Climate Study data file headers

I. SPECTRAL FILES (these are formatted)

A. Main Header

	VARIABLE NAME	DIMENSION and TYPE	FORMAT	INFORMATION
	1. ISTA	INTEGER	I4	Station #
	2. ITAP	INTEGER	I3	Tape #
	3. STATN	BYTE(20)	20A1	Station Name
	4. LATD	INTEGER	I3	Latitude (degrees)
	5. RLATM	REAL	F5.1	Latitude (minutes)
	6. LATNS	BYTE	A1	"N" or "S"
	7. LOND	INTEGER	I3	Longitude (degrees)
	8. RLONM	REAL	F5.1	Longitude (minutes)
	9. LONEW	BYTE	A1	"E" or "W"
	10. NRECS	INTEGER	I4	No. of data records in file
*	11. DELT	REAL	F5.2	Sampling interval (sec.)
	12. ITIM	INTEGER	I4	Start time (HHMM)
	13. IDAY	INTEGER	I3	Start day (DD)
	14. MON	BYTE(4)	4A1	Month (MMM)
	15. IYR	INTEGER	I2	Year (YY)
	16. INSTYP	INTEGER	I2	Instrument type code
	17. ITZ	INTEGER	I2	Time Zone
	18. DECLIN	REAL	F5.1	Magnetic Declination
	19. DECEW	BYTE	A1	Mag. Dec. "E" or "W"
	20. DEPTH	REAL	F6.1	Water Depth
	21. COMENT	BYTE(46)	46A1	Misc. Comments

* Sampling interval for the Wavec is .78125 while delt truncates it to .78

B. Individual record headers for spectral files - 4 lines
(for all instrument types except Satellite Data)

	VARIABLE NAME	DIMENSION and TYPE	FORMAT	INFORMATION
	line #1:			
	1. IREC	INTEGER	I4	Record #
	2. ITIM	INTEGER	I5	Start time (HHMM)
	3. IDAY	INTEGER	I3	Day
	4. WNDLOC	BYTE(20)	20A1	Location for wind data
	5. WNDSPD	REAL	F5.1	Wind speed (m/s)
	6. WNDDIR	REAL	F5.1	Wind direction
	7. NSUM	INTEGER	I3	No. of blocks averaged
	8. BLKLEN	REAL	F6.1	Block length (seconds)
	9. IFLG	INTEGER	I2	Data quality flag
	10. QUAL	BYTE(20)	20A1	Description of data quality
	11. DELB	REAL	F5.1	Interval between burst samples (hours)
*	line #2:			
	1. RM0	!	!	Zeroth Spectral Moment
	2. RM1	!	written	First Spectral Moment

3.	RM2		¦	with	Second Spectral Moment
4.	RM4		¦	10(1PG13.6)	Fourth Spectral Moment
5.	HS		¦	(packed)	Significant Wave Height
6.	QP		¦	¦	Peakedness Parameter
7.	SPMIN		REAL	read	Spectral minimum (m**2/hz)
8.	PMIN		¦	with	Period of SPMIN (sec)
9.	SPMAX		¦	20(F20.0)	Spectral maximum (m**2/hz)
10.	PMAX		¦	¦	Peak Period (sec)

* line #3:

1.	HMIN	**	¦	¦	Minimum Wave Height (m)
2.	HMINNS	**	¦	written	N-S Slope of mimimum wave
3.	HMINEW	**	¦	with	E-W Slope of mimimum wave
4.	HMAX	**	¦	9(1PG13.6)	Maximum Wave Height (m)
5.	HMAXNS	**	¦	(packed)	N-S Slope of maximum wave
6.	HMAXEW	**	¦	¦	E-W Slope of maximum wave
7.	SMINNS	**	REAL	read	Minimum N-S Slope
8.	SMINEW	**	¦	with	Minimum E-W Slope
9.	SMAXNS	**	¦	20(F20.0)	Maximum N-S Slope

* line #4:

1.	SMAXEW	**	¦	¦	Maximum E-W Slope
2.	SMIN	**	¦	written	Minimum Slope
3.	SMAX	**	¦	with	Maximum Slope
4.	DMAX		¦	9(1PG13.6)	Direction of Peak Energy
5.	EPSLON		¦	(packed)	Spectral Width Parameter
6.	TM01		¦	¦	Average Period
7.	TM02		REAL	read	Average Apparent Period
8.	TM24		¦	with	Apparent Crest Period
9.	XKNU		¦	20(F20.0)	Spectral Narrowness Parameter

* Format for lines 1,2 and 3 for the Wavec files is: 10(1X,E12.5)
** Generally left blank

C. Individual record headers for Satellite Data files - 4 lines

Waverider data received via satellite is in the form of spectral estimates rather than time series of heave. Because of this, the slots in the record header set aside for stats calculated from the raw time series are used instead to store various other pieces of information transmitted in the headers of the satellite data records. The first two lines of the spectral record header are the same as above. Only lines 3 and 4 are different.

line #1:

	VARIABLE NAME	DIMENSION and TYPE	FORMAT	INFORMATION
1.	IREC	INTEGER	I4	Record #
2.	ITIM	INTEGER	I5	Start time (HHMM)
3.	IDAY	INTEGER	I3	Day
4.	WNDLOC	BYTE(20)	20A1	Location for wind data
5.	WNDSPD	REAL	F5.1	Wind speed (m/s)
6.	WNDDIR	REAL	F5.1	Wind direction
7.	NSUM	INTEGER	I3	No. of blocks averaged
8.	BLKLEN	REAL	F6.1	Block length (seconds)
9.	IFLG	INTEGER	I2	Data quality flag
10.	QUAL	BYTE(20)	20A1	Description of data quality
11.	DELB	REAL	F5.1	Interval between burst samples (hours)

line #2:

```
 1. RM0       ¦       ¦        Zeroth Spectral Moment
 2. RM1       ¦    written     First Spectral Moment
 3. RM2       ¦      with      Second Spectral Moment
 4. RM4       ¦  10(1PG13.6)   Fourth Spectral Moment
 5. HS        ¦   (packed)     Significant Wave Height
 6. QP        ¦       ¦        Peakedness Parameter
 7. SPMIN    REAL   read       Spectral minimum (m**2/hz)
 8. PMIN      ¦     with       Period of SPMIN (sec)
 9. SPMAX     ¦  20(F20.0)     Spectral maximum (m**2/hz)
10. PMAX      ¦       ¦        Peak Period (sec)
```

line #3:

```
 1. XMEM      ¦       ¦        Memory test. 0-OK 1-failure
 2. SNCNT     ¦    written     Synoptic Counter
 3. TSRC      ¦     with       Time series recorded counter
 4. BATVT     ¦   9(1PG13.6)   Battery voltage
 5. TMEAN1    ¦   (packed)     Mean of Off-synoptic series(cm)
 6. AVPER1    ¦       ¦        Ave. wave period (Off-Syn.)(sec.)
 7. HMAX1    REAL   read       Max Heave of Off-synoptic series (m)
 8. VAR1      ¦     with       Variance (m**2) (Off-Synoptic)
 9. SWH1      ¦  20(F20.0)     Sig. Wave Ht. (m) (Off-Synoptic)
```

line #4:

```
 1. TMEAN2    ¦       ¦        Mean of On-synoptic series(cm)
 2. AVPER2            ¦     written    Ave. wave period (On-Syn.)(sec.)
 3. HMAX2     ¦     with       Max Heave of On-synoptic series (m)
 4. VAR2      ¦   9(1PG13.6)   Variance (m**2) (On-Synoptic)
 5. EPSLON    ¦   (packed)     Spectral Width Parameter
 6. TM01      ¦       ¦        Average Period
 7. TM02     REAL   read       Average Apparent Period
 8. TM24      ¦     with       Apparent Crest Period
 9. XKNU      ¦  20(F20.0)     Spectral Narrowness Parameter
```

D. Values of INSTYP: (applies to all Wave Climate Study files)

INSTYP specifies the type of instrument from which the data was taken. It determines the type of processing in many Wave Climate Study programs. Its value is as follows:

```
INSTYP = 1, Standard Waverider Buoy (heave only)
         2, WAVEC Directional Wave Buoy (heave, slope, slope)
         3, ENDECO Directional Wave Buoy (heave, tilt, tilt)
         4, Satellite Waverider Buoy (heave only)
```

E. Values of IFLG: (applies to all Wave Climate Study files)

IFLG is the data quality flag set by the user when running SPCPLT. It can have the following values:

```
IFLG   = -1, not checked (after running SPCTRA)
       =  0 - 8, various degrees of goodness
       =  9 - 99, various degrees of badness
```

F. Data Format

1. For stations 211,212,213(heave)(ie. waverider and Wave-track)
   Each line of data consists of :
   - Frequency number(1 to 60)
   - Frequency(hz)
   - Spectral density(M**2/hz)

written with 3(1PG13.6)(packed) and read with 20(F20.0)

2. For satellite data(stations 215,216)
   Each line of data consisits of :
   - Frequency number(1 to 27)
   - Frequency(hz)
   - Spectral density(M**2/hz)
   - Number of bands averaged to give the density value

   written with 4(1PG13.6)(packed) and read with 20(F20.0)

3. For Wavec data(station 214)
   Each line of data consists of :
   - Frequency number(1 to 64)
   - Frequency
   - Spectral density(M**2/hz)(CO11 value)
   - CO22 estimate(Spectral density from the NS slope)
   - CO33 estimate(Spectral density from the EW slope)
   - QD12 estimate(Quad-spectral value between heave and NS slope)
   - QD13 estimate(Quad-spectral value between heave and EW slope)
   - CO23 estimate(Co-spectral value between NS and EW slope)
   - Mean direction at this frequency
   - Angular spread at this frequency
   - Cosine spread factor at this frequency

   written and read with the format:
   (1X,I2,9(1X,E12.5),1X,F8.2)

APPENDIX 4

SEASONAL WIND AND WAVE DATA SUMMARIES

1. SEASONAL SUMMARIES OF WAVE DATA

Summaries of wave data are presented on microfiche by season (spring, summer, fall, winter). For the purposes of this analysis, the following "seasonal" assignment was selected.

Spring	- March, April, May
Summer	- June, July, August
Fall	- September, October, November
Winter	- December, January, February

In addition, an annual summary of these data (for calendar year 1983) is presented. Please note that the seasonal summary for summer - Station 213 (Bonilla Island) has been omitted due to lack of data. The following plots are included for each station and season:

a) Scattergram of significant wave height versus peak period.

b) Scattergram of significant wave height versus average apparent period.

Note 1 c) Scattergram of significant wave height versus peak direction.

Note 1 d) Scattergram of peak period and peak direction.

Note 1 e) Scattergram of average apparent period and peak direction.

f) Exceedance plot for significant wave height values.

g) Persistence histograms for favourable and unfavourable significant wave heights. The upper line represents the maximum observed persistence and the lower line represents the average observed persistence. The numbers represent the number of occurrences. For the purposes of these plots, "favourable" significant wave heights are those less than or equal to the plotted significant wave height. Unfavourable significant wave heights are those greater than the plotted significant wave height.

h) Persistence histogram for wave period values. The total height indicates the maximum observed persistence and the lower bar indicates the average observed persistence. The numbers on the bars indicates the number of occurrences.

Note 1 i) Persistence histogram for wave directions. The total height indicates the maximum persistence and the lower bar indicates the average persistence. The numbers on the bars indicates the number of occurrences.

2. SEASONAL SUMMARIES OF WIND DATA

Summaries of wind data are presented by season (defined as above) and station, on a single microfiche. The following plots are included:

a) Scattergram of wind speed versus wind direction.

b) Exceedance plot (and table) for wind speed values.

Note 2 c) Persistence histogram for maximum (total column height) and average (lower bar) persistence of wind directions. The numbers on the plot indicate the number of occurrences.

Note 2 d) Persistence histograms for favourable (≤) and unfavourable (>) wind speed values. The upper line represents the maximum observed persistence and the lower line indicates the average observed persistence. The numbers on the plot indicate number of occurrences.

Note 1: This data presented for wave direction measuring buoys only (Station 213 - Bonilla Island and Station 214 - McInnes Island).

Note 2: This data presented for McKenny Rock weather station only. Irregular sampling interval at the other locations does not allow meaningful analysis in this manner.

APPENDIX 5

MONTHLY WAVE DATA SUMMARIES

Wave data summaries are presented by month for the period October, 1982 to May, 1984 for all stations (when operating). Each monthly report is contained on one microfiche, with the exception of September, 1983 and October, 1983, which have been presented on 2 microfiche each.

The monthly reports contain the following:

a) Short written summary of station performances over the month, including data recovery rates and explanations for any missing data.

b) Contoured energy density spectra plots (2 pages). The contoured intervals on these plots are 1.0, 10, 25, 50, 100, 250 and 500 m^2/hz. Only energy densities for frequencies than 0.2 hz (5 second period) are contoured. Due to limitations of array size, the data from Station 211 - Langars West is decimated to 3 hour sampling for this analysis. Where extensive gaps in the data are present, this analysis has been omitted.

c) Time series plots of significant wave height and peak period.

Note 1 d) Time series plots of peak direction and average apparent period.

e) Tables of root mean square wave heights, by wave period band.

f) Time series plots of wind speed and direction from McInnes Island, Cape St. James, Bonilla Island, Langara Island and McKenny Rock.

Note 1: This data presented for wave direction measuring buoys only (Station 213 - Bonilla Island and Station 214 - McInnes Island).