Currents, Waves and Water Levels, October 2004 to October 2005, St. Lawrence River at Gros Cacouna

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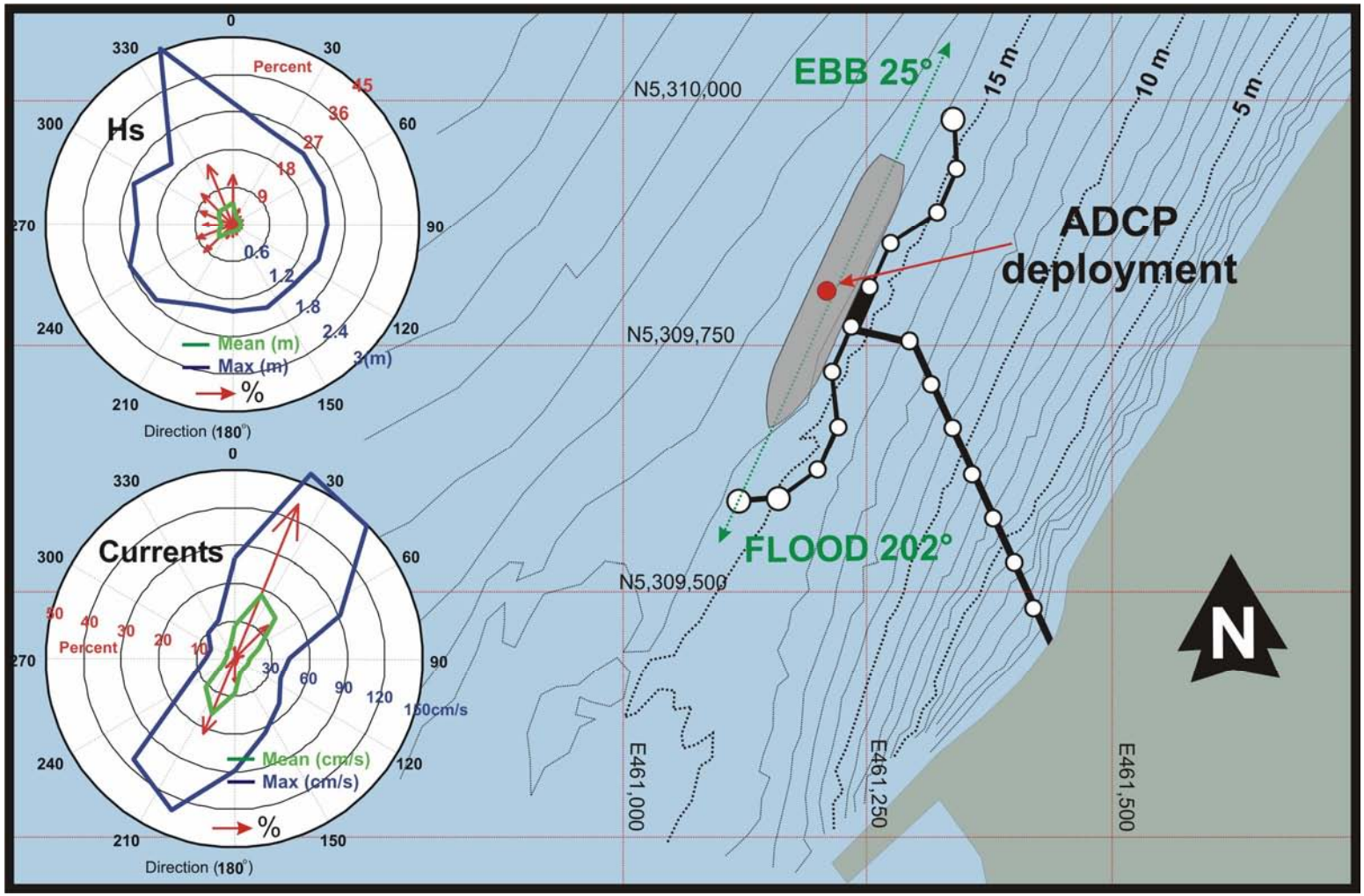

The proposed LNG Carrier terminal at Gros Cacouna (based on Sandwell Engineering drawing D.142829-8011). The histogram plots illustrate the directional distribution of the near-surface current speeds, as well as the significant wave heights, measured over the October 7, 2004 – October 13, 2005 period. The red arrows indicate the % occurrence by direction bin, using the red coloured radial scale. The maximum (dashed line) and mean (solid line) values for Hs and the currents use the same blue coloured radial scale with the units being cm/s for currents and m for Hs.

Executive Summary

This report presents the results of a year-long project for current profile, wave, water level and other oceanographic measurements at Gros Cacouna, Quebec, from October 7 2004 to October 13 2005. The measurements and data analysis obtained from this site investigation study have been conducted for a proposed LNG offloading terminal.

Waves

Of the many episodic wave events over the full year of observations, 18 had peak significant wave height values (Hs) exceeding 1.1 m, including the largest measured Hs of 3.04 m. Waves are considerably larger in winter (Jan.-Mar.) than any other season. The median/99th percentile value of Hs is 0.40 m/1.34 m in winter as compared to 0.19 m/ 1.27 m and 0.17 m/1.19 m in fall (Oct.-Dec.) and spring (Apr.-June) respectively. In summer, the waves are the smallest with a median/99th percentile Hs value of only 0.08 m/0.82 m.

For the largest wave events, the peak periods range from 5 to 9 seconds with the very largest wave events tending to have larger periods. The wave spectra for the full year reveal that significant low frequency contributions are rarely below 0.08 Hz and never below 0.06 Hz, corresponding to infrequent activity from waves with periods greater than 12.5 seconds and never any activity from waves at periods exceeding 16.7 seconds. Other than in relation to the increase of wave period with wave heights, the wave peak periods exhibit only minor variations with the seasons.

For the mean wave directions, the values range from the southwest sector or up-river (3 events), through the north-west (6 events) and from the north (9 events of the 18 largest wave events exceeding 1.1 m). Refractive steering of waves as they approach the shoreline, contribute to the wave events that have directions that originate from the northwest and north. These wave events can result from waves traveling up the river or down the river. Mean wave directions exhibit a seasonal variation with the median wave direction being from the northwest in fall, winter and spring (302, 313 and 299 º respectively) while the median wave direction is usually from the southwest (up-river) in summer (250º)

Large wave and wind events almost always coincide. However, the peak wave heights can vary by a factor of two or more for the same peak wind speeds among the cases examined. In most of the cases, the large waves were from the north-northwest and the coincident winds were from the northwest, north or northeast, although there are a few cases of waves and winds from the southwest. Some cases exhibit large wave events in which the peak values of Hs are elevated by 50 to 100% from the adjoining values on time scales of an hour. The very largest wave event of Dec. 11, 2004 (Hs of 3.04 m) is one of these cases, characterized by complex directional wave properties with several distinct peaks in the spectral wave densities for different combinations of wave frequency and direction.

Currents

The maximum current speeds occurred at the near-surface level reaching 159 cm/s in May 2005. At the 95th percentile level, the current speed was 88.5 cm/s. The major current component

statistics indicate that at the near-surface level, the largest ebb currents (84.7 cm/s 95% level) are somewhat stronger than the largest flood currents (-65.4 cm/s 5% level). At the near-bottom the situation is reversed with -60.7 cm/s flood currents (5% level) versus 44.2 cm/s ebb currents (95% level).

The measured currents are very much dominated by the tidal flows, which are primarily semi-diurnal (two tidal cycles per day) in this area. The tidal analyses show that the combined major semi-diurnal tidal constituents (M2 & S2) exhibit large changes in amplitudes of up to 30% according to the time of year. These large variations indicate that tidal analyses and predictions should be done in a piece-wise fashion over the year to provide accurate predictions of tidal currents for future and past times.

Of the full measured near-surface current signal (100%) as computed for the most recent deployment period of late July to October, the predicted tidal currents account for 81% of the signal in terms of variance or 22.2 cm/s of 24.6 cm/s in terms of standard deviations. The remaining "detided" currents represent only 19% of the total variance, corresponding to a standard deviation of 10.9 cm/s.

The detided currents can be separated into two parts: the low passed portion (residual currents having periods > 1-2 days) which amounts to only 4% of the variance, or 4.8 cm/s standard deviation; and the high passed portion of the detided current (associated with internal, non-predictable tides and higher frequency current variations) which accounts for 16% of the variance or 9.8 cm/s in standard deviation. Even though the currents are highly dominated by the predictable tidal currents (81% of total current variance), the effects of the non-tidal phenomena can still be large, at least occasionally, as indicated by the comparison of the maximum observed near-surface currents of 134 cm/s (between July and October 2005) for the full signal, 86 cm/s for the maximum tidal current, 78 cm/s for the high pass portion of the detided current and 32 cm/s for the low pass (residual) portion of the detided current.

Further examination of the residual low frequency detided currents indicates down-river flow at near-surface levels. The variability in the near-surface residual currents consists of fluctuations over periods of a few to several days with typical amplitudes of 10 – 20 cm/s and a longer period quasi-seasonal variation with typical amplitudes of 20 cm/s. Over the full year, the maximum residual currents occurred in June (28, 42 [mean/max cm/s]), while a smaller local minimum is found in December (18, 31 [mean/max cm/s]).

A comparison was made of local winds with the residual currents at near-surface levels. The response of residual currents to direct wind forcing appears to be weak and marginal in terms of possible correlations.

Water Levels

Water levels were derived from the ADCP bottom pressure measurements after correcting for the effect of local atmospheric pressure changes. Due to the small changes in location and local water depth between deployments, the water levels are referenced to the average value of each the four

instrument deployments, which will tend to reduce somewhat the variability that can be resolved at seasonal time scales. The lowest water levels were -3.03 m (January 13), and the highest water level was 3.0 m (December 12). At the 5%-95% level, the total water level range was 3.4 m. The largest water levels were observed between December and February.

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1 Introduction

1.1 Background

An LNG offloading terminal is being planned for a site on the south shore of the St. Lawrence River, at the port of Gros Cacouna, Quebec. As part of the study, ASL Environmental Sciences Inc. (ASL), in association with Procean Environnement Inc., has been contracted to provide current and wave data during the open water periods, as well as ice draft and velocity data during the ice-covered months. In October 2004 an ADCP was deployed to measure currents and waves. The initial results are presented in Fissel et al. (2005a). In November, two ADCPs and one Ice Profiling Sonar (IPS) were deployed for the over-winter period. The first ADCP was to measure waves, the second ADCP was to measure the currents and ice velocities, and the IPS was to measure the ice drafts. The results for the waves and currents are presented in Fissel et al. (2005b) and the results for the ice study are presented in Fissel et al., (2005c). The ADCP instrument was then re-deployed from April 29 to July 27 2005, and the interim results are presented in Fissel et al., (2005d).

A final deployment of the ADCP instrument followed from July 27 to October 13, 2005. In this report, we present the results for this last period of the measurement program along with a statistical summary of the oceanographic results for the complete year-long measurement period from October 7, 2004 to October 13, 2005.

Figure 1-1: The St. Lawrence River and estuary, downstream of Quebec City. The red square marks the location of the port of Gros Cacouna.

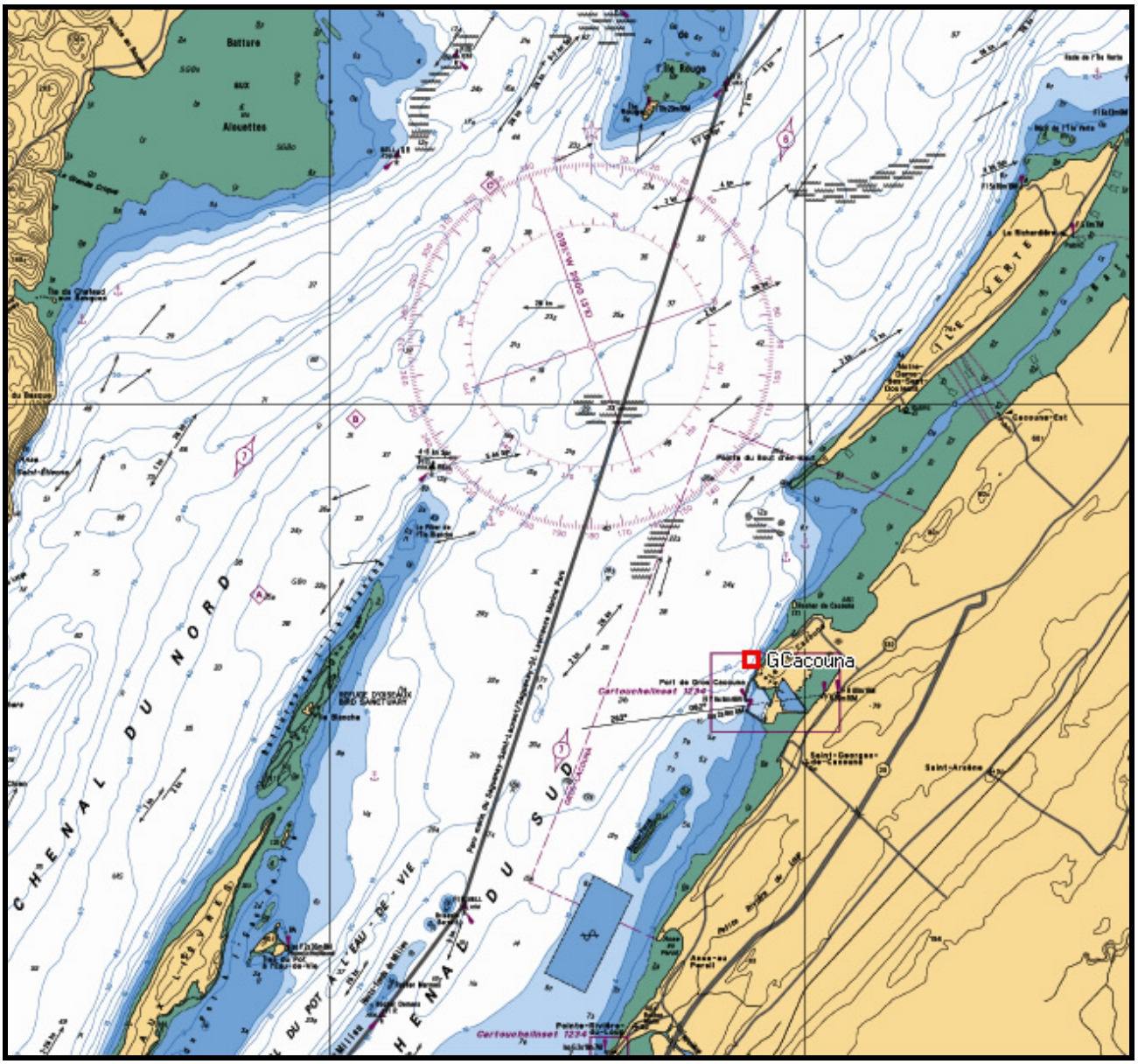

Figure 1-2: Bathymetry of the St. Lawrence River off the Port of Gros Cacouna (CHS chart #123501; depths in metres). The red square marks the location of the current/wave measurements.

Gros Cacouna is located about 180 km downstream of Quebec City, along the south shore of the St. Lawrence River, across from the Saguenay River (Figure 1-1). The St. Lawrence River is about 20 km wide at this point. There are two main islands nearby; Île Verte just downstream, and Île aux-Lievres to the southwest that separates the River into two channels (Figure 1-2). The water depth at the terminal site is about 18 m (Figure 1-3 and Figure 1-4). The bottom frame is located in 17.5 m water depth (LLW) at the proposed central position of the LNG carriers.

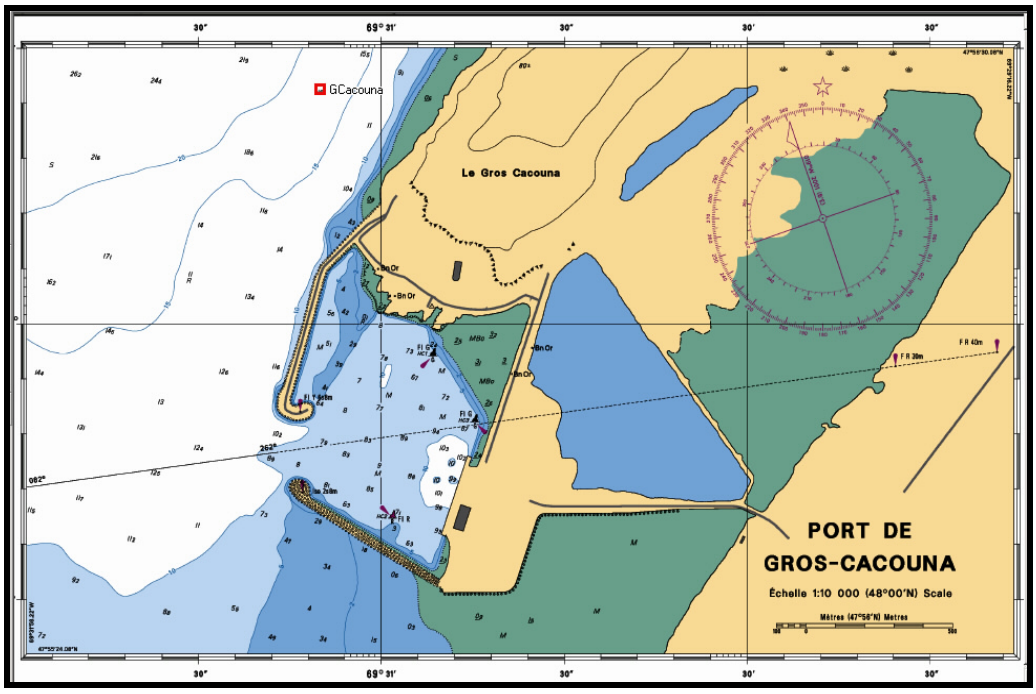

Figure 1-3: The Port of Gros Cacouna and mooring site (red square) (CHS chart 123501 insert).

1.2 Data Collection

The current and wave measurements which are presented in this report come from four separate deployments: October 7 to November 17, 2004; November 18, 2004 to April 29, 2005; April 29 to July 27, 2005; and July 28 to October 13, 2005. Information on the moorings used and instrument deployment parameters are provided in Birch et al., (2004a, 2004b) and Fissel et al., (2005a, 2005b and 2005c). For the most recent deployment from late July to October 2005, the instrument settings were identical to those used in the April to July 2005 deployment (Fissel et al., 2005c).

The over-winter deployment from November to April was slightly different from the other deployments. In this deployment ice velocities and currents were measured with one ADCP, and wave conditions were measured with a second ADCP. To accommodate the data storage and battery capacity limitations, the sampling rates had to be reduced. The current sampling rate changed from the typical 10 minute interval to 30 minutes, and the wave sampling rate changed from 60 minutes to 90 minutes. The sampling rates, and the water depths used for the near-surface, mid-depth, and near-bottom analysis are summarized in Table 1-1 for each deployment.

Table 1-1: The depth of the near-surface, mid-depth, and near-bottom bins used for each of the deployment time intervals, given in UTC, and the sampling interval for the currents and the waves.

	Oct 7 – Nov 17, 2004	Nov 18, 2004 – Apr 29, 2005	Apr 29 – Jul 27, 2005	Jul 28 – Oct 13, 2005
Nr-Srf Depth (m)	4	3	2	3
Mid Depth (m)	8	8	9	7
Nr-Bot Depth (m)	12	13	15	15
Current Sample Rate (min)	10	30	10	10
Wave Sample Rate (min)	60	90	60	60

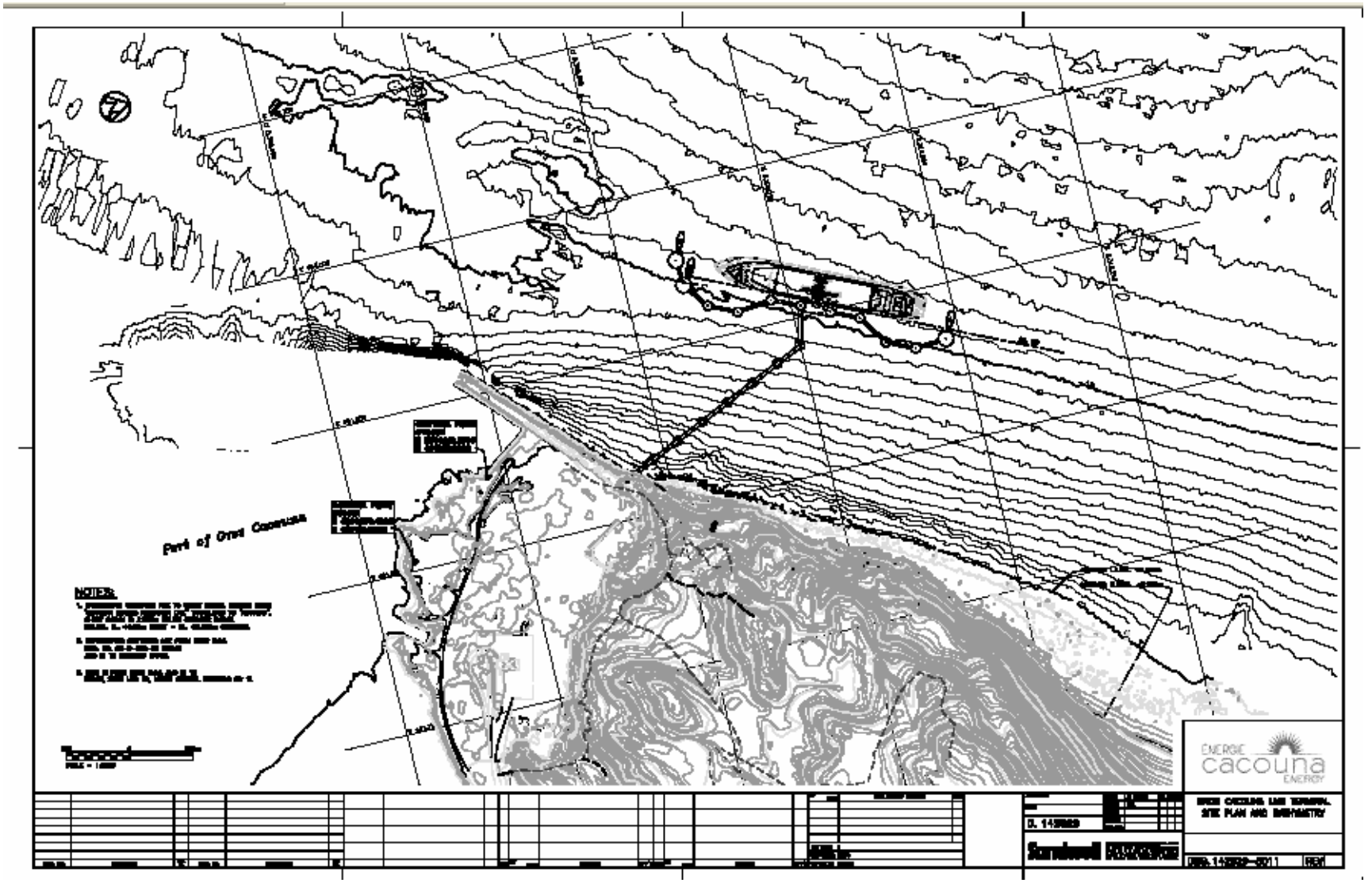

Figure 1-4: The planned LNG marine terminal at Gros Cacouna (TransCanada Pipeline drawing #142675-8006). The mooring site is located at the centre of the proposed LNG carrier position.

2 Waves

2.1 Wave Measurements Using ADCP Instruments

The non-directional wave spectra are calculated from the ADCP wave measurements. The ADCP provides three independent measurement systems from which non-directional wave parameters can be determined: wave orbital velocities and sea surface elevation measurements which are made acoustically, and water level which is made using a pressure sensor. The wave orbital velocities provide the most complete representation of the wave directional information, while the pressure sensor provides no directional information. With water levels of 16 to 22 m, there is a large degree of attenuation in the pressure measurements of the high frequency sea waves that constitute the largest part of the wave spectra. Surface tracking is a viable alternative which does not have issues with attenuation of the high frequency waves; however, the ADCP is optimized to take advantage of the 2 Hz near-surface wave orbital velocity measurements for reasons of obtaining optimal wave directions. The results given in this report will be based primarily on the orbital velocity derived wave parameters.

During periods of ice coverage, there were no wave measurements and the records for ice covered times were set to null values. The fall, spring and summer deployment periods did not have sea-ice present at any time.

The key wave statistical parameters are the significant wave height (Hs) (computed as four times the square root of the area under the velocity auto spectral curve) and the peak period (Tp) (defined as the period at which the velocity auto spectrum reaches a maximum). Directional spectra were calculated with 128 frequency bins and 90 directional bins in order to obtain the mean wave direction, and peak direction.

2.2 Annual and Seasonal Statistics

Time Series Plots

The complete set of wave results, from October 2004 to October 2005, is plotted over durations of two months in Figures 2-1 to 2-7 inclusive. The plotted wave parameters are significant wave height (Hs), peak period (Tp), peak wave direction (Dp) and mean wave direction (MWD). Tp, Dp and MWD are plotted only when the significant wave height exceeds 0.3 m, highlighting measurements for which these parameters are more meaningful and reliable. The wave parameters for the 18 wave events with Hs values exceeding 1.1 m are provided in Table 2-1.

The wave activity is very episodic being associated with wave generation from passing storms in the St. Lawrence River and the nearby Gulf of St. Lawrence. From October 7 through November 2004, there are several identifiable wave events all with significant wave heights of less than 1.0 m. However, in December 2004, there were four wave events having peak Hs values exceeding 1.1 m (Table 2-1). The largest measured waves over the full year occurred on December 11 having a significant wave height of 3.04 m, a peak period (Tp) of 8.5 seconds and a mean wave direction (MWD) of 346°.

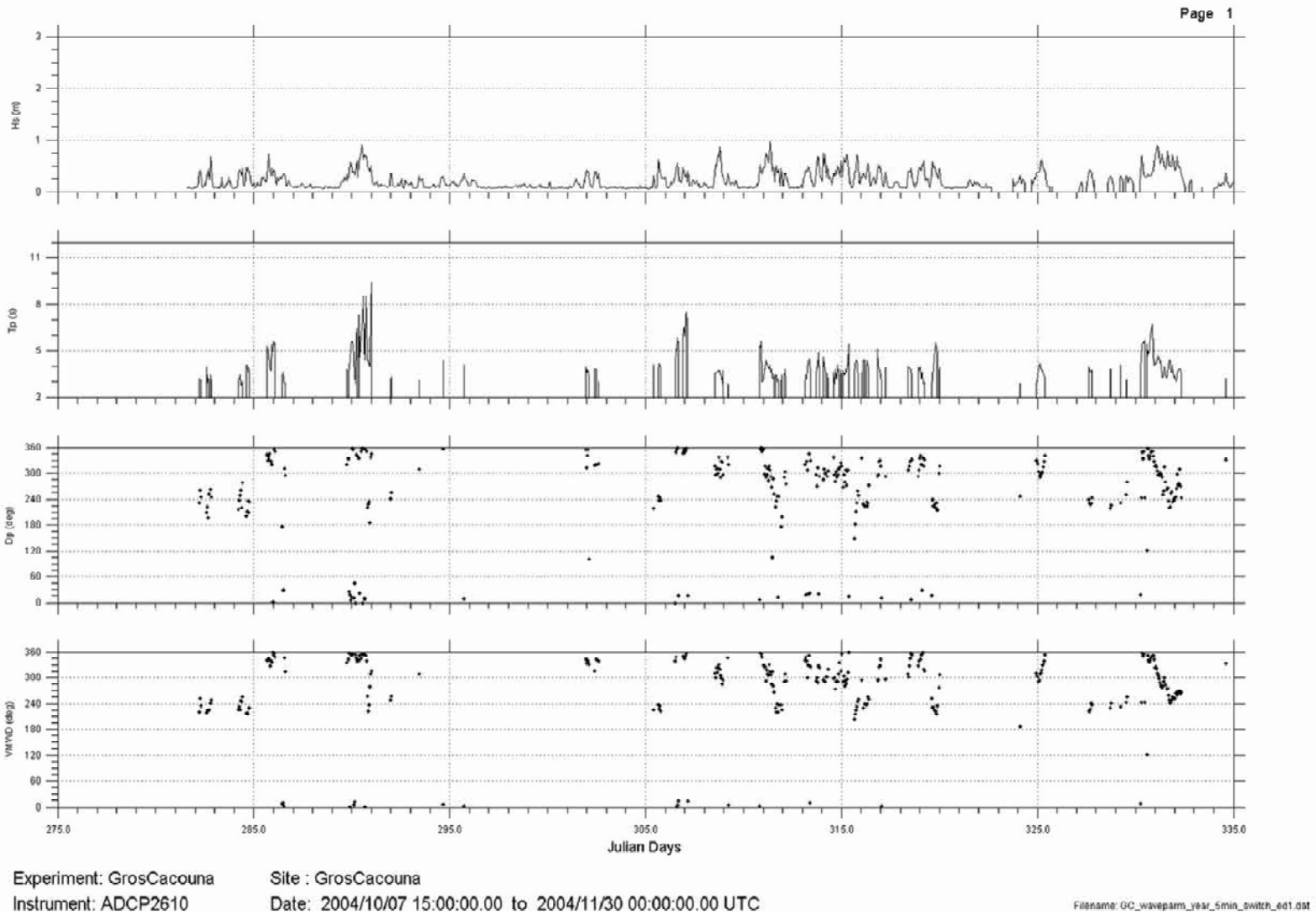

Figure 2-1: Significant wave height (Hs), and peak period (Tp), peak direction (Dp), and vector-mean-wave-direction (VMWD) between October and November, 2004 when Hs>0.3 m.

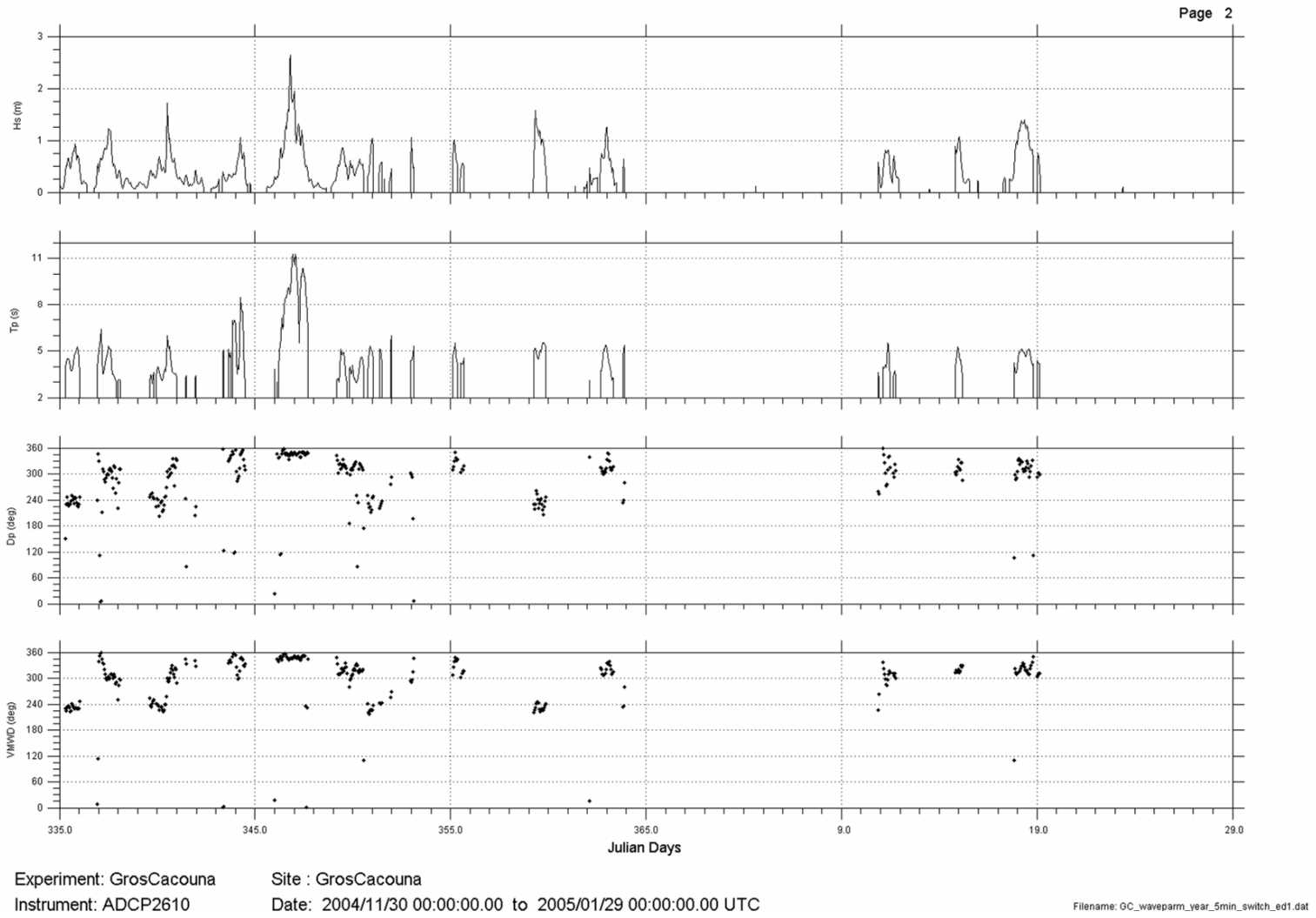

Figure 2-2: Significant wave height (Hs), and peak period (Tp), peak direction (Dp), and vector-mean-wave-direction (VMWD) between November, 2004 and January, 2005 when Hs>0.3m.

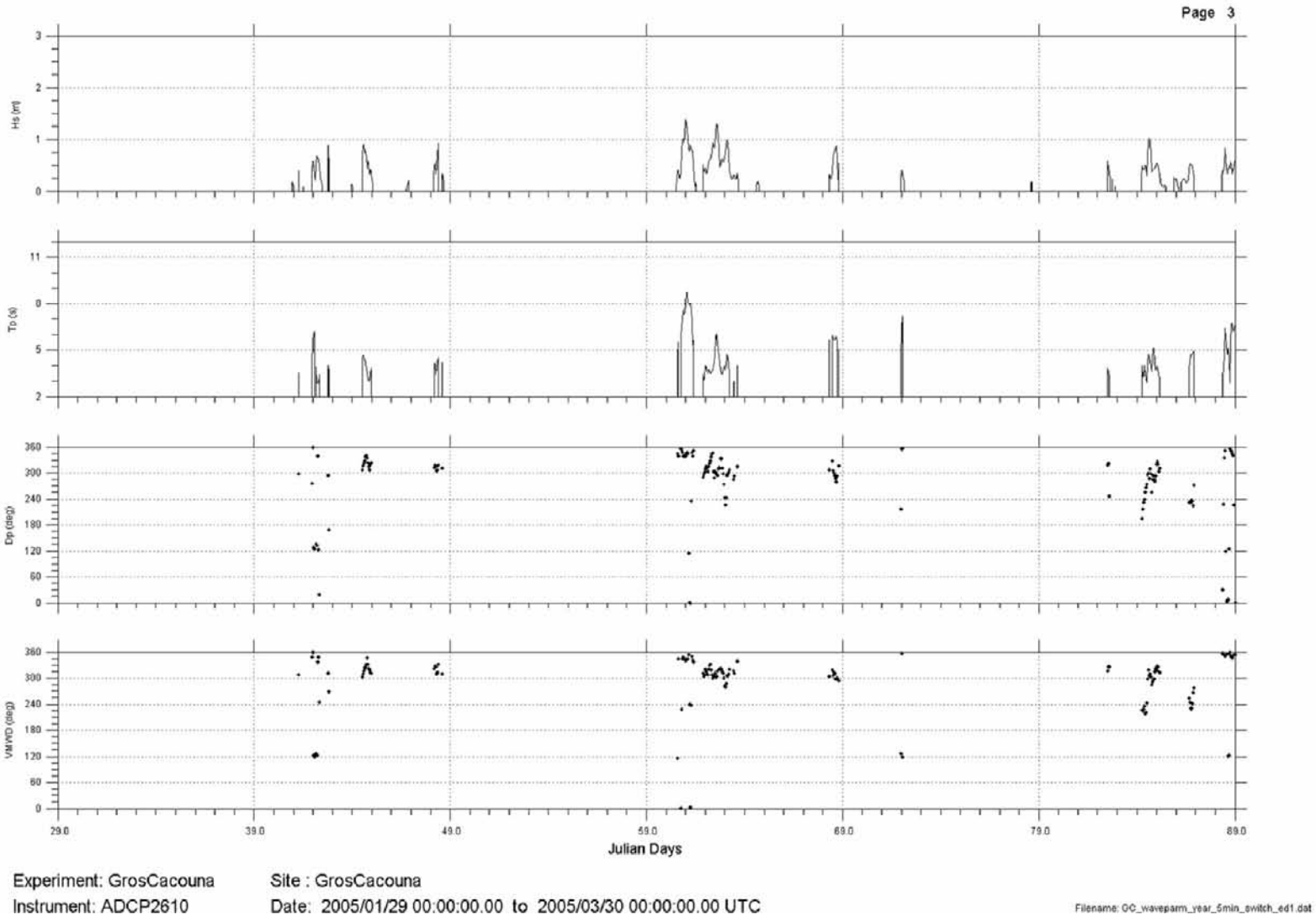

Figure 2-3: Significant wave height (Hs), and peak period (Tp), peak direction (Dp), and vector-mean-wave-direction (VMWD) between January and March, 2005 when Hs>0.3 m.

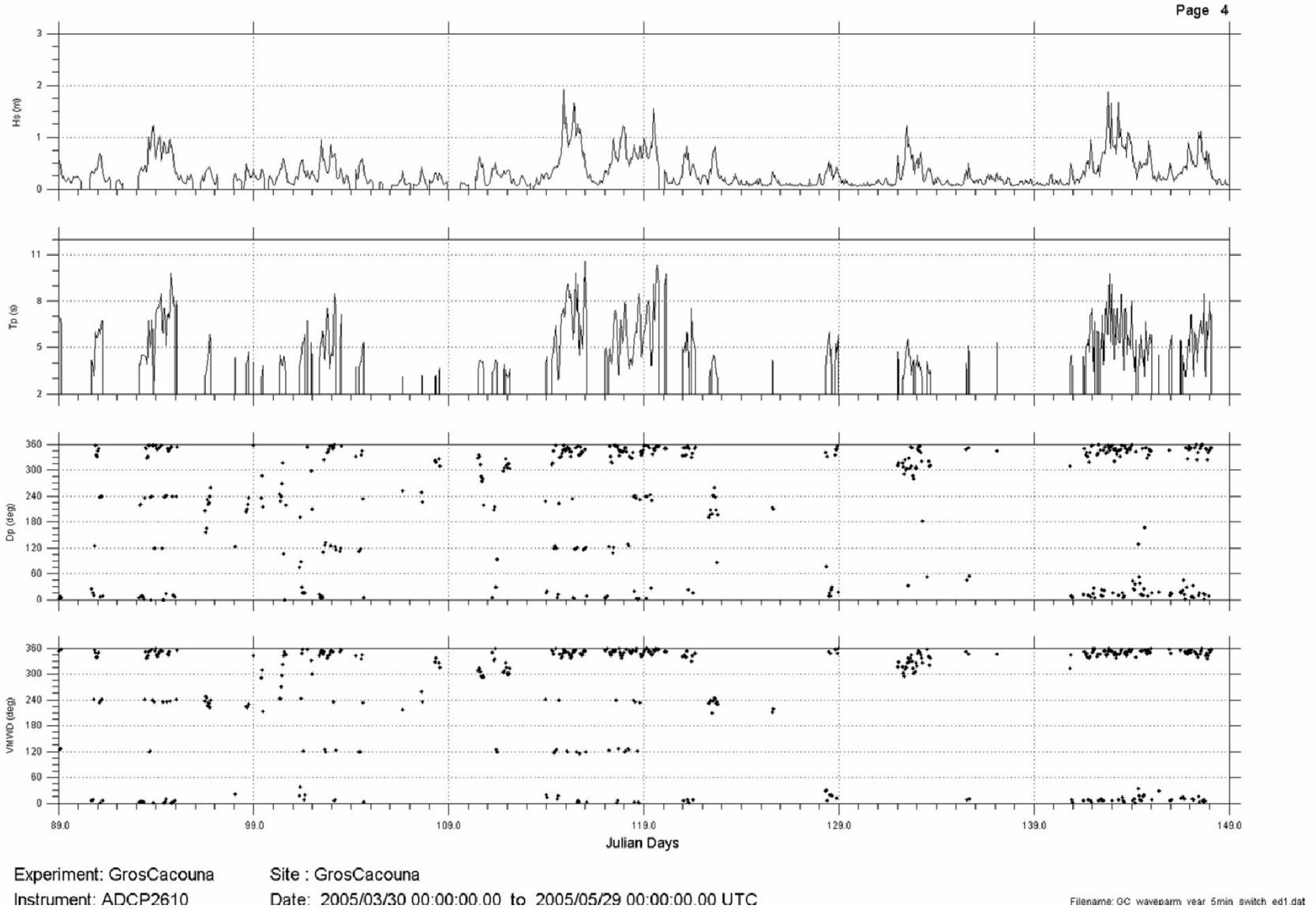

Figure 2-4: Significant wave height (Hs), and peak period (Tp), peak direction (Dp), and vector-mean-wave-direction (VMWD) between March and May, 2005 when Hs>0.3 m.

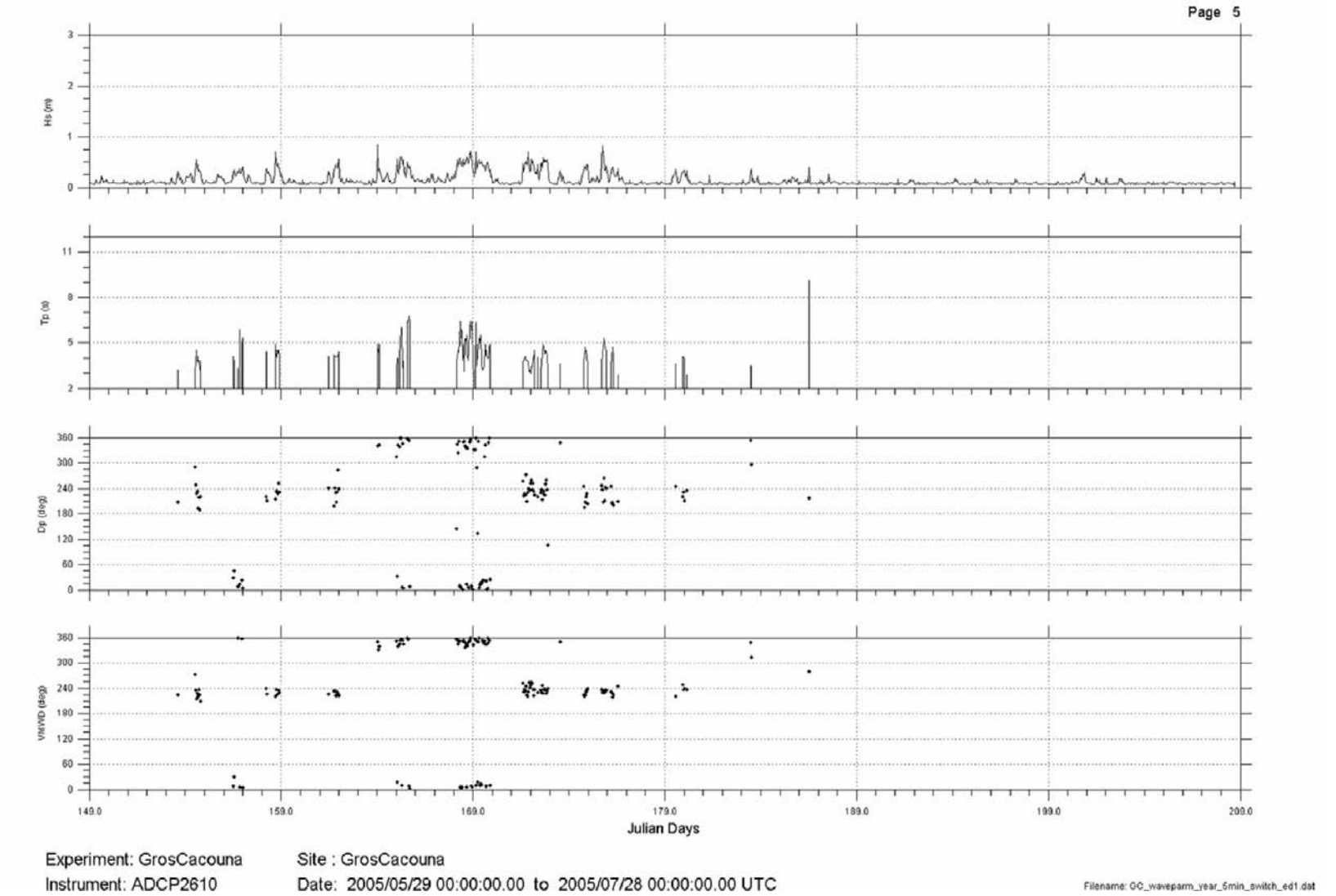

Figure 2-5: Significant wave height (Hs), and peak period (Tp), peak direction (Dp), and vector-mean-wave-direction (VMWD) between May and July, 2005 when Hs>0.3 m.

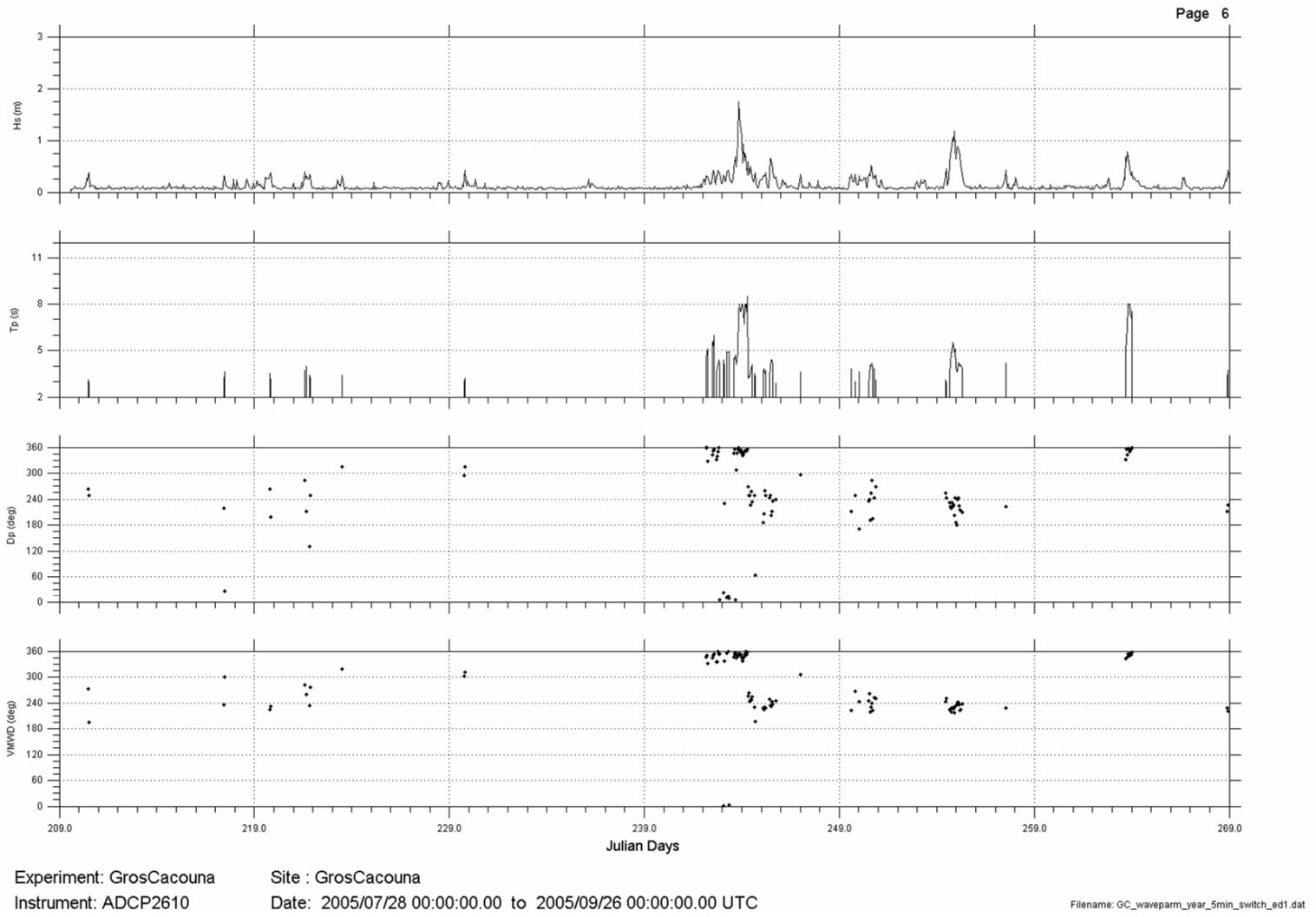

Figure 2-6: Significant wave height (Hs), and peak period (Tp), peak direction (Dp), and vector-mean-wave-direction (VMWD) between July and September, 2005 when Hs>0.3 m.

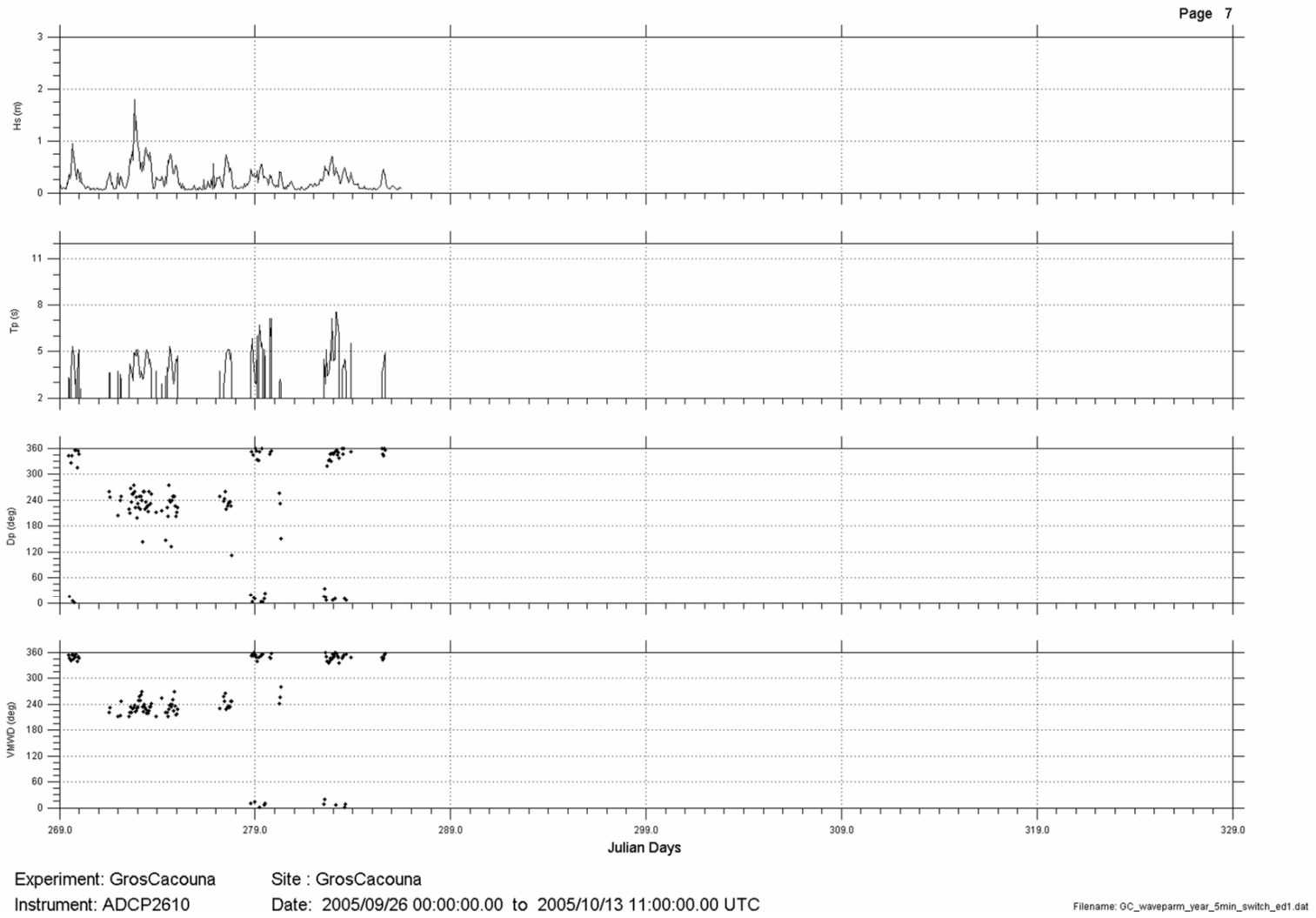

Figure 2-7: Significant wave height (Hs), and peak period (Tp), peak direction (Dp), and vector-mean-wave-direction (VMWD) between September and October, 2005 when Hs>0.3 m.

Table 2-1: The spectral wave parameters for the largest wave events having a significant wave height (Hs) exceeding 1.1 m.

Wave Events > 1.1m Hs	Hs	Tp	Dp	MWD
Date/Time	(m)	(s)	(º)	(º)
12/11/2004 19:30	3.04	8.5	348.0	346.4
4/24/2005 21:00	1.92	7.5	357.0	357.4
5/22/2005 19:00	1.86	5.8	356.8	353.1
9/30/2005 0:00	1.79	4.9	259.0	237.9
9/1/2005 0:00	1.74	7.5	359.0	353.4
12/5/2004 12:00	1.72	6.0	306.0	299.2
12/24/2004 7:30	1.72	5.3	214.0	227.2
4/29/2005 12:00	1.54	9.1	350.0	354.5
1/18/2005 9:00	1.39	4.9	310.0	325.2
3/2/2005 0:00	1.38	8.0	339.0	341.4
3/3/2005 13:30	1.32	6.4	298.0	297.0
12/28/2004 0:00	1.25	5.1	334.0	336.0
4/27/2005 22:30	1.25	4.9	343.0	346.4
12/2/2004 12:00	1.23	5.3	298.0	303.6
4/3/2005 21:00	1.23	7.5	17.0	11.0
5/12/2005 12:00	1.23	5.3	304.0	325.2
9/12/2005 2:00	1.18	4.9	202.0	217.4
5/27/2005 13:00	1.12	6.7	355.0	353.8

Ice was present from mid-December to late March and it too was episodic in nature with occasional periods of loosening and partial clearing (Fissel et al., 2005c). During this winter period from mid-December until early April, large wave events continued to occur during occasional periods of ice clearing or very thin sea-ice: 24 December (1.72 m, MWD 227°, 5.3s), 18 January (1.39 m, MWD 325°, 4.9s), 2 March (1.38 m, MWD 341°, 8s), and 3 March (1.32 m, MWD 297°, 7.5s).

Following the clearance of sea-ice in late March, two other large wave events were measured on 24 April (1.92 m, MWD 357°. 7.5s), and 29 April (1.54 m, MWD 354°, 9.1s). Another large wave event occurred on May 21-23 with a significant wave height (Hs) of 1.87 m, and a peak period (Tp) of 5.8 s, and a mean wave direction (MWD) of 353º. However, the wave events generally are reduced in magnitude through the spring months and remained below 1.0 m Hs from June through August 2005.

In late August, wave activity increased starting with a large wave episode on September 1 (1.74 m Hs, 7.5 s, 353º) followed by episodic wave events of 0.5 to 1.0 m (Hs). Another larger wave event occurred on September 30, with an Hs of 1.79 m, a period of 4.9 s and a wave direction (MWD) of 238º.

For these largest wave events, the peak periods range from 5 to 9 seconds with the very largest wave events tending to have larger periods. For the mean wave directions, the values range from the southwest sector or up-river (3 events), through the north-west (6 events) and from the north (9 events). Refractive steering of waves, approaching the shoreline, contributes to the wave events that have directions that originate from the northwest and north. These wave events can result from waves traveling up the river or down the river.

2.2.1 Statistical Summaries

The statistics of significant wave height computed by each quarter or season (Table 2-1) indicate that the waves are considerably larger in winter (Jan.-Mar.) than any other season. The median value of Hs is 0.40 m in winter as compared to 0.19 m and 0.17 m in fall (Oct.-Dec.) and spring (Apr.-June) respectively. In summer, the waves are the smallest with a median Hs value of only 0.08 m. The largest waves follow the same seasonal pattern of being largest in winter. The Hs value for the 95th percentile is 1.18 m in winter vs. 0.81 and 0.82 m in fall and spring and only 0.41 m in summer.

Table 2-2: Statistical summary of all measured significant wave heights by quarter, and for the year. The statistics are computed from interpolated samples at 5 minutes, derived from the original wave data measured at 60 or 90 minute intervals.

Hs	min	mean	50%	75%	95%	99%	std	max	# valid	total
Oct-Dec	0.06	0.29	0.19	0.39	0.81	1.27	0.27	3.04	18710	24588
Jan-Mar	0.05	0.49	0.40	0.69	1.18	1.34	0.32	1.39	4016	25920
Apr-Jun	0.04	0.27	0.17	0.34	0.82	1.19	0.25	1.92	24764	26208
Jul-Oct	0.04	0.14	0.08	0.13	0.41	0.82	0.15	1.79	29834	30085
Annual	0.04	0.24	0.13	0.29	0.76	1.21	0.25	3.04	77324	106801

Table 2-3: Statistical summary of peak periods which were measured when the significant wave height exceeded 30 cm, by quarter and for the year.

Tp (Hs>0.3m)	min	mean	50%	75%	95%	99%	std	max	# valid	total
Oct-Dec	2.8	4.5	4.0	5.0	8.2	10.5	1.6	11.6	6318	12196
Jan-Mar	2.9	4.6	4.3	5.2	7.2	8.3	1.2	9.1	2548	24452
Apr-Jun	2.0	5.1	4.7	6.0	8.1	9.4	1.5	10.6	7361	8805
Jul-Oct	2.6	4.5	4.2	5.0	7.5	8.0	1.3	9.3	2749	3013
Annual	2.0	4.8	4.4	5.4	7.9	9.7	1.5	11.6	18976	48466

Table 2-4: Statistical summary of peak directions which were measured when the significant wave height exceeded 30 cm, by quarter and for the year.

Dp (Hs>0.3m)	min	mean	50%	75%	95%	99%	std	max	# valid	total
Oct-Dec	0.0	268.0	293.3	321.4	349.5	356.0	76.9	360.0	6318	12196
Jan-Mar	0.0	274.7	305.8	324.3	347.5	356.0	88.2	359.0	2548	24452
Apr-Jun	0.0	223.9	244.4	339.3	355.1	358.0	122.8	360.0	7361	8805
Jul-Oct	1.0	243.3	241.3	332.8	354.8	358.8	91.9	360.0	2737	3013
Annual	0.0	248.2	278.4	329.8	353.5	357.5	102.7	360.0	18964	48466

Table 2-5: Statistical summary of vector average mean wave directions which were measured when the significant wave height exceeded 30 cm, by quarter and for the year.

MWD (Hs>0.3m)	min	mean	50%	75%	95%	99%	std	max	# valid	total
Oct-Dec	0.0	284.1	302.3	334.4	353.2	357.4	68.7	360.0	6318	12196
Jan-Mar	0.4	292.9	313.1	326.2	352.3	355.9	69.8	359.7	2548	24452
Apr-Jun	0.3	247.4	298.5	348.1	356.3	358.3	120.7	359.9	7361	8805
Jul-Oct	0.5	271.4	250.3	347.0	354.9	357.5	75.1	359.9	2737	3013
Annual	0.0	269.2	304.0	343.1	355.2	357.9	95.0	360.0	18964	48466

As noted previously, the largest measured wave event with an Hs of 3.04 m occurred in the late fall on Dec. 11, 2004. Note that the larger statistical values of Hs in the winter reflect the fact that most of the time (84.5%) ice is present in sufficient quantities to suppress wave activity; the wave

statistics are computed on wave samples representing only 15.5% of the total elapsed time during winter which tends to bias the wave statistics upwards especially for the mean and median statistics.

The wave peak periods (Table 2-3) exhibit only minor variations with the seasons. However, mean wave directions (Table 2-5) show a much greater variation with the median wave direction being from the northwest in fall, winter and spring (302, 313 and 299 º respectively) while the median value is southwest to south in summer (250 º)

2.2.2 Joint Frequency Tables

Significant Wave Height versus Vector Average Mean Wave Direction:

The joint bivariate distribution of significant wave height (Hs) vs. mean wave direction (MWD) is presented in Table 2-6 for the full year of observations, and for each season in Tables 2-7, 2-8, 2-9 and 2-10. Volume II contains the appendices, starting with instrument specifications in Appendix A. Appendix B.1 illustrates these bivariate distributions graphically by season. Monthly bivariate distributions are given in Appendix B.2, and are illustrated in Appendix B.3. The dominance of waves originating from the northwest to north sectors, along with the largest waves being in this sector, is clearly evident over the full measurement period and in the fall, winter and spring seasons. In summer (Table 2-10), although the waves are reduced considerably in height, there are many waves that arrive from the southwest and west or from up-river as well as from the northwest and north. The largest summer waves of up to 1.74 m originate from the north and the southwest.

Table 2-6: Joint frequency table of significant Hs versus MWD for October 2004 to October 2005.

Location: GrosCacouna at site GrosCacouna
Instrument: ADCP2610
For period: Oct.07,2004 15:00:00 to Oct.13,2005 11:00:00 UTC Sample Interval: 5 min

	Hs (m)																
Direction (deg)	0 to 0.2	0.2 to 0.4	0.4 to 0.6	0.6 to 0.8	0.8 to 1	1 to 1.2	1.2 to 1.4	1.4 to 1.6	1.6 to 1.8	1.8 to 2	2 to 2.2	2.2 to 2.4	2.4 to 2.6	2.6 to 2.8	2.8 to 3	3 to 3.2	Row Total (%)
11.25 33.75 NNE	3.14	0.67	0.17	0.03	0.01	0.01	0.00		0.00								4.04
33.75 56.25 NE	2.26	0.20	0.09	0.03	0.01	0.01	0.00	0.00	0.00								2.61
56.25 78.75 ENE	2.26	0.24	0.10	0.03	0.01	0.01	0.00	0.00									2.66
78.75 101.25 E	2.27	0.24	0.10	0.03	0.02	0.01	0.00	0.00									2.69
101.25 123.75 ESE	2.21	0.22	0.10	0.02	0.02	0.01	0.00	0.00									2.59
123.75 146.25 SE	2.19	0.19	0.09	0.02	0.01	0.01	0.00										2.52
146.25 168.75 SSE	2.40	0.22	0.10	0.02	0.01	0.01	0.00	0.00									2.77
168.75 191.25 S	2.88	0.25	0.11	0.03	0.01	0.01	0.01	0.00									3.30
191.25 213.75 SSW	3.11	0.61	0.12	0.03	0.01	0.01	0.00	0.00									3.90
213.75 236.25 SW	4.36	2.83	1.41	0.59	0.25	0.13	0.05	0.02	0.01								9.66
236.25 258.75 WSW	5.27	2.73	0.93	0.26	0.10	0.03	0.04	0.00	0.01								9.36
258.75 281.25 W	5.53	1.11	0.33	0.15	0.02	0.01	0.01	0.00									7.16
281.25 303.75 WNW	5.77	1.35	0.67	0.34	0.18	0.07	0.05	0.01	0.01								8.44
303.75 326.25 NW	6.06	1.82	1.20	0.72	0.54	0.18	0.14										10.66
326.25 348.75 NNW	8.38	3.72	1.48	0.92	0.48	0.27	0.17	0.04	0.04	0.02	0.01	0.01	0.01	0.01	0.01	0.00	15.55
348.75 11.25 N	5.20	3.13	1.55	1.03	0.60	0.25	0.19	0.08	0.06	0.02							12.10
Column Total (%)	63.30	19.54	8.55	4.25	2.29	1.02	0.68	0.17	0.12	0.04	0.01	0.01	0.01	0.01	0.01	0.00	

No. of Non-Flagged Records: 77254 No. of Flagged Records 29547
Max. Hs : 3.04 m Filename: gc_waveparm_year_5min_4_JFT.dat
Mean Hs : 0.24 m
Vector-averaged Speed: 0.12 m at 310.9 deg

Table 2-7: Joint frequency table of Hs versus MWD for October –December, 2004.

Location: GrosCacouna at site GrosCacouna
Instrument: ADCP2610
For period: Oct.07,2004 15:00:00 to Dec.31,2004 23:55:00 UTC Sample Interval: 5 min

	Hs (m)																
Direction (deg)	0 to 0.2	0.2 to 0.4	0.4 to 0.6	0.6 to 0.8	0.8 to 1	1 to 1.2	1.2 to 1.4	1.4 to 1.6	1.6 to 1.8	1.8 to 2	2 to 2.2	2.2 to 2.4	2.4 to 2.6	2.6 to 2.8	2.8 to 3	3 to 3.2	Row Total (%)
11.25 33.75 NNE	2.36	0.46	0.07	0.02													2.92
33.75 56.25 NE	1.46	0.22	0.03														1.71
56.25 78.75 ENE	1.54	0.28	0.07	0.01													1.91
78.75 101.25 E	1.49	0.31	0.05	0.01													1.86
101.25 123.75 ESE	1.42	0.29	0.04	0.01													1.76
123.75 146.25 SE	1.30	0.23	0.04														1.57
146.25 168.75 SSE	1.76	0.27	0.04	0.01													2.08
168.75 191.25 S	1.72	0.34	0.05	0.01													2.13
191.25 213.75 SSW	1.85	0.59	0.06	0.01													2.52
213.75 236.25 SW	2.48	2.61	2.20	0.74	0.47	0.28	0.06	0.05	0.03								8.93
236.25 258.75 WSW	3.42	3.90	1.59	0.52	0.03	0.09	0.15	0.01									9.71
258.75 281.25 W	4.06	1.46	0.75	0.35	0.01	0.02	0.01										6.65
281.25 303.75 WNW	4.65	2.61	1.69	0.89	0.27	0.25	0.14	0.04	0.03								10.57
303.75 326.25 NW	5.55	2.76	2.59	1.53	0.82	0.11	0.06										13.42
326.25 348.75 NNW	9.70	5.22	2.57	1.28	0.41	0.32	0.11	0.13	0.15	0.07	0.03	0.03	0.03	0.03	0.03	0.01	20.10
348.75 11.25 N	6.24	3.38	1.11	0.59	0.36	0.12	0.27	0.02	0.02	0.05							12.16
Column Total (%)	51.00	24.94	12.96	5.98	2.37	1.19	0.81	0.26	0.22	0.12	0.03	0.03	0.03	0.03	0.03	0.01	

No. of Non-Flagged Records: 18710 No. of Flagged Records 5878
Max. Hs : 3.04 m Filename: gc_waveparm_year_5min_4_JFT.dat
Mean Hs : 0.29 m
Vector-averaged Speed: 0.18 m at 304.8 deg

Table 2-8: Joint frequency table of Hs versus MWD for January - March, 2005.

Location: GrosCacouna at site GrosCacouna
Instrument: ADCP2610
For period: Jan.01,2005 00:00:00 to Mar.31,2005 23:55:00 UTC Sample Interval: 5 min

	Hs (m)																
Direction (deg)	0 to 0.2	0.2 to 0.4	0.4 to 0.6	0.6 to 0.8	0.8 to 1	1 to 1.2	1.2 to 1.4	1.4 to 1.6	1.6 to 1.8	1.8 to 2	2 to 2.2	2.2 to 2.4	2.4 to 2.6	2.6 to 2.8	2.8 to 3	3 to 3.2	Row Total (%)
11.25 33.75 NNE	0.57	1.37	0.15	0.05	0.05												2.19
33.75 56.25 NE	0.30	0.47	0.15	0.07	0.05												1.05
56.25 78.75 ENE	0.52	0.50	0.17	0.05	0.05												1.29
78.75 101.25 E	0.37	0.60	0.22	0.02	0.10												1.32
101.25 123.75 ESE	0.37	0.47	0.25	0.05	0.05												1.20
123.75 146.25 SE	0.30	0.47	0.27	0.05	0.05												1.15
146.25 168.75 SSE	0.42	0.55	0.20	0.05	0.05												1.27
168.75 191.25 S	0.35	0.47	0.22	0.07	0.05												1.17
191.25 213.75 SSW	0.35	1.27	0.35	0.10	0.02												2.09
213.75 236.25 SW	1.17	1.39	2.56	0.10	0.02												5.25
236.25 258.75 WSW	1.99	3.19	1.10	0.07	0.07												6.42
258.75 281.25 W	2.32	1.94	0.50	0.55	0.17												5.48
281.25 303.75 WNW	1.37	3.24	1.84	1.89	2.04	0.10	0.27										10.76
303.75 326.25 NW	2.91	8.24	7.27	5.38	6.15	2.24	2.34										34.54
326.25 348.75 NNW	2.19	4.93	2.59	2.22	1.39	0.85	2.02										16.19
348.75 11.25 N	0.90	4.01	2.27	1.15	0.32												8.64
Column Total (%)	16.41	33.12	20.12	11.88	10.66	3.19	4.63	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	

No. of Non-Flagged Records: 4016 No. of Flagged Records 21904
Max. Hs : 1.39 m Filename: gc_waveparm_year_5min_4_JFT.dat
Mean Hs : 0.49 m
Vector-averaged Speed: 0.38 m at 315.1 deg

Table 2-9: Joint frequency table of Hs versus MWD for April - June, 2005.

Location: GrosCacouna at site GrosCacouna
Instrument: ADCP2610
For period: Apr.01,2005 00:00:00 to Jun.30,2005 23:55:00 UTC Sample Interval: 5 min

	Hs (m)																
Direction (deg)	0 to 0.2	0.2 to 0.4	0.4 to 0.6	0.6 to 0.8	0.8 to 1	1 to 1.2	1.2 to 1.4	1.4 to 1.6	1.6 to 1.8	1.8 to 2	2 to 2.2	2.2 to 2.4	2.4 to 2.6	2.6 to 2.8	2.8 to 3	3 to 3.2	Row Total (%)
11.25 33.75 NNE	3.80	1.41	0.42	0.06	0.02	0.03	0.01		0.00								5.75
33.75 56.25 NE	1.89	0.32	0.21	0.07	0.03	0.04	0.00	0.00	0.00								2.58
56.25 78.75 ENE	1.68	0.32	0.21	0.06	0.02	0.04	0.00	0.00									2.35
78.75 101.25 E	1.77	0.33	0.22	0.08	0.04	0.04	0.01	0.01									2.52
101.25 123.75 ESE	1.75	0.30	0.21	0.06	0.05	0.03	0.01	0.01									2.42
123.75 146.25 SE	1.74	0.29	0.20	0.06	0.03	0.02	0.01										2.35
146.25 168.75 SSE	1.78	0.30	0.23	0.06	0.03	0.02	0.01	0.00									2.43
168.75 191.25 S	2.17	0.33	0.23	0.07	0.04	0.02	0.02	0.00									2.88
191.25 213.75 SSW	2.60	0.65	0.23	0.06	0.03	0.02	0.01	0.00									3.62
213.75 236.25 SW	4.18	3.67	1.60	0.34	0.06	0.02	0.01										9.88
236.25 258.75 WSW	4.26	2.86	0.80	0.21	0.08	0.02	0.01	0.00									8.25
258.75 281.25 W	3.87	0.87	0.24	0.10	0.04	0.02	0.01	0.00									5.15
281.25 303.75 WNW	4.33	1.15	0.47	0.07	0.04	0.02	0.01	0.00									6.08
303.75 326.25 NW	4.74	1.62	0.56	0.23	0.06	0.11	0.03										7.35
326.25 348.75 NNW	8.21	4.49	1.72	1.20	0.89	0.41	0.13	0.02	0.00								17.07
348.75 11.25 N	6.70	4.74	2.94	2.18	1.48	0.68	0.27	0.18	0.13	0.03							19.33
Column Total (%)	55.48	23.64	10.49	4.92	2.95	1.55	0.55	0.25	0.14	0.03	0.00	0.00	0.00	0.00	0.00	0.00	

No. of Non-Flagged Records: 24764 No. of Flagged Records 1444
Max. Hs : 1.92 m Filename: gc_waveparm_year_5min_4_JFT.dat
Mean Hs : 0.27 m
Vector-averaged Speed: 0.13 m at 331.1 deg

Table 2-10: Joint frequency table of Hs versus MWD for July - September, 2005.

Location: GrosCacouna at site GrosCacouna
Instrument: ADCP2610
For period: Jul.01,2005 00:00:00 to Sep.30,2005 23:55:00 UTC Sample Interval: 5 min

	Hs (m)																
Direction (deg)	0 to 0.2	0.2 to 0.4	0.4 to 0.6	0.6 to 0.8	0.8 to 1	1 to 1.2	1.2 to 1.4	1.4 to 1.6	1.6 to 1.8	1.8 to 2	2 to 2.2	2.2 to 2.4	2.4 to 2.6	2.6 to 2.8	2.8 to 3	3 to 3.2	Row Total (%)
11.25 33.75 NNE	3.55	0.03															3.58
33.75 56.25 NE	3.55	0.05															3.60
56.25 78.75 ENE	3.60	0.07															3.67
78.75 101.25 E	3.66	0.06															3.71
101.25 123.75 ESE	3.53	0.05															3.58
123.75 146.25 SE	3.59	0.04															3.63
146.25 168.75 SSE	3.77	0.05															3.82
168.75 191.25 S	4.79	0.06															4.85
191.25 213.75 SSW	5.08	0.49	0.01														5.58
213.75 236.25 SW	6.59	2.29	0.31	0.74	0.32	0.16	0.10	0.03	0.02								10.56
236.25 258.75 WSW	8.28	1.74	0.45	0.07	0.19				0.02								10.75
258.75 281.25 W	8.84	0.79	0.09														9.72
281.25 303.75 WNW	8.73	0.37	0.02														9.12
303.75 326.25 NW	8.18	0.55	0.03														8.76
326.25 348.75 NNW	8.08	1.32	0.23	0.25	0.08	0.05											10.02
348.75 11.25 N	3.44	0.70	0.34	0.32	0.06	0.00	0.10	0.05	0.03								5.05
Column Total (%)	87.28	8.65	1.48	1.37	0.65	0.21	0.20	0.08	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	

No. of Non-Flagged Records: 26198 No. of Flagged Records 298
Max. Hs : 1.79 m Filename: gc_waveparm_year_5min_4_JFT.dat
Mean Hs : 0.13 m
Vector-averaged Speed: 0.05 m at 271.9 deg

Peak Period versus Vector-Average-Mean-Wave-Direction

The joint bivariate distribution of peak period (Tp) vs. mean wave direction (MWD) is presented in Table 2-11 for the full year of observations, and for each season in Tables 2-12, 2-13, 2-14 and 2-15. Monthly joint bivariate distributions are presented in Appendix B2. Regardless of the season, most of the waves (39-53%) have spectral density peak period values between 3 to 4 s with significant wave heights usually well below 1.0 m. Longer wave periods tend to occur for waves arriving from quite a narrow direction sector of northwest to north (326 to 11 º) throughout the year.

Table 2-11: Joint frequency table of Tp versus MWD for October 2004 to October 2005.

Location: GrosCacouna at site GrosCacouna
Instrument: ADCP2610
For period: Oct.07,2004 15:00:00 to Oct.13,2005 11:00:00 UTC Sample Interval: 5 min

	Tp (s)															
Direction (deg)	0 to 1	1 to 2	2 to 3	3 to 4	4 to 5	5 to 6	6 to 7	7 to 8	8 to 9	9 to 10	10 to 11	11 to 12	12 to 13	13 to 14	14 to 15	Row Total (%)
11.25 33.75 NNE			0.84	1.83	0.78	0.34	0.08	0.06	0.05	0.05						4.04
33.75 56.25 NE			0.76	1.17	0.25	0.18	0.09	0.07	0.05	0.05						2.61
56.25 78.75 ENE			0.73	1.25	0.26	0.16	0.10	0.07	0.06	0.02						2.66
78.75 101.25 E			0.65	1.32	0.26	0.20	0.10	0.06	0.07	0.03						2.69
101.25 123.75 ESE			0.67	1.28	0.24	0.18	0.09	0.07	0.04	0.03						2.59
123.75 146.25 SE			0.66	1.31	0.21	0.15	0.10	0.05	0.03	0.02						2.52
146.25 168.75 SSE			0.69	1.45	0.26	0.18	0.10	0.05	0.03	0.02						2.77
168.75 191.25 S			0.85	1.67	0.26	0.21	0.14	0.07	0.05	0.04						3.30
191.25 213.75 SSW			1.10	2.07	0.29	0.19	0.11	0.07	0.04	0.03						3.90
213.75 236.25 SW			1.49	5.19	2.08	0.61	0.10	0.07	0.05	0.06		0.00				9.66
236.25 258.75 WSW			2.18	5.28	1.17	0.37	0.13	0.09	0.07	0.07	0.00					9.36
258.75 281.25 W			2.02	4.04	0.49	0.28	0.13	0.10	0.06	0.05						7.16
281.25 303.75 WNW			2.07	4.56	0.90	0.50	0.19	0.11	0.08	0.03						8.44
303.75 326.25 NW			2.49	5.40	1.72	0.63	0.14	0.11	0.09	0.08	0.01					10.66
326.25 348.75 NNW			2.70	5.77	2.79	1.89	0.92	0.68	0.50	0.22	0.04	0.04				15.55
348.75 11.25 N			0.98	2.81	2.56	2.41	1.25	0.96	0.66	0.36	0.11	0.01				12.10
Column Total (%)	0.00	0.00	20.88	46.39	14.52	8.48	3.77	2.68	1.93	1.15	0.16	0.05	0.00	0.00	0.00	

No. of Non-Flagged Records: 77254 No. of Flagged Recor 29547
Max. Tp : 11.6 s Filename: gc_waveparm_year_5min_4_JFT.dat
Mean Tp : 3.99 s
Vector-averaged Speed: 1.61 s at 312.0 deg

Table 2-12: Joint frequency table of Tp versus MWD for October to December, 2004.

Location: GrosCacouna at site GrosCacouna
Instrument: ADCP2610
For period: Oct.07,2004 15:00:00 to Dec.31,2004 23:55:00 UTC Sample Interval: 5 min

	Tp (s)															
	0 to 1	1 to 2	2 to 3	3 to 4	4 to 5	5 to 6	6 to 7	7 to 8	8 to 9	9 to 10	10 to 11	11 to 12	12 to 13	13 to 14	14 to 15	Row Total
Direction (deg)																(%)
11.25 33.75 NNE			0.95	1.44	0.34	0.11	0.04	0.03	0.01	0.01						2.92
33.75 56.25 NE			0.68	0.79	0.11	0.06	0.02	0.03	0.01	0.02						1.71
56.25 78.75 ENE			0.59	0.89	0.19	0.13	0.05	0.02	0.03							1.91
78.75 101.25 E			0.60	0.87	0.18	0.15	0.03	0.02	0.02							1.86
101.25 123.75 ESE			0.60	0.77	0.18	0.17	0.03	0.02	0.01							1.76
123.75 146.25 SE			0.49	0.86	0.10	0.07	0.04	0.01	0.01							1.57
146.25 168.75 SSE			0.63	1.08	0.18	0.13	0.04	0.01	0.01							2.08
168.75 191.25 S			0.73	1.02	0.17	0.15	0.05	0.01	0.01							2.13
191.25 213.75 SSW			0.82	1.26	0.25	0.14	0.04	0.01		0.01						2.52
213.75 236.25 SW			1.11	4.51	2.08	1.16	0.03	0.02		0.02		0.01				8.93
236.25 258.75 WSW			1.87	5.40	1.55	0.65	0.07	0.05	0.05	0.05	0.01					9.71
258.75 281.25 W			1.94	3.95	0.34	0.26	0.07	0.05	0.01	0.02						6.65
281.25 303.75 WNW			2.72	5.56	1.43	0.68	0.08	0.05	0.03	0.01						10.57
303.75 326.25 NW			3.40	6.85	2.36	0.50	0.08	0.06	0.06	0.07	0.04					13.42
326.25 348.75 NNW			4.22	7.81	3.03	1.96	1.15	0.52	0.59	0.50	0.17	0.15				20.10
348.75 11.25 N			1.88	3.65	1.73	1.97	1.00	0.55	0.83	0.29	0.23	0.03				12.16
Column Total (%)	0.00	0.00	23.21	46.70	14.21	8.31	2.83	1.44	1.67	0.99	0.44	0.19	0.00	0.00	0.00	

No. of Non-Flagged Records: 18710 No. of Flagged Recor(5878
Max. Tp : 11.6 s Filename: gc_waveparm_year_5min_4_JFT.dat
Mean Tp : 3.91 s
Vector-averaged Speed: 2.08 s at 312.1 deg

Table 2-13: Joint frequency table of Tp versus MWD for January to March, 2005.

Location: GrosCacouna at site GrosCacouna
Instrument: ADCP2610
For period: Jan.01,2005 00:00:00 to Mar.31,2005 23:55:00 UTC Sample Interval: 5 min

	Tp (s)															
	0 to 1	1 to 2	2 to 3	3 to 4	4 to 5	5 to 6	6 to 7	7 to 8	8 to 9	9 to 10	10 to 11	11 to 12	12 to 13	13 to 14	14 to 15	Row Total
Direction (deg)																(%)
11.25 33.75 NNE			0.15	1.15	0.42	0.20	0.15	0.10	0.02							2.19
33.75 56.25 NE			0.10	0.32	0.15	0.20	0.15	0.10	0.02							1.05
56.25 78.75 ENE			0.15	0.35	0.25	0.20	0.25	0.07	0.02							1.29
78.75 101.25 E			0.07	0.30	0.30	0.22	0.25	0.12	0.05							1.32
101.25 123.75 ESE			0.15	0.30	0.25	0.15	0.27	0.05	0.02							1.20
123.75 146.25 SE			0.12	0.30	0.30	0.10	0.25	0.05	0.02							1.15
146.25 168.75 SSE			0.15	0.35	0.32	0.15	0.22	0.05	0.02							1.27
168.75 191.25 S			0.10	0.35	0.25	0.20	0.22	0.02	0.02							1.17
191.25 213.75 SSW			0.70	0.65	0.30	0.17	0.22	0.02	0.02							2.09
213.75 236.25 SW			0.42	3.26	0.90	0.25	0.25	0.02	0.07	0.07						5.25
236.25 258.75 WSW			0.95	3.49	1.12	0.35	0.32	0.12	0.07							6.42
258.75 281.25 W			0.72	2.49	1.52	0.40	0.27	0.02	0.05							5.48
281.25 303.75 WNW			0.62	5.08	1.99	2.56	0.45	0.02	0.02							10.76
303.75 326.25 NW			2.81	14.54	11.58	5.30	0.25	0.02	0.02							34.54
326.25 348.75 NNW			0.85	4.88	3.56	2.74	1.17	1.37	1.44	0.17						16.19
348.75 11.25 N			0.25	1.44	1.57	2.84	1.57	0.62	0.35							8.64
Column Total (%)	0.00	0.00	8.32	39.24	24.78	16.04	6.27	2.81	2.29	0.25	0.00	0.00	0.00	0.00	0.00	

No. of Non-Flagged Records: 4016 No. of Flagged Recor(21904
Max. Tp : 9.8 s Filename: gc_waveparm_year_5min_4_JFT.dat
Mean Tp : 4.43 s
Vector-averaged Speed: 2.95 s at 314.9 deg

Table 2-14: Joint frequency table of Tp versus MWD for April to June, 2005.

Location: GrosCacouna at site GrosCacouna
Instrument: ADCP2610
For period: Apr.01,2005 00:00:00 to Jun.30,2005 23:55:00 UTC Sample Interval: 5 min

	Tp (s)															
	0 to 1	1 to 2	2 to 3	3 to 4	4 to 5	5 to 6	6 to 7	7 to 8	8 to 9	9 to 10	10 to 11	11 to 12	12 to 13	13 to 14	14 to 15	Row Total
Direction (deg)																(%)
11.25 33.75 NNE			0.86	2.20	1.62	0.73	0.15	0.08	0.08	0.04						5.75
33.75 56.25 NE			0.63	1.00	0.41	0.29	0.10	0.08	0.04	0.02						2.58
56.25 78.75 ENE			0.55	0.92	0.36	0.28	0.10	0.09	0.04	0.02						2.35
78.75 101.25 E			0.47	0.96	0.38	0.37	0.15	0.08	0.06	0.05						2.52
101.25 123.75 ESE			0.50	0.97	0.35	0.29	0.14	0.10	0.04	0.02						2.42
123.75 146.25 SE			0.51	0.92	0.36	0.29	0.15	0.06	0.04	0.02						2.35
146.25 168.75 SSE			0.49	1.03	0.37	0.30	0.11	0.07	0.04	0.02						2.43
168.75 191.25 S			0.58	1.30	0.40	0.29	0.17	0.07	0.04	0.02						2.88
191.25 213.75 SSW			0.83	1.84	0.43	0.25	0.13	0.08	0.04	0.02						3.62
213.75 236.25 SW			1.41	5.15	2.56	0.40	0.17	0.09	0.03	0.06						9.88
236.25 258.75 WSW			1.68	4.55	1.33	0.32	0.14	0.11	0.05	0.06						8.25
258.75 281.25 W			1.29	2.56	0.52	0.36	0.17	0.11	0.07	0.05						5.15
281.25 303.75 WNW			1.40	3.34	0.57	0.31	0.19	0.13	0.11	0.04						6.08
303.75 326.25 NW			1.66	3.95	0.95	0.38	0.14	0.11	0.08	0.08	0.01					7.35
326.25 348.75 NNW			2.20	5.48	3.69	2.91	1.17	0.91	0.51	0.19	0.01					17.07
348.75 11.25 N			0.81	3.44	4.65	4.42	2.34	1.70	0.99	0.83	0.16					19.33
Column Total (%)	0.00	0.00	15.85	39.60	18.96	12.19	5.52	3.88	2.27	1.55	0.17	0.00	0.00	0.00	0.00	

No. of Non-Flagged Records: 24764 No. of Flagged Recor 1444
Max. Tp : 10.6 s Filename: gc_waveparm_year_5min_4_JFT.dat
Mean Tp : 4.29 s
Vector-averaged Speed: 1.84 s at 328.8 deg

Table 2-15: Joint frequency table of Tp versus MWD for June to September, 2005.

Location: GrosCacouna at site GrosCacouna
Instrument: ADCP2610
For period: Jul.01,2005 00:00:00 to Sep.30,2005 23:55:00 UTC Sample Interval: 5 min

	Tp (s)															
	0 to 1	1 to 2	2 to 3	3 to 4	4 to 5	5 to 6	6 to 7	7 to 8	8 to 9	9 to 10	10 to 11	11 to 12	12 to 13	13 to 14	14 to 15	Row Total
Direction (deg)																(%)
11.25 33.75 NNE			0.85	1.90	0.39	0.16	0.04	0.07	0.07	0.09						3.58
33.75 56.25 NE			1.10	1.74	0.23	0.16	0.11	0.08	0.08	0.10						3.60
56.25 78.75 ENE			1.06	1.94	0.24	0.09	0.09	0.09	0.10	0.05						3.67
78.75 101.25 E			0.94	2.18	0.19	0.08	0.06	0.07	0.13	0.05						3.71
101.25 123.75 ESE			0.97	2.08	0.18	0.10	0.06	0.08	0.06	0.06						3.58
123.75 146.25 SE			1.00	2.16	0.13	0.10	0.08	0.07	0.04	0.04						3.63
146.25 168.75 SSE			1.00	2.26	0.21	0.11	0.10	0.05	0.05	0.04						3.82
168.75 191.25 S			1.37	2.62	0.21	0.18	0.16	0.12	0.11	0.09						4.85
191.25 213.75 SSW			1.70	3.17	0.21	0.16	0.11	0.10	0.07	0.06						5.58
213.75 236.25 SW			2.09	6.21	1.48	0.40	0.10	0.10	0.09	0.10						10.56
236.25 258.75 WSW			3.25	6.13	0.76	0.16	0.13	0.10	0.11	0.11						10.75
258.75 281.25 W			3.07	5.63	0.42	0.20	0.10	0.13	0.09	0.07						9.72
281.25 303.75 WNW			2.48	5.08	0.77	0.26	0.24	0.13	0.12	0.04						9.12
303.75 326.25 NW			2.79	4.53	0.59	0.26	0.17	0.17	0.13	0.10						8.76
326.25 348.75 NNW			2.25	4.16	1.55	0.71	0.42	0.49	0.34	0.09						10.02
348.75 11.25 N			0.59	1.58	1.05	0.55	0.26	0.63	0.32	0.07						5.05
Column Total (%)	0.00	0.00	26.52	53.39	8.61	3.69	2.24	2.48	1.92	1.15	0.00	0.00	0.00	0.00	0.00	

No. of Non-Flagged Records: 26198 No. of Flagged Recor 298
Max. Tp : 9.8 s Filename: gc_waveparm_year_5min_4_JFT.dat
Mean Tp : 3.7 s
Vector-averaged Speed: 1.07 s at 281.0 deg

Significant Wave Height (Hs) versus Peak Period (Tp):

The joint bivariate distribution of significant wave height (Hs) vs. peak period (Tp) is presented in Table 2-16 for the full year of observations and for each season in Tables 2-17, 2-18, 2-19 and 2-20. Monthly tabulations of the joint bivariate distribution are given in Appendix B.2. The distribution of Hs vs. Tp shows the expected pattern where the most frequent occurrences of peak periods tend to increase as the wave heights increase. At Hs values of < 1m, the most frequent peak periods are < 5 s. For Hs values of 1 to 1.6 m, the most frequent peak periods are in the 5-6 s range, and for Hs values of 1.6-1.8 and 1.8-2.0 n, the most frequent peak period classes increase to 7-8 and 10-11 s respectively.

Table 2-16: Joint frequency table of Hs versus Tp between October 2004 and October 2005.

Location: GrosCacouna at site GrosCacouna
Instrument: ADCP2610
For period: Oct.07,2004 15:00:00 to Oct.13,2005 11:00:00 UTC Sample Interval: 5 min

		Hs (m)																
Tp (s)		0 to 0.2	0.2 to 0.4	0.4 to 0.6	0.6 to 0.8	0.8 to 1	1 to 1.2	1.2 to 1.4	1.4 to 1.6	1.6 to 1.8	1.8 to 2	2 to 2.2	2.2 to 2.4	2.4 to 2.6	2.6 to 2.8	2.8 to 3	3 to 3.2	Row Total (%)
0	1																	0.00
1	2																	0.00
2	3	18.78	1.89	0.14	0.05		0.01	0.01										20.88
3	4	31.47	10.18	3.52	1.00	0.20	0.01	0.00										46.39
4	5	5.06	3.93	2.89	1.44	0.78	0.22	0.18	0.01	0.01								14.52
5	6	3.44	1.86	1.29	0.75	0.53	0.31	0.22	0.05	0.02	0.00							8.48
6	7	1.61	0.87	0.37	0.45	0.25	0.13	0.06	0.01	0.02								3.77
7	8	1.09	0.45	0.20	0.34	0.28	0.17	0.07	0.04	0.03	0.01							2.68
8	9	1.07	0.21	0.08	0.17	0.15	0.09	0.12	0.03	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	1.93
9	10	0.74	0.12	0.06	0.03	0.07	0.06	0.02	0.02	0.01	0.01	0.00	0.00	0.00				1.15
10	11	0.04	0.01	0.02	0.02	0.03	0.02		0.00	0.01	0.02							0.16
11	12		0.00			0.01	0.01	0.00	0.00	0.02	0.00							0.05
Column Total (%)		63.3	19.54	8.55	4.25	2.29	1.02	0.68	0.17	0.12	0.04	0.01	0.01	0.01	0.01	0.01	0	

No. of Non-Flagged Rec 77254 No. of Flagged Records 29547
Max. Hs : 3.04 m Filename: gc_waveparm_year_5min_4_JFT.dat
Mean Hs : 0.24 m

Table 2-17: Joint frequency table of Hs versus Tp between October and December 2004.

Location: GrosCacouna at site GrosCacouna
Instrument: ADCP2610
For period: Oct.07,2004 15:00:00 to Dec.31,2004 23:55:00 UTC Sample Interval: 5 min

		Hs (m)																
		0 to 0.2	0.2 to 0.4	0.4 to 0.6	0.6 to 0.8	0.8 to 1	1 to 1.2	1.2 to 1.4	1.4 to 1.6	1.6 to 1.8	1.8 to 2	2 to 2.2	2.2 to 2.4	2.4 to 2.6	2.6 to 2.8	2.8 to 3	3 to 3.2	Row Total (%)
Tp (s)																		
0	1																	0.00
1	2																	0.00
2	3	19.85	2.93	0.43	0.01													23.21
3	4	22.45	14.75	7.11	2.18	0.22												46.70
4	5	3.38	3.70	3.34	2.17	1.11	0.34	0.17										14.21
5	6	2.39	2.02	1.53	0.87	0.50	0.51	0.33	0.11	0.05								8.31
6	7	1.12	0.97	0.21	0.32	0.16	0.02	0.03		0.01								2.83
7	8	0.64	0.25	0.14	0.27	0.09	0.03	0.03										1.44
8	9	0.84	0.17	0.10	0.06	0.09	0.07	0.19	0.03		0.01	0.01	0.02	0.01	0.03	0.03	0.01	1.67
9	10	0.28	0.09	0.10	0.10	0.05	0.12	0.05	0.10	0.03	0.03	0.02	0.02	0.02				0.99
10	11	0.06	0.05		0.01	0.11	0.09		0.01	0.05	0.07							0.44
11	12		0.01			0.04	0.02	0.02	0.01	0.08	0.01							0.19
Column Total (%)		51.00	24.94	12.96	5.98	2.37	1.19	0.81	0.26	0.22	0.12	0.03	0.03	0.03	0.03	0.03	0.01	

No. of Non-Flagged Rec 18710 No. of Flagged Records 5878
Max. Hs : 3.04 m Filename: gc_waveparm_year_5min_4_JFT.dat
Mean Hs : 0.29 m

Table 2-18: Joint frequency table of Hs versus Tp between January and March 2005.

Location: GrosCacouna at site GrosCacouna
Instrument: ADCP2610
For period: Jan.01,2005 00:00:00 to Mar.31,2005 23:55:00 UTC Sample Interval: 5 min

		Hs (m)																
		0 to 0.2	0.2 to 0.4	0.4 to 0.6	0.6 to 0.8	0.8 to 1	1 to 1.2	1.2 to 1.4	1.4 to 1.6	1.6 to 1.8	1.8 to 2	2 to 2.2	2.2 to 2.4	2.4 to 2.6	2.6 to 2.8	2.8 to 3	3 to 3.2	Row Total (%)
Tp (s)																		
0	1																	0.00
1	2																	0.00
2	3	3.31	3.96	0.12	0.92													8.32
3	4	7.50	15.06	10.71	4.31	1.62	0.05											39.24
4	5	2.61	5.48	4.18	3.88	5.13	1.44	2.04										24.78
5	6	1.57	5.48	2.94	1.54	2.12	0.85	1.54										16.04
6	7	0.42	2.49	1.99	0.70	0.40		0.27										6.27
7	8	0.27	0.65	0.17	0.20	0.85	0.52	0.15										2.81
8	9	0.55			0.32	0.55	0.32	0.55										2.29
9	10	0.17						0.07										0.25
10	11																	
11	12																	
Column Total (%)		16.41	33.12	20.12	11.88	10.66	3.19	4.63	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	

No. of Non-Flagged Rec 4016 No. of Flagged Records 21904
Max. Hs : 1.39 m Filename: gc_waveparm_year_5min_4_JFT.dat
Mean Hs : 0.49 m

Table 2-19: Joint frequency table of Hs versus Tp between April and June 2005.

Location: GrosCacouna at site GrosCacouna
Instrument: ADCP2610
For period: Apr.01,2005 00:00:00 to Jun.30,2005 23:55:00 UTC Sample Interval: 5 min

		Hs (m)																
		0 to 0.2	0.2 to 0.4	0.4 to 0.6	0.6 to 0.8	0.8 to 1	1 to 1.2	1.2 to 1.4	1.4 to 1.6	1.6 to 1.8	1.8 to 2	2 to 2.2	2.2 to 2.4	2.4 to 2.6	2.6 to 2.8	2.8 to 3	3 to 3.2	Row Total (%)
Tp (s)																		
0	1																	0.00
1	2																	0.00
2	3	14.29	1.48	0.04			0.02	0.02										15.85
3	4	25.63	10.64	2.73	0.44	0.10	0.03	0.01										39.60
4	5	6.17	6.53	4.47	1.25	0.41	0.10	0.02										18.96
5	6	4.95	2.65	2.03	1.20	0.73	0.38	0.14	0.06	0.03	0.01							12.19
6	7	1.56	1.26	0.61	0.91	0.59	0.38	0.13	0.02	0.06								5.52
7	8	0.95	0.64	0.33	0.70	0.64	0.38	0.08	0.09	0.05	0.02							3.88
8	9	0.96	0.20	0.11	0.34	0.29	0.17	0.15	0.07	0.00								2.27
9	10	0.88	0.25	0.10	0.03	0.18	0.09	0.01	0.00									1.55
10	11	0.07		0.05	0.05													0.17
11	12																	
Column Total (%)		55.48	23.64	10.49	4.92	2.95	1.55	0.55	0.25	0.14	0.03	0.00	0.00	0.00	0.00	0.00	0.00	

No. of Non-Flagged Rec 24764 No. of Flagged Records 1444
Max. Hs : 1.92 m Filename: gc_waveparm_year_5min_4_JFT.dat
Mean Hs : 0.27 m

Table 2-20: Joint frequency table of Hs versus Tp between July and September 2005.

Location: GrosCacouna at site GrosCacouna
Instrument: ADCP2610
For period: Jul.01,2005 00:00:00 to Sep.30,2005 23:55:00 UTC Sample Interval: 5 min

		Hs (m)																
		0 to 0.2	0.2 to 0.4	0.4 to 0.6	0.6 to 0.8	0.8 to 1	1 to 1.2	1.2 to 1.4	1.4 to 1.6	1.6 to 1.8	1.8 to 2	2 to 2.2	2.2 to 2.4	2.4 to 2.6	2.6 to 2.8	2.8 to 3	3 to 3.2	Row Total (%)
Tp (s)																		
0	1																	0.00
1	2																	0.00
2	3	25.41	1.06	0.04														26.52
3	4	46.77	5.52	0.71	0.29	0.10												53.39
4	5	5.66	1.13	0.54	0.73	0.32	0.09	0.08	0.03	0.03								8.61
5	6	3.00	0.26	0.05	0.08	0.18	0.08	0.04										3.69
6	7	2.11	0.03	0.01	0.08			0.00	0.01									2.24
7	8	1.73	0.34	0.08	0.11	0.03	0.03	0.08	0.03	0.03								2.48
8	9	1.50	0.25	0.04	0.09	0.02	0.01		0.00									1.92
9	10	1.10	0.06															1.15
10	11																	
11	12																	
Column Total (%)		87.28	8.65	1.48	1.37	0.65	0.21	0.20	0.08	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	

No. of Non-Flagged Rec 26198 No. of Flagged Records 298
Max. Hs : 1.79 m Filename: gc_waveparm_year_5min_4_JFT.dat
Mean Hs : 0.13 m

2.3 Monthly Statistical Results

Statistical summaries of the spectral wave parameters are presented in Table 2-21 (significant wave height), Table 2-22 (peak period), Table 2-23 (peak Direction) and Table 2-24 (mean wave direction. Selected wave spectral statistics are plotted by month in Figure 2-8.

Table 2-21: Monthly statistics of the significant wave height.

Hs	min	mean	50%	75%	95%	99%	std	max	# valid	total
Oct-04	0.06	0.17	0.12	0.21	0.44	0.68	0.13	0.91	7020	7020
Nov-04	0.06	0.29	0.23	0.41	0.68	0.85	0.19	1.00	6990	8640
Dec-04	0.06	0.48	0.35	0.65	1.24	1.81	0.40	3.04	4700	8928
Jan-05	0.05	0.61	0.55	0.88	1.32	1.38	0.39	1.39	1038	8928
Feb-05	0.05	0.42	0.40	0.61	0.83	0.93	0.23	0.97	552	8064
Mar-05	0.06	0.45	0.39	0.59	1.00	1.30	0.28	1.38	2426	8928
Apr-05	0.05	0.37	0.26	0.52	1.03	1.37	0.31	1.92	7196	8640
May-05	0.05	0.26	0.16	0.33	0.83	1.16	0.26	1.86	8928	8928
Jun-05	0.04	0.19	0.12	0.25	0.50	0.62	0.14	0.83	8640	8640
Jul-05	0.05	0.09	0.08	0.09	0.15	0.25	0.04	0.39	8628	8927
Aug-05	0.04	0.11	0.08	0.10	0.28	0.41	0.09	1.68	8928	8928
Sep-05	0.05	0.19	0.10	0.22	0.71	1.18	0.23	1.79	8640	8640
Oct-05	0.05	0.22	0.16	0.31	0.53	0.70	0.16	0.75	3589	3589

Table 2-22: Monthly statistics of the peak period (Tp) when the significant wave height exceeded 30 cm.

Tp (Hs>0.3m)	min	mean	50%	75%	95%	99%	std	max	# valid	total
Oct, 2004	2.8	4.4	4.0	5.2	7.3	8.8	1.4	9.7	961	7019
Nov, 2004	2.8	4.0	3.8	4.4	5.7	6.8	0.8	7.5	2703	8640
Dec, 2004	2.9	5.1	4.6	5.3	9.8	11.1	2.0	11.6	2654	8928
Jan, 2005	2.9	4.3	4.3	4.9	5.2	5.5	0.6	6.0	656	8927
Feb, 2005	2.9	4.0	3.9	4.4	6.0	6.3	0.8	6.4	355	8064
Mar, 2005	2.9	4.9	4.6	5.8	7.9	8.6	1.4	9.1	1537	8928
Apr, 2005	2.0	5.6	5.3	7.0	8.9	9.8	1.8	10.6	3226	8639
May, 2005	2.9	5.1	5.0	5.8	7.5	8.5	1.3	9.8	2432	8928
Jun, 2005	2.9	4.3	4.2	4.7	6.0	6.5	0.8	6.7	1702	8640
Jul, 2005	2.9	4.1	3.4	3.5	9.2	9.3	2.1	9.3	45	8927
Aug, 2005	2.9	4.3	4.3	4.8	5.5	6.4	0.8	7.3	366	8928
Sep, 2005	2.6	4.5	4.0	4.9	7.8	8.0	1.4	8.5	1404	8640
Oct, 2005	2.9	4.6	4.5	5.1	6.7	7.5	1.1	7.5	933	946

Table 2-23: Monthly statistics of the peak direction (Dp) when the significant wave height exceeded 30 cm.

Dp (Hs>0.3m)	min	mean	50%	75%	95%	99%	std	max	# valid	total
Oct, 2004	0.0	226.2	241.0	322.3	351.2	355.9	106.3	358.0	961	7019
Nov, 2004	0.0	265.6	288.9	311.3	348.9	356.3	70.0	360.0	2703	8640
Dec, 2004	0.0	285.5	306.9	332.0	349.3	355.0	63.8	358.0	2654	8928
Jan, 2005	1.0	298.9	309.1	324.7	340.3	352.0	51.7	359.0	656	8927
Feb, 2005	14.0	265.9	311.8	321.8	339.1	342.6	95.2	359.0	355	8064
Mar, 2005	0.0	266.5	299.6	325.5	350.7	356.6	96.5	359.0	1537	8928
Apr, 2005	0.0	230.5	278.2	343.7	356.0	357.8	126.8	359.0	3226	8639
May, 2005	0.2	226.5	292.2	341.6	354.8	358.6	130.3	359.8	2432	8928
Jun, 2005	0.0	207.9	229.6	252.4	352.5	358.1	100.6	360.0	1702	8640
Jul, 2005	201.9	274.0	258.0	311.1	349.1	352.6	43.4	352.6	45	8927
Aug, 2005	4.0	246.4	296.5	347.0	358.0	359.0	114.4	359.0	366	8928
Sep, 2005	1.0	251.7	240.8	278.0	353.7	357.0	66.9	360.0	1392	8640
Oct, 2005	3.0	228.0	238.0	340.0	354.8	358.3	111.8	360.0	933	946

Table 2-24: Monthly statistics of the vector average mean wave direction (MWD) when the significant wave height exceeded 30 cm.

MWD (Hs>0.3m)	min	mean	50%	75%	95%	99%	std	max	# valid	total
Oct, 2004	0.0	265.5	267.0	341.1	354.9	356.6	93.8	360.0	961	7019
Nov, 2004	0.8	279.6	293.9	324.4	351.5	356.8	63.4	359.9	2703	8640
Dec, 2004	0.6	295.3	312.3	338.7	352.4	357.5	60.7	359.4	2654	8928
Jan, 2005	8.1	308.1	314.6	321.7	334.8	348.1	39.2	355.6	656	8927
Feb, 2005	3.8	287.8	316.7	326.5	348.0	355.7	79.1	359.7	355	8064
Mar, 2005	0.4	287.6	310.3	330.3	353.2	356.5	76.5	358.6	1537	8928
Apr, 2005	0.3	254.4	321.1	349.8	356.7	358.9	125.3	359.9	3226	8639
May, 2005	0.3	244.7	320.2	348.3	356.4	358.1	130.5	359.7	2432	8928
Jun, 2005	0.6	238.1	235.3	332.1	355.4	358.1	93.6	359.2	1702	8640
Jul, 2005	194.0	274.8	264.9	322.3	343.9	347.9	49.2	347.9	45	8927
Aug, 2005	0.6	305.1	344.7	351.1	356.9	358.7	71.5	359.6	366	8928
Sep, 2005	196.9	266.7	238.9	340.5	353.5	356.5	52.7	358.7	1392	8640
Oct, 2005	0.5	265.0	264.2	348.6	355.2	357.7	98.8	359.9	933	946

The Hs results for the 50% (median) and 75% percentile levels demonstrate the considerable seasonal cycle in wave heights at Gros Cacouna with the largest waves present in December and January, and following somewhat reduced wave activity in February, larger waves are present in March and April. The wave heights are much reduced in June, July and most of August followed by increased wave heights in September and October. The somewhat reduced wave heights of February may reflect the presence of extensive quantities of sea ice.

The very largest waves (the 99 percentile levels and maximum) follow a seasonal pattern that is somewhat more complicated than those of the 50 and 75 percentile levels. The very largest Hs value measured of 3.04 m, in December, as well as the early September value measured Hs value of 1.74 m, are both very unusual events in that the 99 percentile level for these months are much lower. To a lesser degree April, May and September also have maximum Hs values that are considerably larger than the 99 percentile values.

A closer examination of the time series of the particular wave events (having a duration of 1 to 2 days) in which these maximum Hs values were measured, reveal a high degree of variation from one sampling period to the next at time intervals of one hour (or 90 minutes in the second deployment period from late November to late April). The 20 minute measurement interval, in which the unusually large Hs value occurred, was characterized by an Hs value that was 30 to 50% greater than the measurements in the before and after sampling periods. In all of the cases of the very large Hs measurements, the wave spectra appeared to be reasonable and were consistent among the multiple sensors used to measure wave spectra; orbital wave velocity, surface tracking and bottom pressures (except for the December 2004 case in which the surface tracking mode provided unrealistic wave spectra). The source regions from which waves can originate at Gros Cacouna include up-river locations from the west, down-river locations from the east including the Gulf of St. Lawrence and from within the local regions including Isle Rouge to the north across the River near the Saguenay River delta (see Figure 1-2). The rapidly changing wave conditions within a major wave event may reflect the interaction between the waves arriving from different source regions due to a single weather system or a multiple set of weather disturbances. This type of process is consistent with the multi-model directional wave spectra realized in the 20 minute measurement burst data on December 11, 2004 which had the largest wave recorded of 3.04 m (see Figure 2-9).

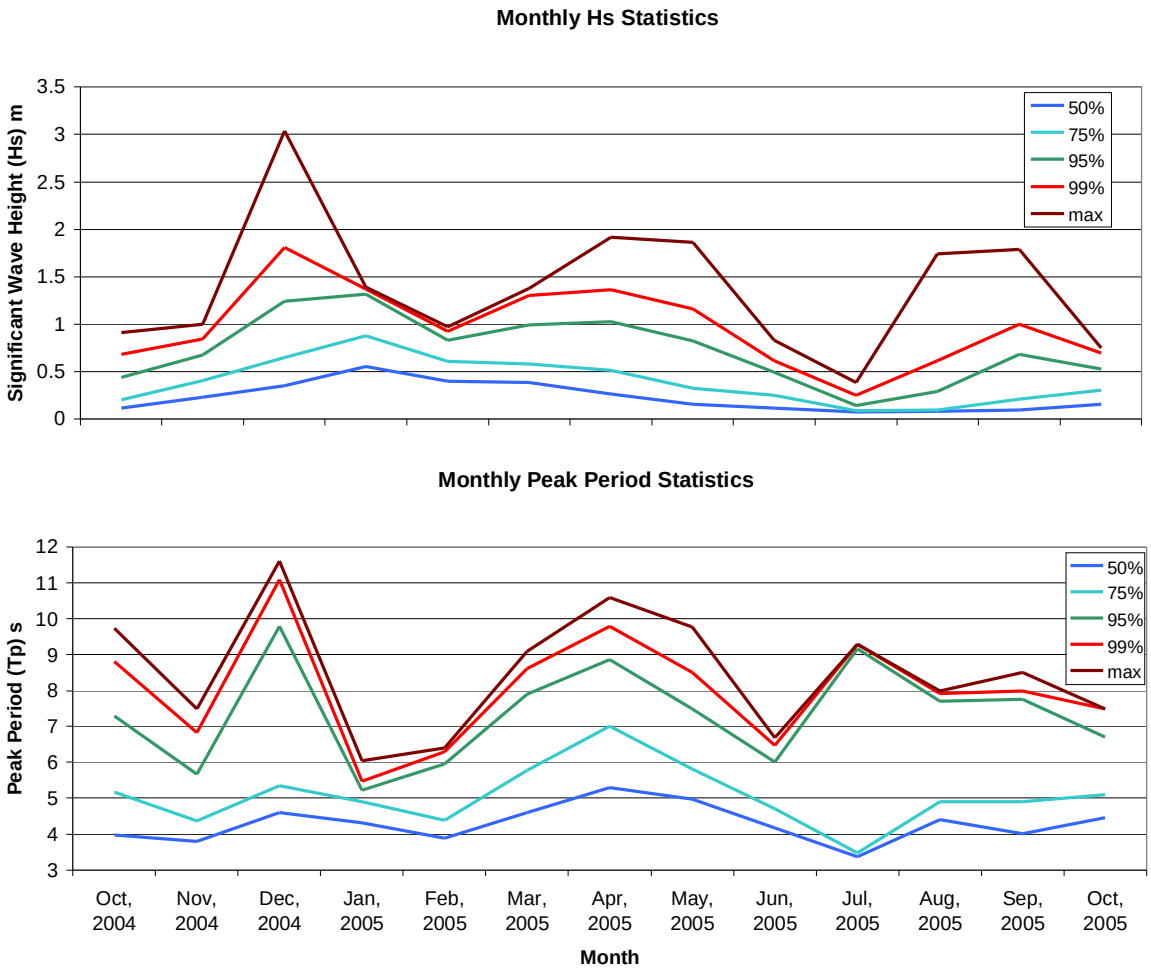

Figure 2-8: Monthly statistics of the significant wave height and peak period for those measurements in which the significant wave height exceeds 30 cm.

The statistics of the monthly peak periods (Figure 2-8) tend to follow those of monthly Hs due to the larger Hs values being associated with larger peak periods in the wave spectra, as would be expected in the wave generation process. The longer wave periods in both January and February are reduced considerably by comparison to adjoining months. This reduction to maximum wave periods of just over 6 seconds may reflect the presence of sea ice either reducing wind fetch or the much reduced sample size resulting in less representative wave parameter statistics.

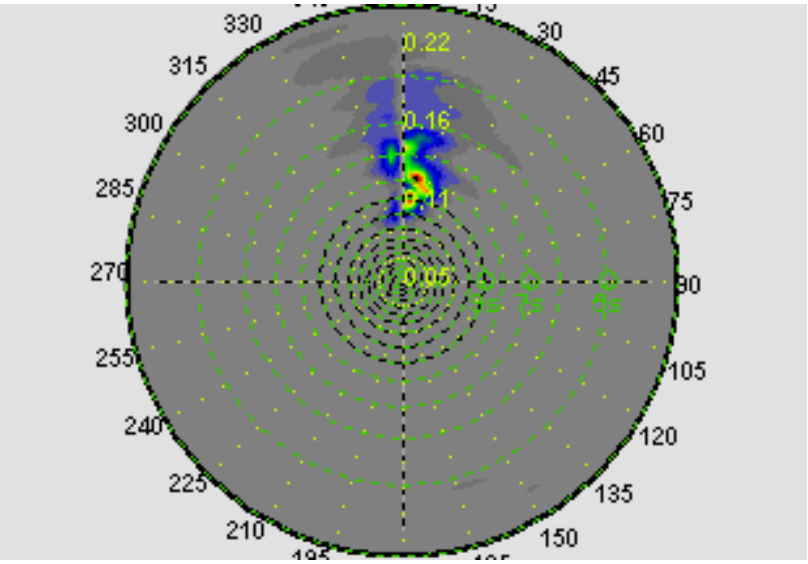

Figure 2-9: Directional wave spectra for the 19:30 Dec. 11, 2004 wave measurements having the largest measured significant wave height of 3.04 m.

2.4 Large Wind and Wave Events

Winds are important in terms of wave conditions since the local and regional winds generate the measured waves and moreover, winds also exert a loading force on vessels in addition to the wave and current loading.

Available wind data includes direct measurements of winds made for this project at Gros Cacouna. A weather station was installed on Dec. 23, 2004 and operated throughout the remainder of the oceanographic measurements. A second weather station was put into operation on May 9, 2005, located a short distance to the east of the first weather station at a site that is more representative for use in assessing wind loading on the vessels at berth. Correlation analyses of the two wind time series indicate that the winds at the original measurement site (GC1) are approximately 30% larger than those at the second site (GC2). The wind directions generally agree to within 15 degrees except for wind directions from 150 to 220 degrees where the wind directions are about 30 degrees higher than those at GC2.

Wind measurements are also available from Environment Canada at Île Rouge off the mouth of the Saguenay River. Île Rouge, located directly north of Gros Cacouna, is known to have strong winds which may contribute to the generation of waves at Gros Cacouna.

Winds associated with the 18 largest wave events (with Hs > 1.1 m) and 8 additional large wind events, so as to include all winds exceeding 30 knots (15.5 m/s), were identified and compiled (see Table 2-25). These 26 individual events were examined in some detail to quantify the magnitude and variability of waves and winds over periods of a few days around each event, and for analysis of correlations between winds and waves.

Table 2-25: Summary statistics for the 26 largest wave and wind events which includes 18 wave events with Hs exceeding 1.1 m and 8 additional wind events in which wind speeds exceeded 30 knots (15.5 m/s). The wind and wave values, exceeding 15.5 m/s and 1.1 m Hs, respectively, are highlighted in bold font.

Event Time (GMT)	Case	Hs	Tp	Dp	MWD	GC1 Spd	GC1 Dir	GC2 Spd	GC2 Dir	IR Spd	IR Dir
	Study	m	s	deg	deg	m/s	deg	m/s	deg	m/s	deg
2-Dec-04 12:00		**1.23**	**5.3**	**298**	**304**	NA	NA	NA	NA	**19.2**	**280**
5-Dec-04 12:00		**1.72**	**6.0**	**306**	**299**	NA	NA	NA	NA	**21.6**	**290**
11-Dec-04 19:30	A	**3.04**	**8.5**	**348**	**346**	NA	NA	NA	NA	**16.9**	**50**
14-Dec-04	A	0.85	4.9	333	315	NA	NA	NA	NA	**20.0**	**300**
24-Dec-04 7:30		**1.72**	**5.3**	**214**	**227**	NA	NA	NA	NA	**22.8**	**210**
28-Dec-04 0:00		**1.25**	**5.1**	**334**	**336**	NA	NA	NA	NA	**17.5**	**310**
1-Jan-05		ice	ice	ice	ice	14.3	343	NA	NA	**20.6**	**300**
11-Jan-05		0.81	4.1	302	299	15.4	335	NA	NA	**19.4**	**290**
18-Jan-05 9:00	B	**1.39**	**4.9**	**310**	**325**	**17.0**	**354**	NA	NA	**19.4**	**300**
20-Jan-05	B	ice	ice	ice	ice	14.4	353	NA	NA	**22.8**	**300**
11-Feb-05		0.71	2.9	30	16	**16.8**	**46**	NA	NA	**15.6**	**360**
2-Mar-05 0:00	C	**1.38**	**8.0**	**339**	**341**	14.2	46	NA	NA	**19.2**	**50**
3-Mar-05 13:30	C	**1.32**	**6.4**	**298**	**297**	13.0	336	NA	NA	NA	NA
9-Mar-05		0.88	5.8	276	297	**20.1**	**349**	NA	NA	**25.3**	**300**
3-Apr-05 21:00		**1.23**	**2.0**	**358**	**0**	9.0	64	NA	NA	13.9	30
24-Apr-05 21:00	D	**1.92**	**7.5**	**357**	**357**	10.0	66	NA	NA	**15.6**	**30**
27-Apr-05 22:30	D	**1.25**	**4.9**	**343**	**346**	10.9	56	NA	NA	**15.6**	**30**
29-Apr-05 12:00	D	**1.54**	**9.1**	**350**	**355**	9.7	57	NA	NA	12.8	40
12-May-05 12:00		**1.23**	**5.3**	**304**	**325**	13.7	349	12.8	347	13.9	300
22-May-05 19:00	E	**1.86**	**5.8**	**357**	**353**	12.3	64	6.5	50	13.9	50
27-May-05 13:00	E	**1.12**	**6.7**	**355**	**354**	10.5	56	5.3	52	12.8	30
20-Jun-05		0.71	3.7	240	232	11.5	237	9.3	235	**16.4**	**210**
26-Jun-05		0.1	2.9	228	220	3.9	240	2.3	49	**17.5**	**310**
1-Sep-05 0:00	F	**1.74**	**7.5**	**359**	**353**	11.7	65	8.7	48	**16.9**	**30**
12-Sep-05 2:00		**1.18**	**4.9**	**202**	**217**	13.3	234	11.2	233	**16.4**	**210**
30-Sep-05 0:00	G	**1.79**	**4.9**	**259**	**238**	**20.3**	**235**	**17.7**	**230**	**22.8**	**210**

The winds measured at Île Rouge and Gros Cacouna differ significantly, with wind speeds at Île Rouge being about 25% higher than those at the GC1 measurement site for large wind events. Since GC1 winds are 30% greater than those at GC2 near the berth site, the large wind events at Île Rouge are considerably higher, by about 60% on average, than those at GC2.

Of the 26 large events, a total of seven cases have been selected to present the wave and wind speeds and directions each over a duration of approximately six days. The wind and wave data for each of these case studies are plotted in Figures 2-10 to 2-16 inclusive, which include 13 of the 26 individual largest wave-wind events. Note that in the plots, the values of significant wave height are multiplied by 10 and the winds at Gros Cacouna are represented by the measurements at GC2, or when these wind measurements are not available, by the GC1 winds divided by 1.3 to simulate GC2 winds.

The plots for each case study reveal that the wind and wave time series exhibit a rough correspondence with episodes of both increasing and decreasing within a few to several hours of one another. However, as can be seen from Table 2-25, there is no consistent relationship between the peak values of wave height and the peak wind speed in the wave/wind events. Significant wave heights of 1 – 2 m are associated with peak wind speeds of 12.5 to 25 m/s at Île Rouge and with peak wind speeds of 7 to 16 m/s at the weather station nearest the terminal site (GC2).

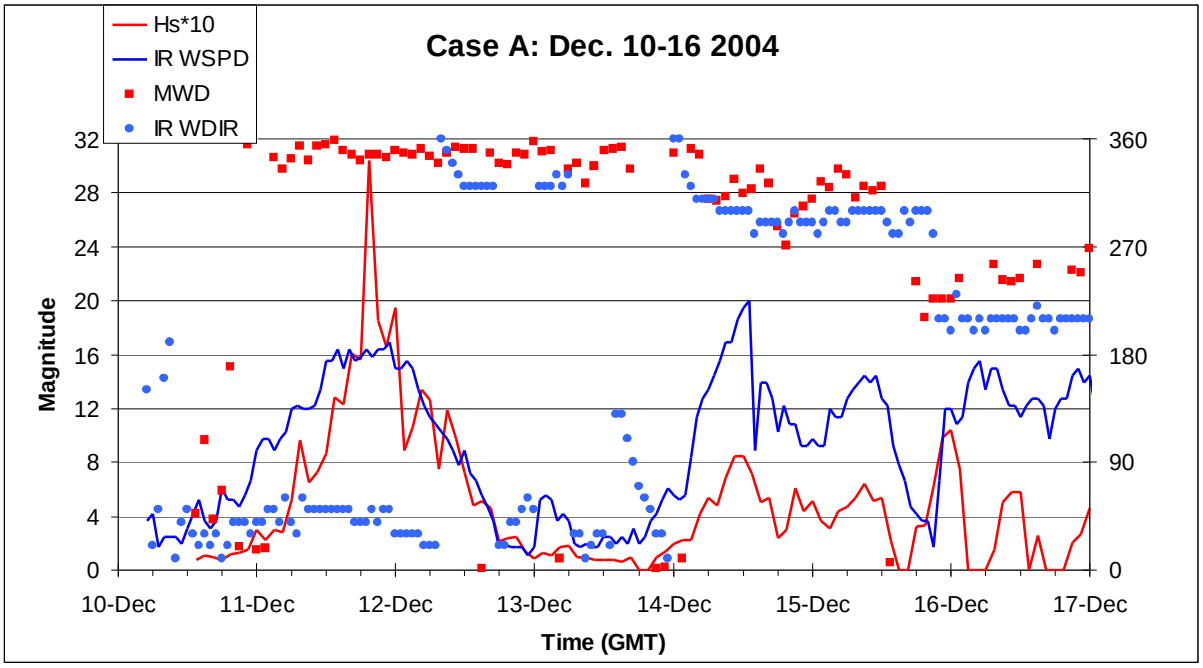

Figure 2-10: Wind and waves measurements during case study A of Dec. 10-16, 2004 which includes the largest wave event of Dec. 11, 2004 with Hs of 3.04 m.

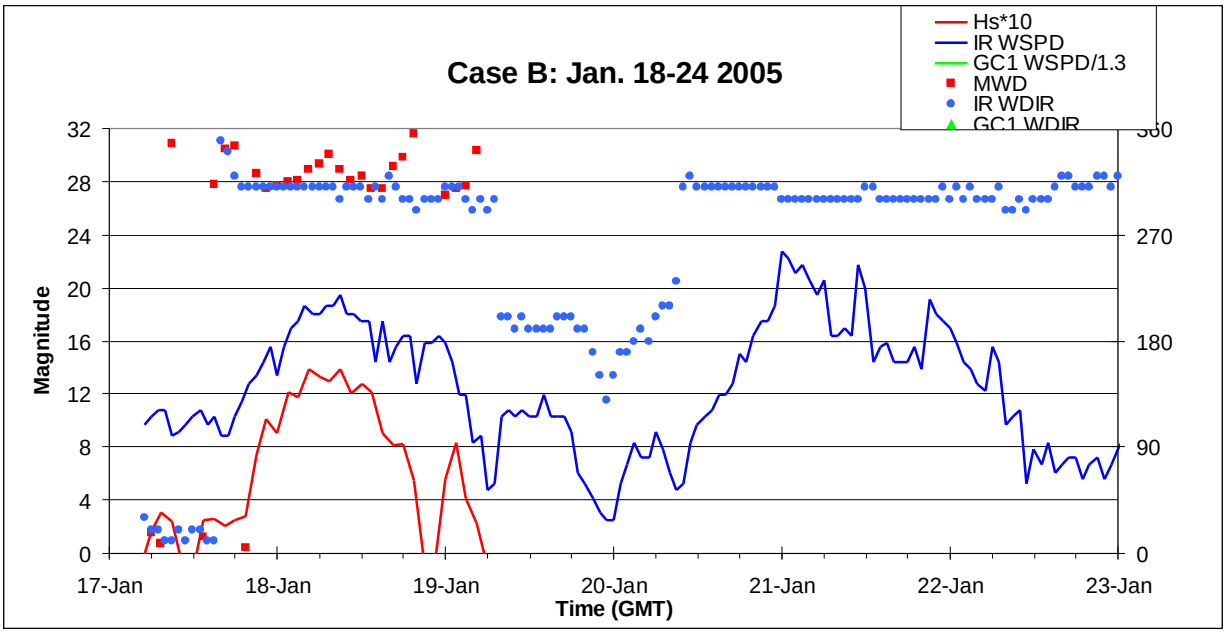

Figure 2-11: Wind and waves measurements during case study B of Jan. 18-24, 2005 which includes the large wave event of Jan. 18 with Hs of 1.39 m and two large wind events at Île Rouge of 19.4 m/s (Jan. 18) and 22.8 m/s (Jan. 20). Note that ice is presented in parts of this measurement period, as indicated when wave results are not shown.

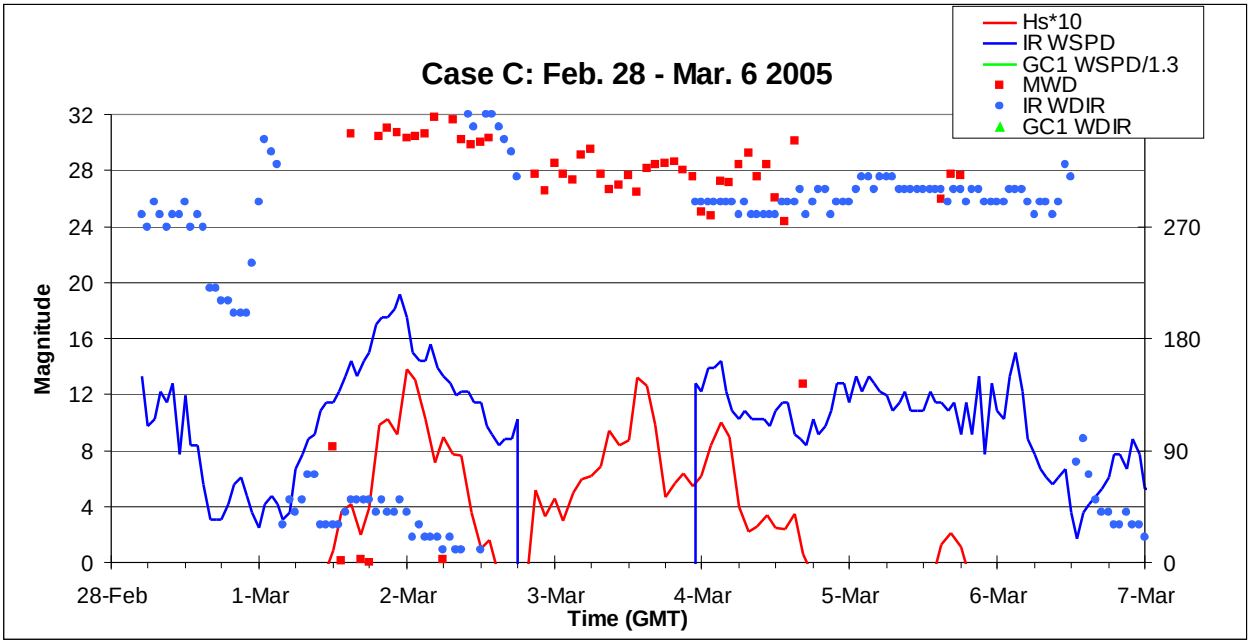

Figure 2-12: Wind and waves measurements during case study C of Feb. 28 – Mar. 6, 2005 which includes two large wave events of March 2 and March 3 with Hs of 1.38 m and 1.32 m, respectively.

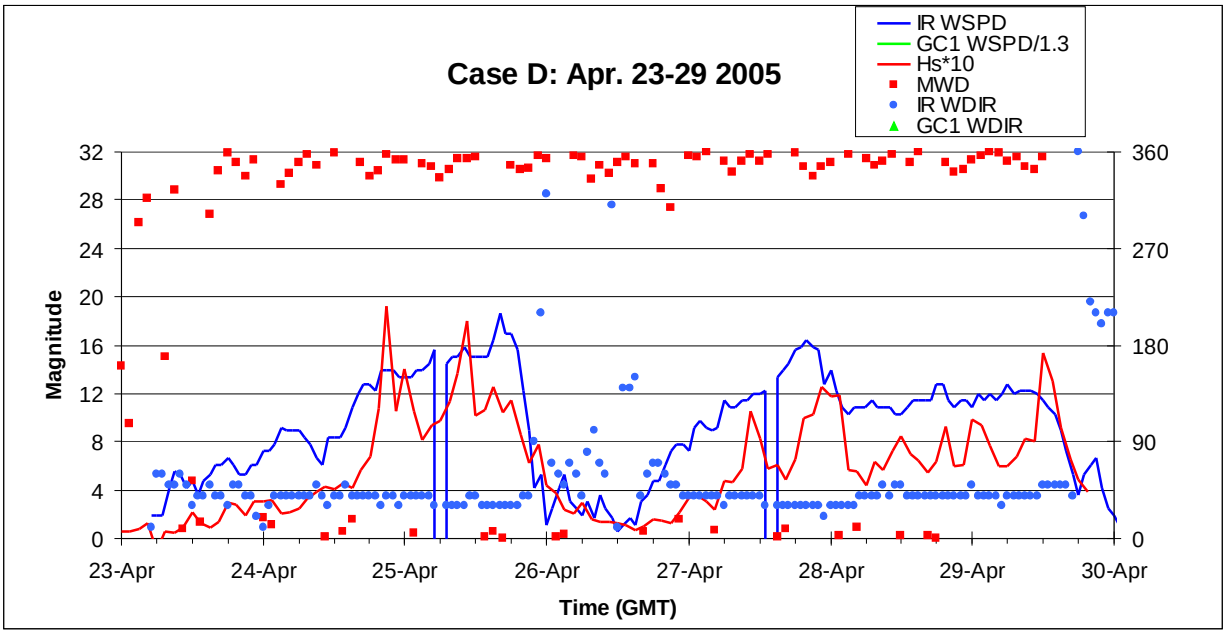

Figure 2-13: Wind and waves measurements during case study D of April 23-29, 2005 which includes three large wave events of April 24, April 27 and April 29 with Hs of 1.92 m, 1.25 m and 1.54 m respectively. The first event in this case is the second largest wave episode measured in this one year study.

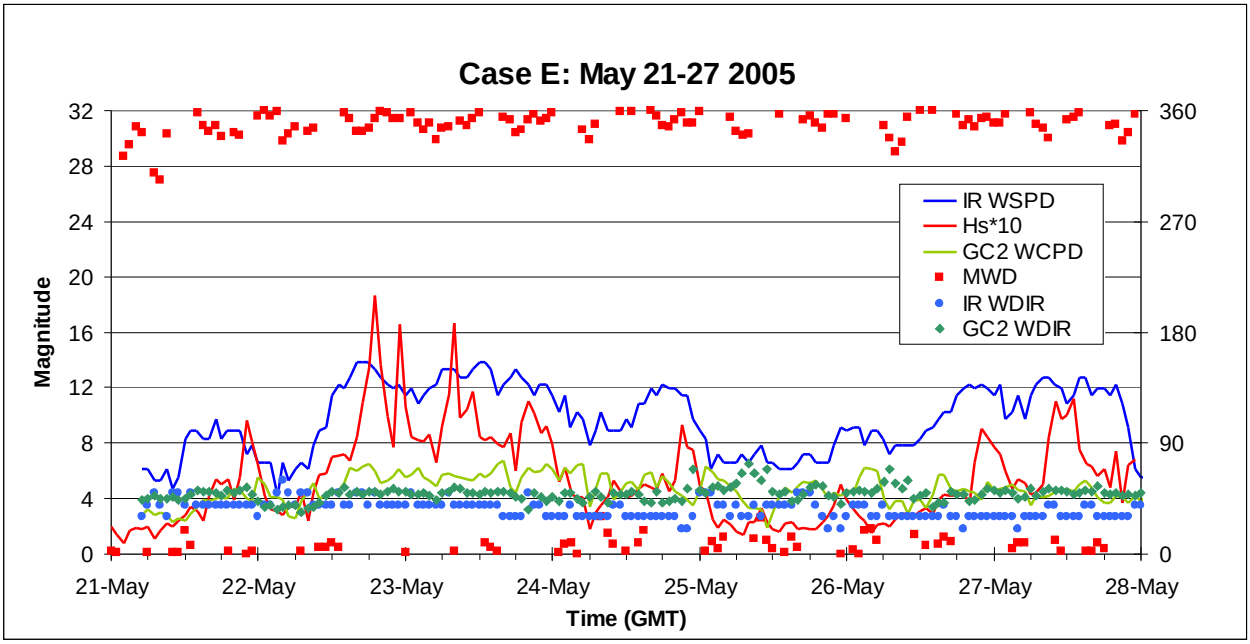

Figure 2-14: Wind and waves measurements during case study E of May 21-27, 2005 which includes two large wave events of May 22 and May 27 with Hs of 1.86 m and 1.12 m respectively. The winds were below 15.5 m/s throughout this period.

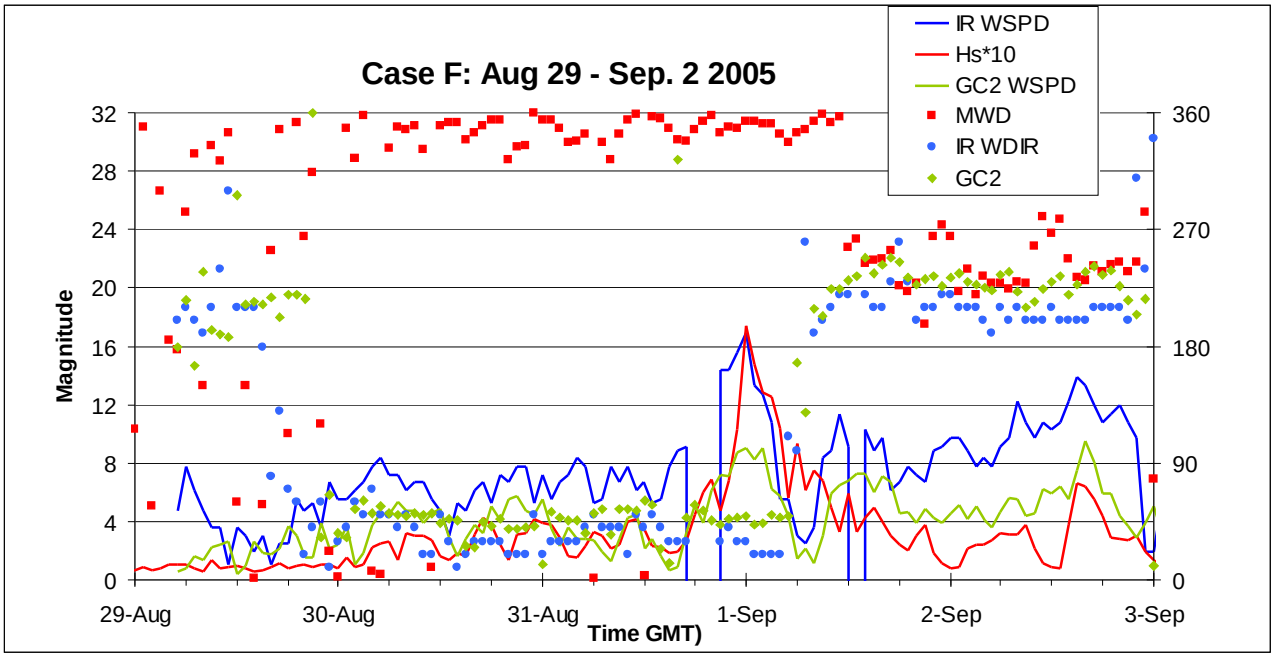

Figure 2-15: Wind and waves measurements during case study F of Aug. 29 to Sept. 2, 2005 which includes a single large wave event on Sep. 1 with Hs of 1.74 m.

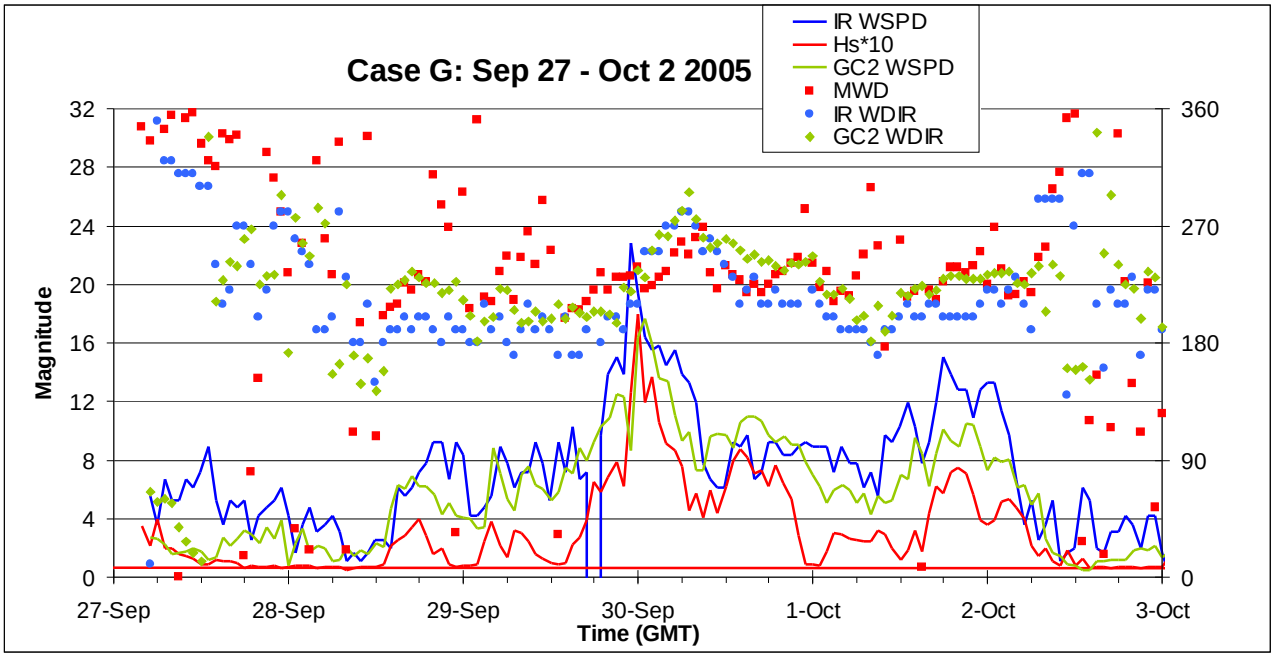

Figure 2-16: Wind and waves measurements during case study F of Sep. 27 to Oct. 2, 2005 which includes a single large wave event on Sept. 29 with Hs of 1.79 m accompanied by winds exceeding 20 m/s at Île Rouge and at the GC1 weather station.

Much of the variability between wave heights and local winds arises from the dominant contributions to wave generation being beyond the local portion of the St. Lawrence River from Gros Cacouna to Île Rouge. In some of the case studies, such as Cases B and C (Figures 2-11 and 2-12), the events of Jan. 18 and March 2 (1.3 m and 1.4 m Hs) seem to fit well with the pattern of change of local winds, with the peak of the local wind occurring a few hours before the maximum measured waves. However, even in both these case studies, the next large wind event of a few days later was associated with a much smaller wave response, possibly due to changing sea ice conditions. The late summer case F (Figure 2-15) also exhibits a reasonably good match between a distinct wind event of up to 17 m/s at Île Rouge and 12 m/s at Gros Cacouna (GC2) with a peak Hs wave value of 1.74 m occurring a few hours after the wind had peaked.

Case G (Figure 2-16) is another case of a strong wind event accompanied by large waves. In this case the wave height is almost identical to that in case F, at 1.79 m, yet the peak wind speeds are considerably larger with the largest recorded wind speed at GC2 being 18 m/s, while the winds at Île Rouge were also very large at 23 m/s. In most of the cases examined, the large waves were from the north-northwest and the coincident winds were from the northwest, north or northeast. In case G, both the dominant winds and the waves originate from the southwest, or from up-river.

Cases A, D and E (Figures 2-10, 2-13 and 2-14) each exhibit large wave events in which the peak values of Hs are elevated by 50 to 100% from the adjoining values on time scales of an hour. Case A has already been described in some detail above with its complex directional wave properties displayed in Figure 2-9. Cases D and E, in late April and late May, exhibit very large values of Hs in two and three distinct ensembles, respectively relative to the overall envelope of the broad wave peak which has a duration of about 2 days. In all three of these cases (A, E, and E), the peak Hs

value appears to be higher relative to the local wind speeds than is the case with the other wind/wave episodes examined. It may be that these particular high wave events are the result of a more complicated set of wave generation mechanisms in terms of the source of the wave generation and the route by which the waves arrived at the measurement site.