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MEASUREMENT OF WAVES AND CURRENTS OFF BRANT ST, LAKE ONTARIO

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MEASUREMENT OF WAVES AND CURRENTS OFF BRANT ST, LAKE ONTARIO

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Burlington Ontario

Preamble

The City of Burlington is undertaking a Class Environmental Assessment and detailed design of a waterfront pier and a transient marina at the foot of Brant St in Lake Ontario. There are no existing data on waves and currents in the location of the proposed facility. To provide some data on these important processes in the nearshore zone, the City entered into an agreement with the National Water Research Institute to deploy one of their instruments near the study site to measure waves and currents.

The measurement period was marked by numerous wind events from the west and several from the east. A significant storm out of the east occurred on 26-27 January 2004. This storm had wind speeds out of the east close to the highest recorded at Toronto Island. Wave heights greater than 2 m and wave periods greater than 9 s were recorded in 5 m of water. Currents nearly 0.8 m/s were also recorded during this storm.

It was very fortunate to be able to capture the wave and current data from such a severe storm during the short time period the instrument was deployed. This data set provides a remarkable record for design guidance.

MESURE DE LA HOULE ET DES COURANTS DANS LE LAC ONTARIO AU BAS DE LA RUE BRANT

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Préambule

La Ville de Burlington entreprend actuellement une évaluation environnementale par catégorie et la conception détaillée d'une jetée et d'un port de plaisance dans le lac Ontario, au bas de la rue Brant. Il n'y a aucune donnée sur la houle et les courants à l'emplacement projeté. En vue d'obtenir des données sur ces processus importants dans la zone riveraine, la Ville a conclu une entente avec l'Institut national de recherche sur les eaux en vue de l'installation d'un appareil de mesure de la houle et des courants près du site d'étude.

La période de mesure a été ponctuée par de nombreux épisodes de vent soufflant de l'ouest et par plusieurs épisodes de vent soufflant de l'est. Les 26 et 27 janvier, une forte tempête a balayé le secteur par l'est. Les vents d'est ont atteint des vitesses proches des records enregistrés dans l'île de Toronto. Les vagues ont dépassé 2 mètres et des périodes de houle supérieures à 9 secondes dans 5 mètres d'eau ont été enregistrées. Des courants de près de 0,8 m/s ont également été enregistrés pendant la tempête.

C'est une grande chance d'avoir pu recueillir des données sur la houle et les courants pendant une tempête de cette ampleur, compte tenu du court laps de temps où l'appareil a été utilisé. Ces données seront fort utiles pour la conception des installations.

MEASUREMENT OF WAVES AND CURRENTS OFF BRANT ST

LAKE ONTARIO

M G Skafel, National Water Research Institute, Burlington Ontario

Summary

The measurement period was marked by numerous wind events from the west and several from the east. A significant storm out of the east occurred on 26-27 January 2004. This storm had wind speeds out of the east close to the highest recorded at Toronto Island. It was very fortunate to be able to capture such a storm during the short time period the instrument was deployed. This data set provides a remarkable record for design guidance.

The currents monitored over the period of record were generally less than 0.2 m/s and shore parallel to the easterly direction. During wind events from the east the currents reversed and were to the westerly direction and again shore parallel. The large storm on 26-27 January 2004 produced large currents up to 0.78 m/s shore parallel in a westerly direction.

The waves at the site were typically less than 0.3 m. Six events were recorded when waves were greater than 0.3 m. During the easterly storm of 26-27 January 2004 the waves were large and from a direction consistent with both wave generation under these conditions on Lake Ontario and refraction due to the shallow water at the site. The wave height peaked at 2.3 m and the period reached 9.8 s. Directions when the period was 9 s or greater were from about 98 to 110°T. These waves appear to be quite close to the maximum likely to occur at the site.

Introduction

The City of Burlington is undertaking a Class Environmental Assessment and detailed design of a waterfront pier at the foot of Brant St in Lake Ontario. The National Water Research Institute (NWRI) has an ongoing research project addressing the problem of attached algae growth along the Lake Ontario waterfront from Burlington to Mississauga. Both projects need information on the physical processes of waves and currents in the nearshore to provide guidance in other aspects of their respective projects. There are no existing data on waves and currents in the location of the proposed facility, nor anywhere along that reach of shoreline in the very shallow nearshore waters. To provide some data on these important processes, the City entered into an agreement with the National Water Research Institute (NWRI) to deploy one of NWRI's instruments near the study site to measure waves and currents which will serve to benefit both parties.

NWRI deployed a bottom mounted RD Instruments acoustic Doppler current profiler with waves package (ADCP Waves Array) in 5 m of water off Brant St in Lake Ontario at 43° 19.3440'N 79° 47.3630'W, approximately half a kilometre east of the base of Brant St (Figure 1a). The first deployment, from October to December, did not return any data due to instrument malfunction. After assessing the risks of deploying over winter and concluding that the instrument would likely survive if placed in at least 5 m of water, the ADCP was redeployed from 15 Dec 2003 to 6 April 2004. This report summarizes the wave and current data from that deployment.

Period of Record

During the deployment, several storms out of the east produced sizable waves at the site. Upon first inspection of the site in the spring, on 24 March 2004, it was found that the instrument was completely buried by sand. It was estimated that the top of the instrument was 0.2 to 0.3 m below the surface of the sand bottom. Several attempts were required to retrieve it, and with the use of diver operated water jets to mobilize the sand, it was finally recovered on 6 April 2004. Preliminary analysis of the data indicated good data from the deployment on 15 December 2003 but that the quality of the signal deteriorated after the storm on 26-27 January 2004, and finally became completely unacceptable on 2 February 2004. It was initially believed that the subsidence and/or burial of the instrument took place mainly during the height of that storm and that the sand thickness over it finally became thick enough to prevent operation by 2 February. A photo of the instrument as it was being recovered is show in Figure 1b.

Currents

The currents are characterized in Figures 1 to 3. Figure 1a shows the principal axes of the currents at four depths in the water column. For each depth, the long line indicates the direction containing the most variance of the current and the short line the least, and the length of the line indicates the magnitude of the currents. These results show that the overall currents are very similar from near the water surface to near the bottom. The flow is dominantly in the alongshore direction, with very modest onshore-offshore flow. For comparison, the principal axes for the winds from the Toronto Island Airport are also show. The winds were mainly east-west, but winds from other directions were also of some importance. The currents are driven by the winds, but very strongly influenced by the close proximity of the shoreline and shore parallel bathymetric contours.

Current roses for the same four depths are shown in Figure 2. In this presentation the time the currents are in a particular speed and direction class are represented by the size and orientation of the coloured areas. Relatively modest currents towards the NNE and NE dominate the results. These figures confirm those of Figure1 that the flow is mostly shore parallel, but additionally show that for most of the time the flow was in an easterly direction.

Finally, time series of the Toronto Island winds and the currents (at the same depths as previously) are shown in Figure 3. Here the time series have been filtered with a 24 hour filter to highlight the events or storms, at the expense of showing the short period fluctuations. During the period there were numerous relatively strong westerly wind events. During these events the currents at all depths were modest and towards the east and predominantly shore parallel. There were several events with winds out of the east, but only four were of sufficient magnitude and duration to generate currents to the west, again predominantly shore parallel. The storm on 26-27 January 2004 was by far the most important of these. The currents peaked on 26 January 2004 at 2100 Z at 0.78 m/s at the top three depths and at 0.74 m/s at the lowest depth. The direction varied from 224

at the top to 230°T (reported as 'direction towards') at the bottom, all closely shore parallel.

The winds at Toronto Island during this storm peaked on 26 January 2004 at 1300 and 1500 EST at 61 km/hr, from 80°T (and at Burlington Pier on 26 January 2004 at 1000 EST at 59 km/hr, from 90°T). To put the strength of the wind in this storm in perspective, over a recent 20 year interval the strongest winds out of the NE to E directions at Toronto Island were in the 65 to 70 km/hr range, and only occurred for 0.01% of the 20 year record. This storm was one of the worst in terms of magnitude from that direction.

Waves

The wave data are summarized in Figure 4 and Table 1. Both the figure and the table only show wave readings when the significant wave height (H_s) was greater than 0.3 m. Six events resulted in waves greater that 0.3 m. By far the most important event was the storm of 26-27 January 2004. The wave height peaked at 2.3 m with a corresponding peak period (T_p) of 9.1 s and peak direction from (D_p) of 98°T on 26 January at 2100 Z. The longest peak period occurred six hours later and was 9.8 s with a corresponding wave height of 1.96 m and direction from of 109°T.

When winds blow approximately along the long axis of a lake the resulting waves take the direction of that long axis, or in the case of this site, from about 80°T. As the waves approach shallow water they are refracted (that is, change direction) because of the difference in direction of the bottom contours and the wave direction in deep water. At this site 9 s waves would be expected to change direction from 80°T to about 105°T, based on theoretical considerations. The measured directions were in the range from 98 to 110°T, closely matching the expected direction.

Elevation of the ADCP

At the end of the deployment the ADCP was buried under about 0.2 to 0.3 m of sand so that the bottom of the instrument frame was about 0.7-0.8 m below the bed. It was not clear whether the instrument subsided or stayed at the same elevation and was buried by a large scale movement of bottom sediment, or some combination. To shed some light on this issue, the elevation time series as measured by the depth sensor on the ADCP, corrected for water level using the gauge maintained by the Canadian Hydrographic Service at the Burlington Ship Canal, was constructed as shown in Figure 5. If the instrument stayed at the same level and was buried by bottom sediment migrating over it, the elevation record should by relatively constant. If the instrument subsided, there should be a general negative slope of the time series. In fact the elevation record of Figure 5 shows a gradual lowering throughout the period with an abrupt lowering of about 0.4 m during the storm of 5 January 2004, but not during the storm of 26-26 January. This evidence suggests that the primary mode of burial was subsidence, not a change in bed elevation caused by the sediment migration.

Bottom Sediment

During the retrieval operation of the ADCP, a sample of bottom sediment was obtained for size analysis. In summary the sediment contained the following size fractions: gravel 0.56%; sand 97.8%; silt and clay 1.64%. The median diameter was 166.46 microns. Loss by ignition was 0.8%, indicating low organic content.

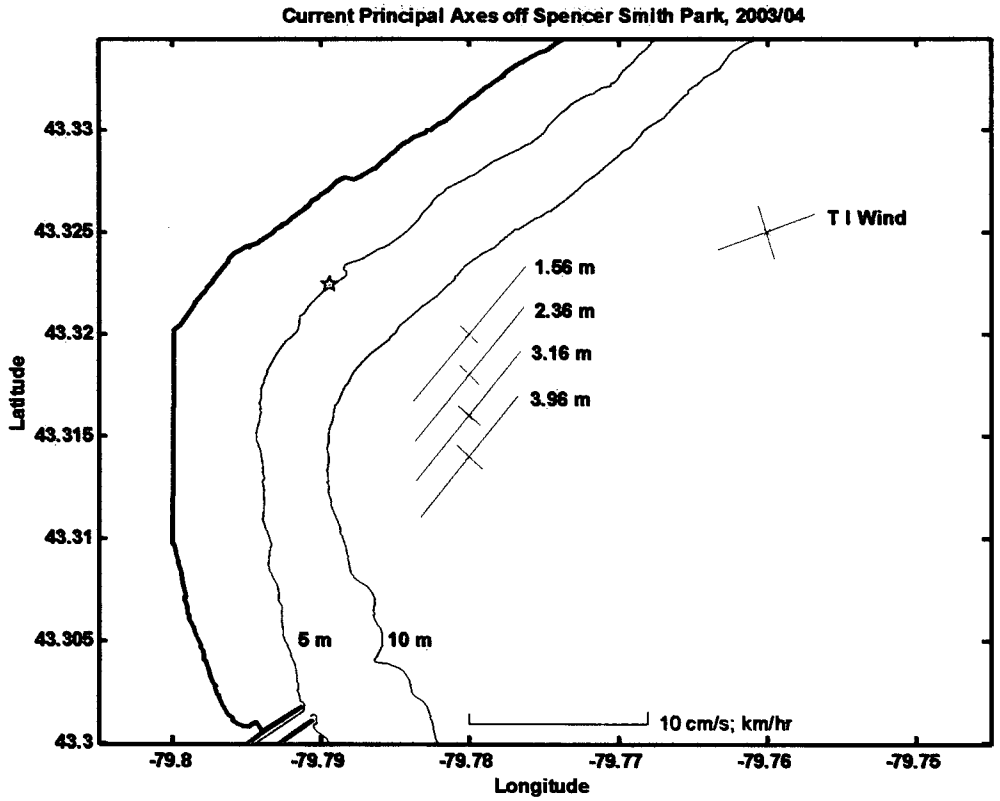

Figure 1a. The principal axes of the currents off Spencer Smith Park at four depths, in 5 m of water indicate that the flow was strongly shore-parallel and showed very little variation from near the surface to near the bottom.

Figure 1b. The ADCP Wave Array meter with protective ring partially uncovered during retrieval. The meter and base frame extended about 0.45 m underneath the sand at the time of this photo.

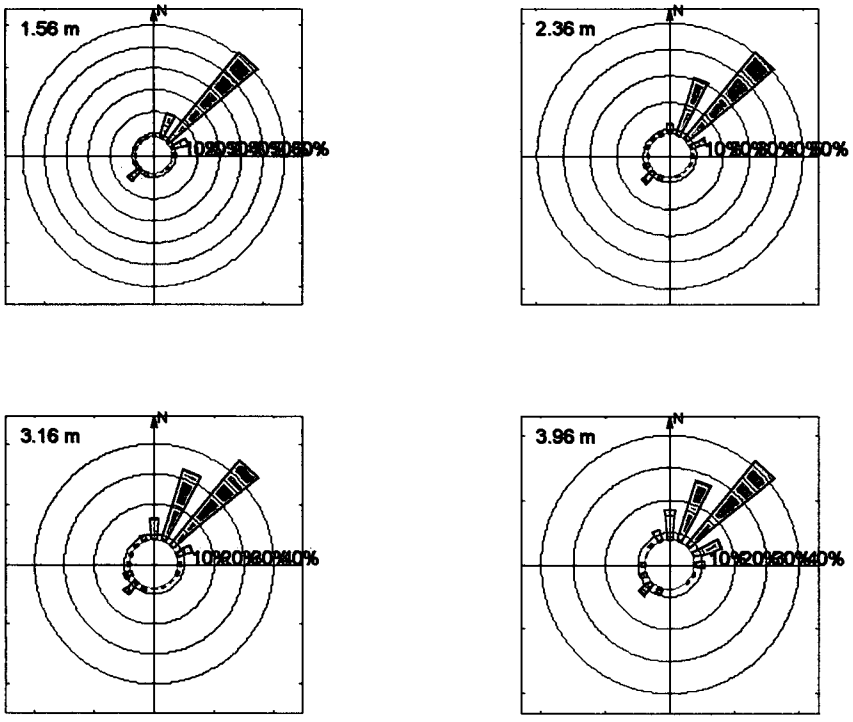

Figure 2. Current roses at four depths. Most of the time the flow is shore parallel in a northeasterly direction. The very strong southwesterly flows during storms were of such short duration that they are hardly discernable in this format. The inner circle represents flows less than 0.005 m/s; magenta: 0.005 to 0.02; cyan: 0.02 to 0.05; red 0.05 to 0.1; green: 0.1 to 0.2; blue: 0.2 to 0.5; magenta: 0.5 to 1.0;... Directions are "to".

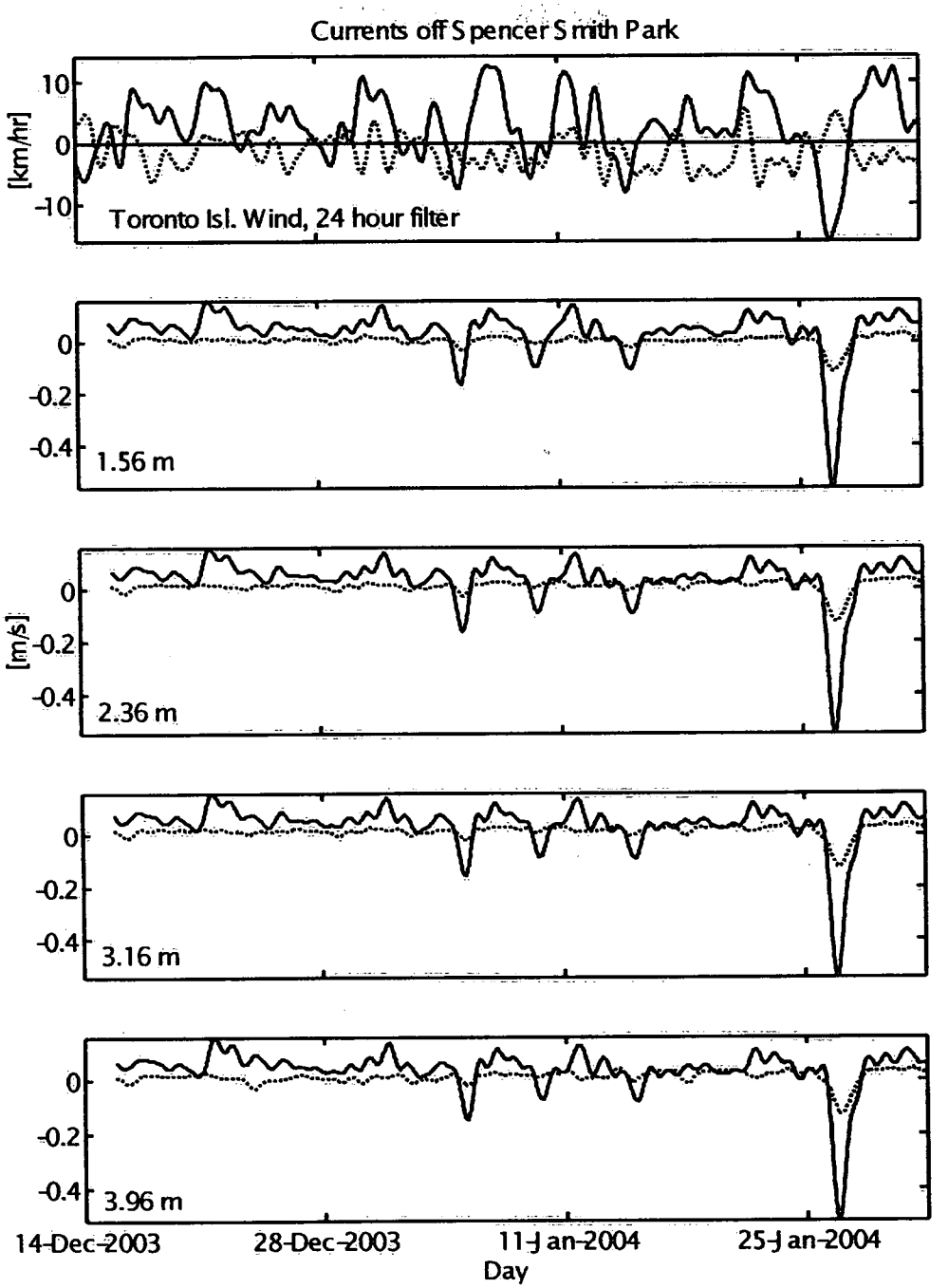

Figure 3. Time series of the Toronto Island winds and currents at four depths, all filtered at 24 hours. The solid line is alongshore (positive is towards the easterly direction, 20°T for the winds and 37°T for the currents), and the dashed line is the cross-shore flow (positive is onshore).

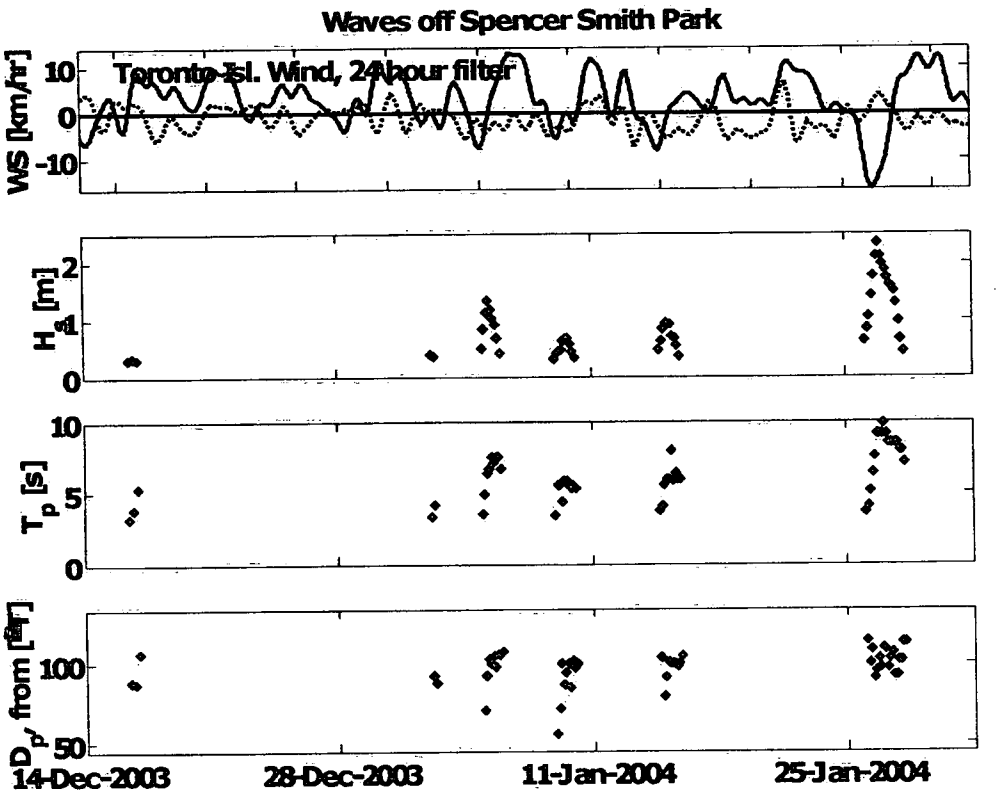

Figure 4. Time series of the wave parameters and the winds from Toronto Island. The solid line in the upper panel is the alongshore component of the wind (Negative is from the east) and the dashed line is the cross-shore component (negative is offshore). Only wave records with significant height greater than 0.3 m are shown.

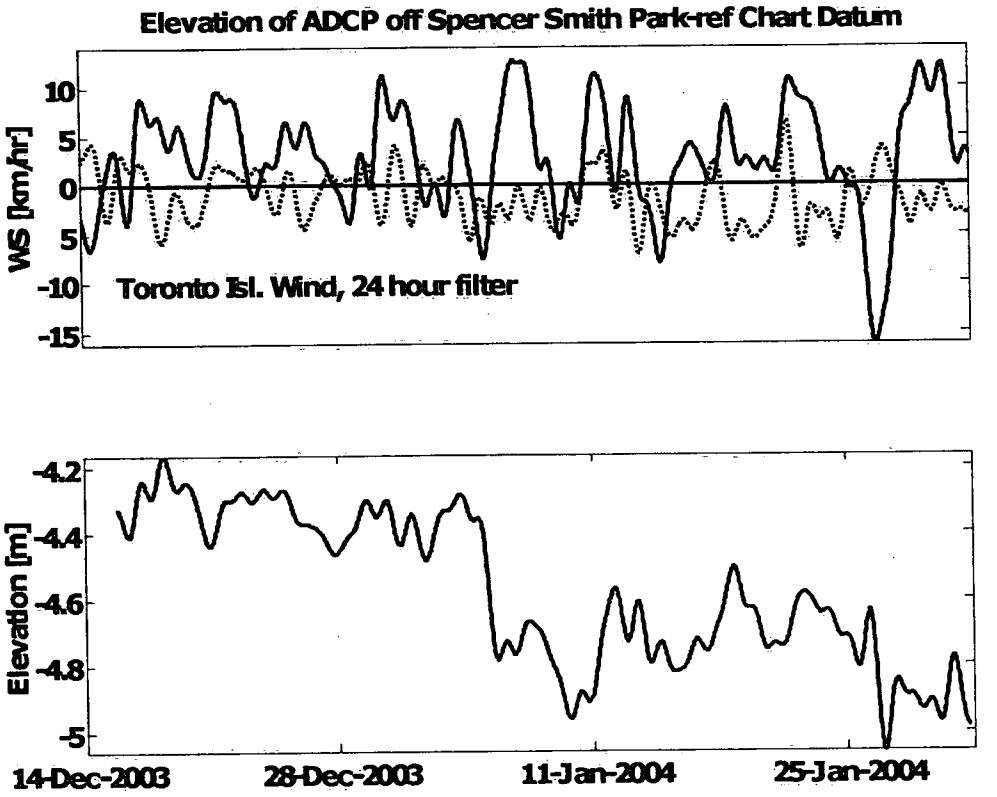

Figure 5. Elevation of the ADCP relative to chart datum. Both the wind record and the elevation record have been passed through a low pass filter with 24 hour cutoff.

Table . Summary of waves greater than 0.3 m in height.

Year	Month	Day	Hour	Hs [m]	Tp [s]	Dp [°T, from]
3	12	16	12	0.3	3.2	89
3	12	16	18	0.32	3.8	88
3	12	17	0	0.3	5.3	107
4	1	2	6	0.38	3.3	93
4	1	2	9	0.36	4.2	88
4	1	5	0	0.48	3.5	71
4	1	5	3	0.83	4.9	93
4	1	5	6	1.13	6.4	103
4	1	5	9	1.34	6.7	100
4	1	5	12	1.17	7.5	105
4	1	5	15	1.01	7.1	99
4	1	5	18	0.92	7.5	106
4	1	5	21	0.68	7.5	106
4	1	6	0	0.4	6.7	108
4	1	9	0	0.3	3.4	56
4	1	9	3	0.42	5.5	72
4	1	9	6	0.43	5.5	100
4	1	9	9	0.47	4.4	87
4	1	9	12	0.63	5.8	95
4	1	9	15	0.66	5.8	100
4	1	9	18	0.66	5.5	85
4	1	9	21	0.56	5.3	102
4	1	10	0	0.44	5.5	98
4	1	10	3	0.34	5.3	100
4	1	14	18	0.47	3.7	104
4	1	14	21	0.63	4.1	80
4	1	15	0	0.83	5.5	92
4	1	15	3	0.93	6	101
4	1	15	6	0.9	6	100
4	1	15	9	0.9	8	100
4	1	15	12	0.71	5.8	100
4	1	15	15	0.68	6.4	99
4	1	15	18	0.54	6	100
4	1	15	21	0.35	6	105
4	1	26	3	0.63	3.6	115
4	1	26	6	0.82	4.1	100
4	1	26	9	1.05	5.1	109
4	1	26	12	1.42	6.4	91
4	1	26	15	1.74	7.5	96
4	1	26	18	2.08	9.1	103
4	1	26	21	2.32	9.1	98
4	1	27	0	2.08	9.1	110
4	1	27	3	1.96	9.8	109
4	1	27	6	1.86	9.1	98
4	1	27	9	1.72	8.5	103
4	1	27	12	1.58	8.5	107

4	1	27	15	1.56	8.5	93
4	1	27	18	1.5	8.5	93
4	1	27	21	1.28	8.5	102
4	1	28	0	0.96	8	102
4	1	28	3	0.64	8	114
4	1	28	6	0.44	7.1	114
4	2	2	15	0.56	3.4	66
4	2	2	18	0.7	4.7	81
4	2	2	21	0.73	3.7	122

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