HYDRAULICS DIVISION

Technical Note

DATE: July 1981 **REPORT NO:** 81-21

TITLE: Verification of 1972 Lake Ontario Waverider Data

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REASON FOR REPORT: To document a series of computer runs that were used to check 1972 Lake Ontario Waverider data obtained by the Marine Environmental Data Service.

CORRESPONDENCE FILE NO:

5690 (Study No. 4358)

1.0 BACKGROUND

The measurement of wind-generated gravity waves by a Waverider accelerometer buoy is a commonly accepted practice. However, a comprehensive verification of the measured data is seldom carried out. In fact, verification was hardly possible until the recent advent of reliable numerical wave prediction models.

Waverider data for Lake Ontario collected in 1972 was used recently in a comparison of steady-state wave prediction models (Bishop, 1981). In that study, the steady-state predictions compared poorly with the Waverider data for one particular station - Cobourg. Furthermore, a similarly poor comparison had been obtained for the Cobourg data in another study (Skafel et al, 1979) using the numerical model described by Baird and Glodowski (1978). It was decided to verify the 1972 Waverider data for Lake Ontario using the model of Donelan (1977) to ascertain if the Cobourg data is reliable.

2.0 DATA SET

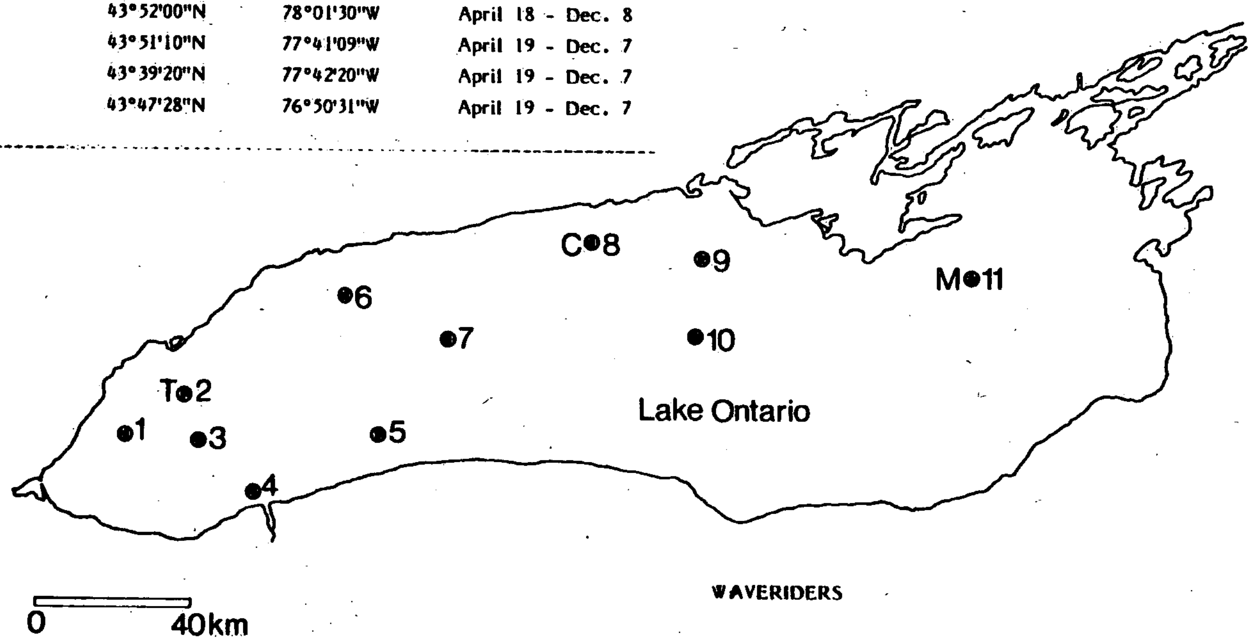
A comprehensive meteorological and wave data set was collected for Lake Ontario in 1972 as part of the International Field Year on the Great Lakes (IFYGL). Three Waveriders and eleven meteorological buoys were deployed at the locations shown in Figure 1. Deep water wave conditions prevailed at all three Waverider locations (maximum measured peak period=8.0 s, minimum ratio of water depth to dominant wavelength =0.69).

Wave data was collected for 20 minutes at three hour intervals and digitized at a sampling frequency of 1 Hz. The variance spectral densities of the water surface elevation have been computed by the Marine Environmental Data Service of Fisheries and Oceans Canada at approximately 60 discrete values of frequency between 0.05 and 0.50 Hz using the Cooley-Tukey fast Fourier transform algorithm. The characteristic wave height is four times the square root of the area under the spectrum. The peak period is the inverse of the frequency at which the maximum spectral density occurred. No measurements of wave direction were made. The characteristic wave height, peak period and variance spectral density-frequency data are stored on magnetic tape.

Measured meteorological parameters include wind speed and direction and air and water temperatures. These were recorded every ten minutes. Wind speed is a true average wind run, the others are single samples from instruments

METEOROLOGICAL BUOYS

Station Number	Latitude	Longitude	Period of Deployment
1	43°25'34"N	79°30'51"W	April 6 - Dec. 11
2	43°30'53"N	79°19'01"W	April 6 - Dec. 11
3	43°24'23"N	79°17'20"W	April 10 - Dec. 9
4	43°17'31"N	79°07'55"W	April 10 - Dec. 11
5	43°26'03"N	78°43'40"W	April 11 - Dec. 12
6	43°43'56"N	78°49'23"W	April 11 - Dec. 8
7	43°38'48"N	78°29'30"W	April 18 - Dec. 8
8	43°52'00"N	78°01'30"W	April 18 - Dec. 8
9	43°51'10"N	77°41'09"W	April 19 - Dec. 7
10	43°39'20"N	77°42'20"W	April 19 - Dec. 7
11	43°47'28"N	76°50'31"W	April 19 - Dec. 7



WAVERIDERS

Location	Latitude	Longitude	Period of Deployment	Depth of Water (m)
Toronto T	43°31'N	79°19'W	March 11 - Nov. 30	108
Cobourg C	43°49'05"N	78°02'05"W	April 12 - Dec. 4	70
Main Duck Island M	43°47'45"N	76°49'39"W	April 19 - Nov. 21	69

Figure 1 Locations of meteorological and waverider buoys, 1972

with various time constants (Donelan et al, 1974). These ten minute samples have been combined into hourly averages centred on the hour (Donelan et al, 1979). The wind direction was averaged vectorially assuming a constant (unit) wind speed over the hour. The wind speed was determined as a scalar average over the hour. The hourly-averaged data set is stored on magnetic tape.

The shoreline configuration of Lake Ontario was obtained from a digital bathymetric data set for the lake on a 2 km grid (Robertson and Jordan, 1978). The shoreline position was estimated by linear interpolation between adjacent grid points.

3.0 MODEL

Details of Donelan's finite difference numerical model are given in Trotoux and Donelan (1977) and Donelan (1977). Briefly, it is a momentum balance parametric model using the JONSWAP spectral form of Hasselmann et al (1973). In this application, the model's adjustable grid spacing was set at a relatively coarse value of 20 km. The hourly averaged wind observations (adjusted to the standard 10 m height by multiplying the wind speeds by 1.092) from the 11 meteorological buoys were interpolated onto each grid point using a weighted average of the inverse square of the distance from the three nearest buoys. The model was run on a one hour time step. A startup time of about six hours is required at the beginning of each simulation before achieving meaningful estimates of the wave parameters.

4.0 RESULTS

The graphical comparison of predicted and measured wave data at Toronto, Cobourg and Main Duck Island is provided in the Appendix. Predictions for Burlington are also provided. The corresponding numerical data is available from the authors.

It can be seen that the comparisons for Toronto and Main Duck Island are excellent. Due to the difficulty involved in locating the spectral peak for small waves, the measurements of peak period for characteristic wave heights less than about 0.5 m should not be considered reliable. The occasional saw-toothed predictions (see for example November 27) indicate numerical instability; this could have been removed by using a shorter time step. An upcoming version of the numerical model will automatically check for instability and will adjust the time step as required in accord with the Courant condition.

The timing of the Cobourg data appears to be in error on several occasions. The actual wave heights and periods seem to be correct but shifted in time. Similarly, there appears to be one occasion involving a time shift for each of Toronto and Main Duck Island. These time shifts have been estimated by eye, using tracing paper, and are summarized in Table 1. Possible reasons for these time shifts include errors in writing down the time when changing magnetic tapes, unrecorded power failures, or errors in recording or processing the data.

5.0 SUMMARY

Wave measurements made at three locations on Lake Ontario in 1972 using Waverider accelerometer buoys have been compared with wave predictions using the numerical model of Donelan (1977). The measurements at Toronto and at Main Duck Island can be considered to have been verified as good data. However, the measurements at Cobourg include numerous time shifts. It is recommended that the Cobourg data only be used with caution after examining the graphical comparison in the Appendix. As a source of wave climatology, the Cobourg data is still of use in its present form provided no attempt is made to relate wave and wind statistics.

TABLE 1 **ESTIMATES OF TIMING ERRORS IN 1972 IFYGL LAKE ONTARIO WAVE DATA**

From	To	Station	Description
2210 June 21	1010 June 24	Cobourg	9 hours late
1910 June 24	July 4	Cobourg	6 hours late
410 June 23	1310 July 24	Main Duck	15 hours late
2210 July 23	110 July 26	Cobourg	3 to 6 hours late
110 August 16	410 August 20	Cobourg	15 hours late
110 August 31	1010 September 3	Cobourg	152 hours early
1010 September 15	1910 September 18	Cobourg	90 hours early
October 17	October 18	Cobourg	Several lapses
October 30	October 31	Cobourg	Double values at 4 times
410 October 31	1610 November 3	Cobourg	27 hours early
1610 October 31	710 November 6	Toronto	6 hours early
1910 November 7	1010 November 10	Cobourg	27 hours early
710 November 18	1310 November 19	Cobourg	105 hours late

REFERENCES

Baird, W. F., and Glodowski, C. W., 1978. "Estimation of Wave Energy Using a Wind Wave Hindcast Technique". International Symposium on Wave and Tidal Energy, Canterbury, England.

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Donelan, M. A., Elder, F. C. and Beesley, D., 1979. "Evaluation of Measurements from the Canada Centre for Inland Waters Meteorological Buoy". National Water Research Institute, Unpublished Report.

Hasselmann, K., Barnett, T. P., Bouws, E., Carlson, H., Cartwright, D. E., Enke, K., Ewing, J. A., Gienapp, H., Hasselman E., Kruseman, P., Meerburg, A., Muller, P., Olbers, D. J., Richter, K., Sell, W. and Walden, H., 1973. "Measurements of Wind-Wave Growth and Swell Decay During the Joint North Sea Wave Project (JONSWAP)". Deut. Hydrogr. Z. Reihe A, 8, pp. 95.

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Skafel, M. G., Bishop, C. T. and Glodowski, C. W., 1979. "Cobourg Harbour - Investigation of Wave Agitation and Related Remedial Structures". National Water Research Institute, Unpublished Report.

Trotoux, J. and Donelan, M. A., 1977. "The Computational Scheme of a Numerical Model for Wave and Wind Stress Prediction". National Water Research Institute, Unpublished Report.

APPENDIX

Graphical Comparison of
Measured and Predicted Wave Data

NOTES TO APPENDIX

- Time is Greenwich Mean Time
- On the wind speed and direction plots, the direction is denoted by the crosses.
- A period of about six hours at the beginning of each run is required to achieve meaningful wave predictions.
- The peak period is in units of seconds.
- The predicted periods and wave heights are denoted by the solid lines; the measured values are denoted by the circled dots.

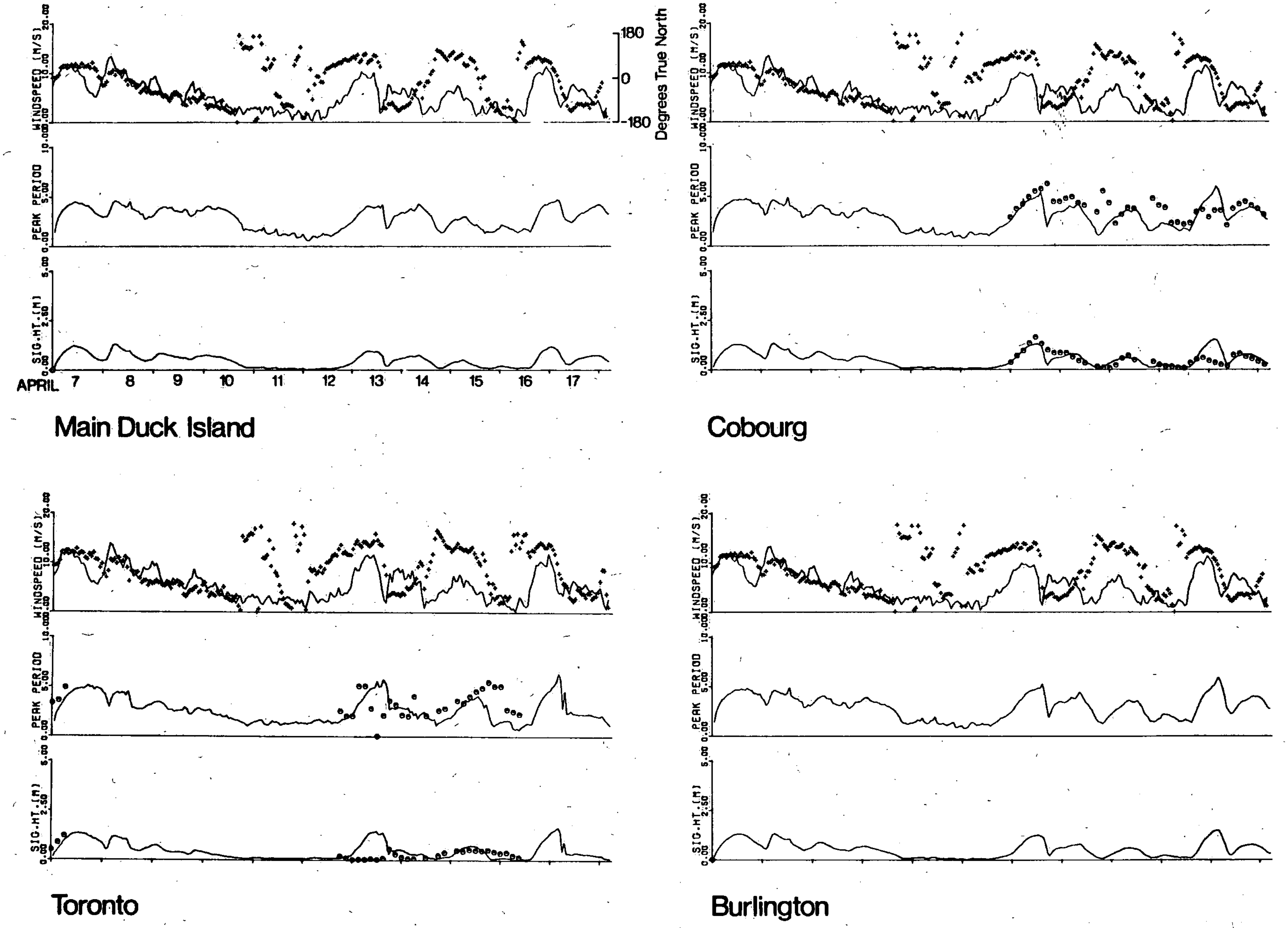


Figure A1 April 7 to 17, 1972

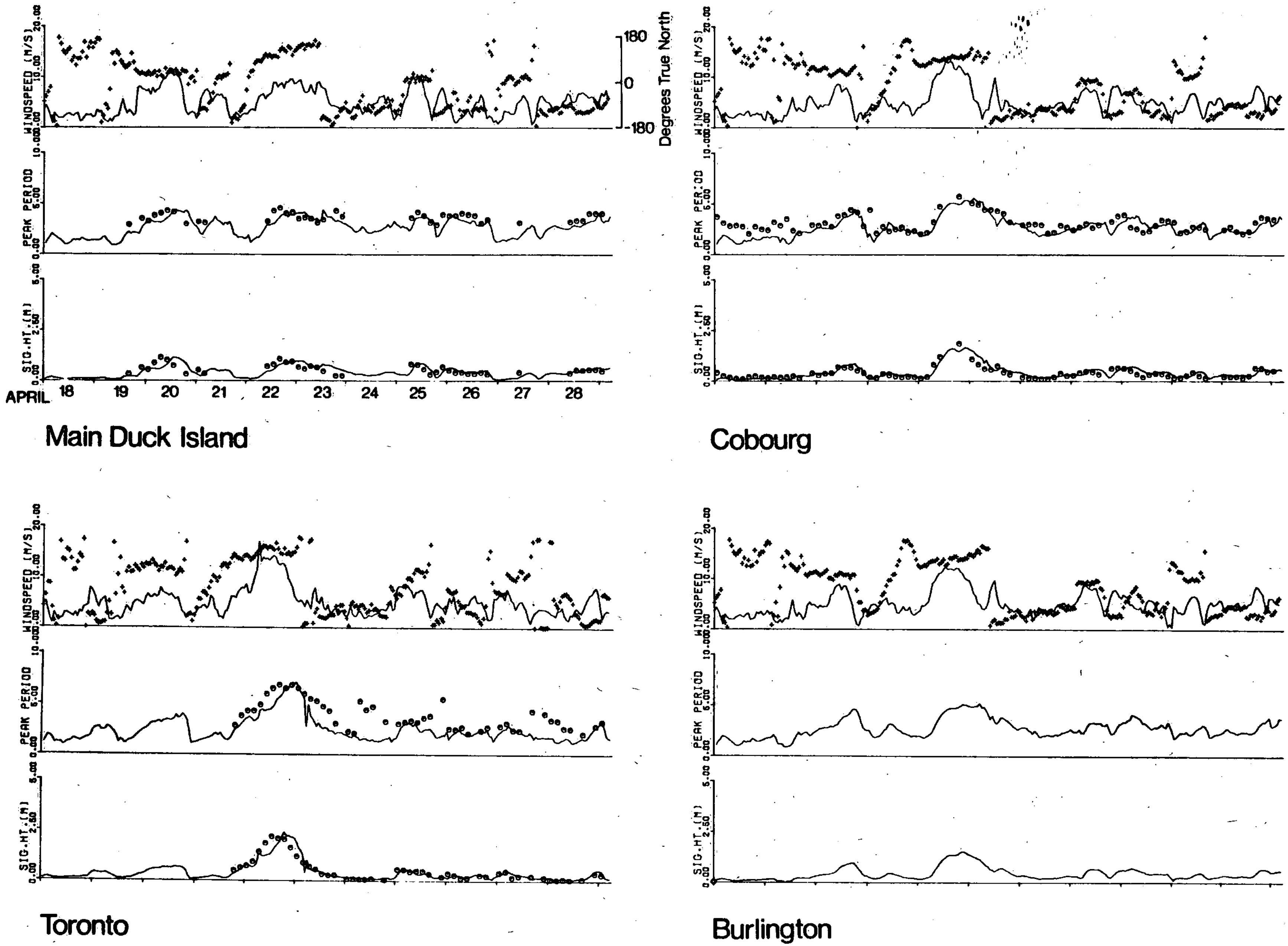


Figure A2 April 18 to 28, 1972

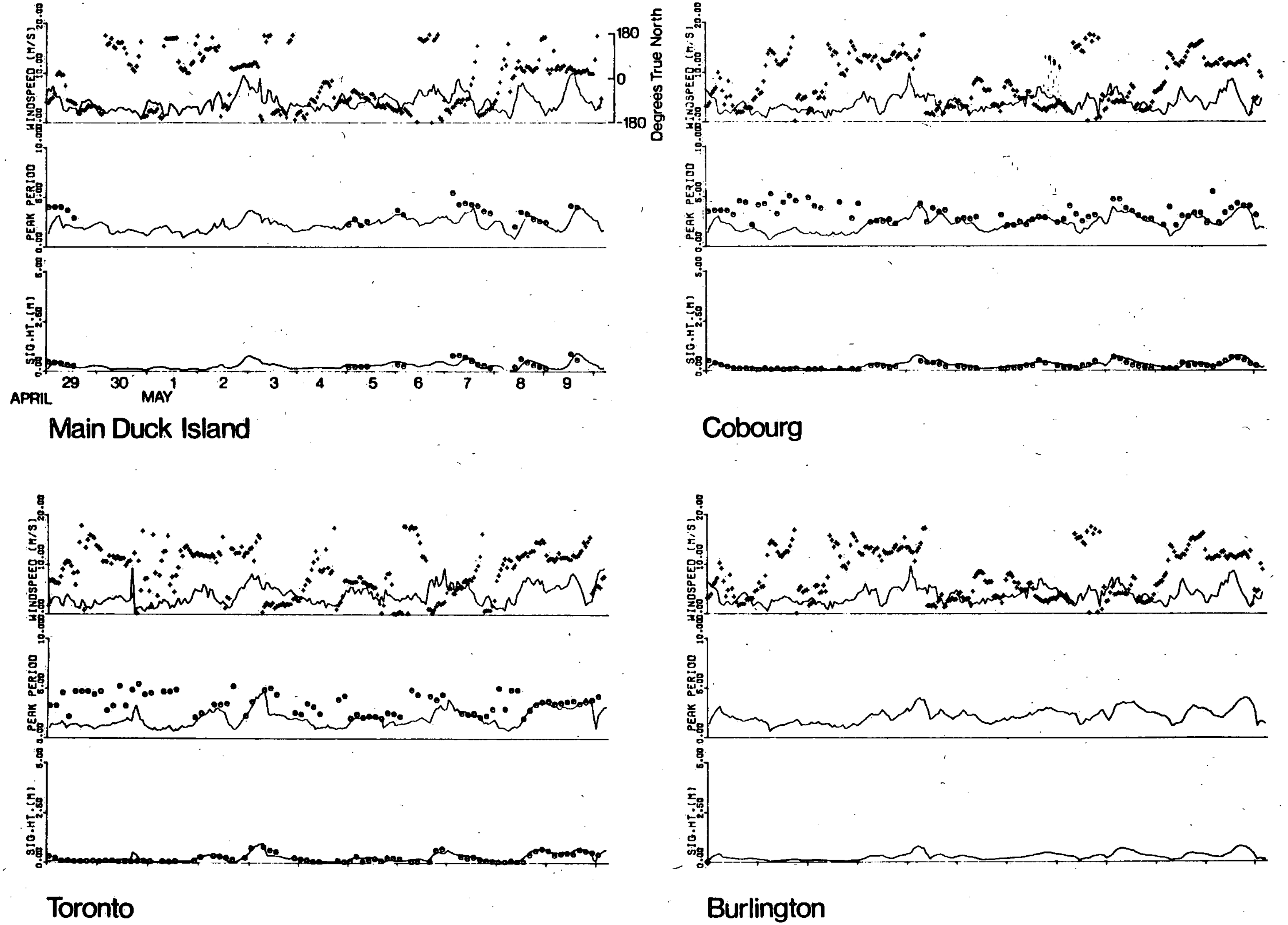


Figure A3 April 29 to May 9, 1972

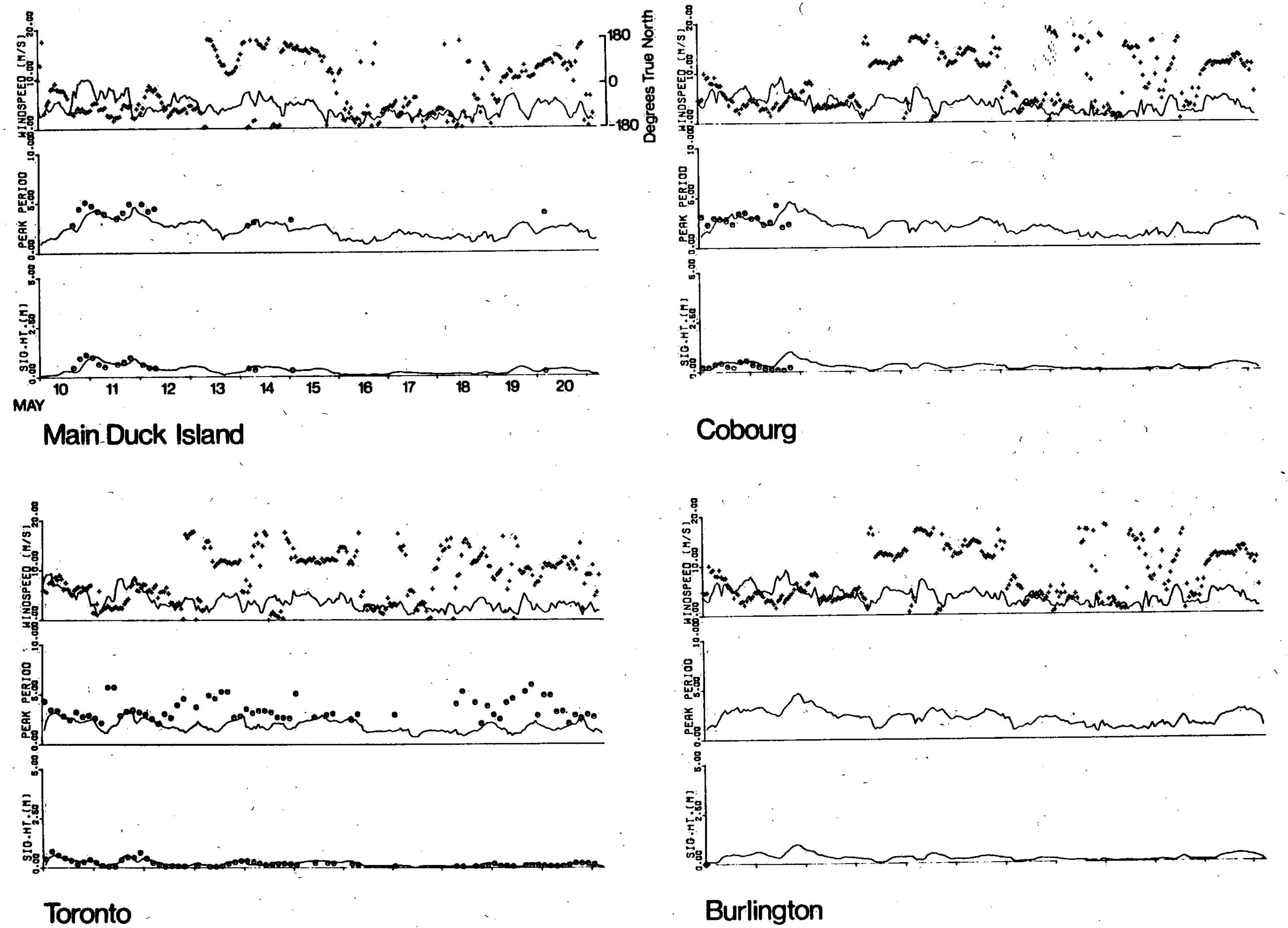


Figure A4 May 10 to 20, 1972

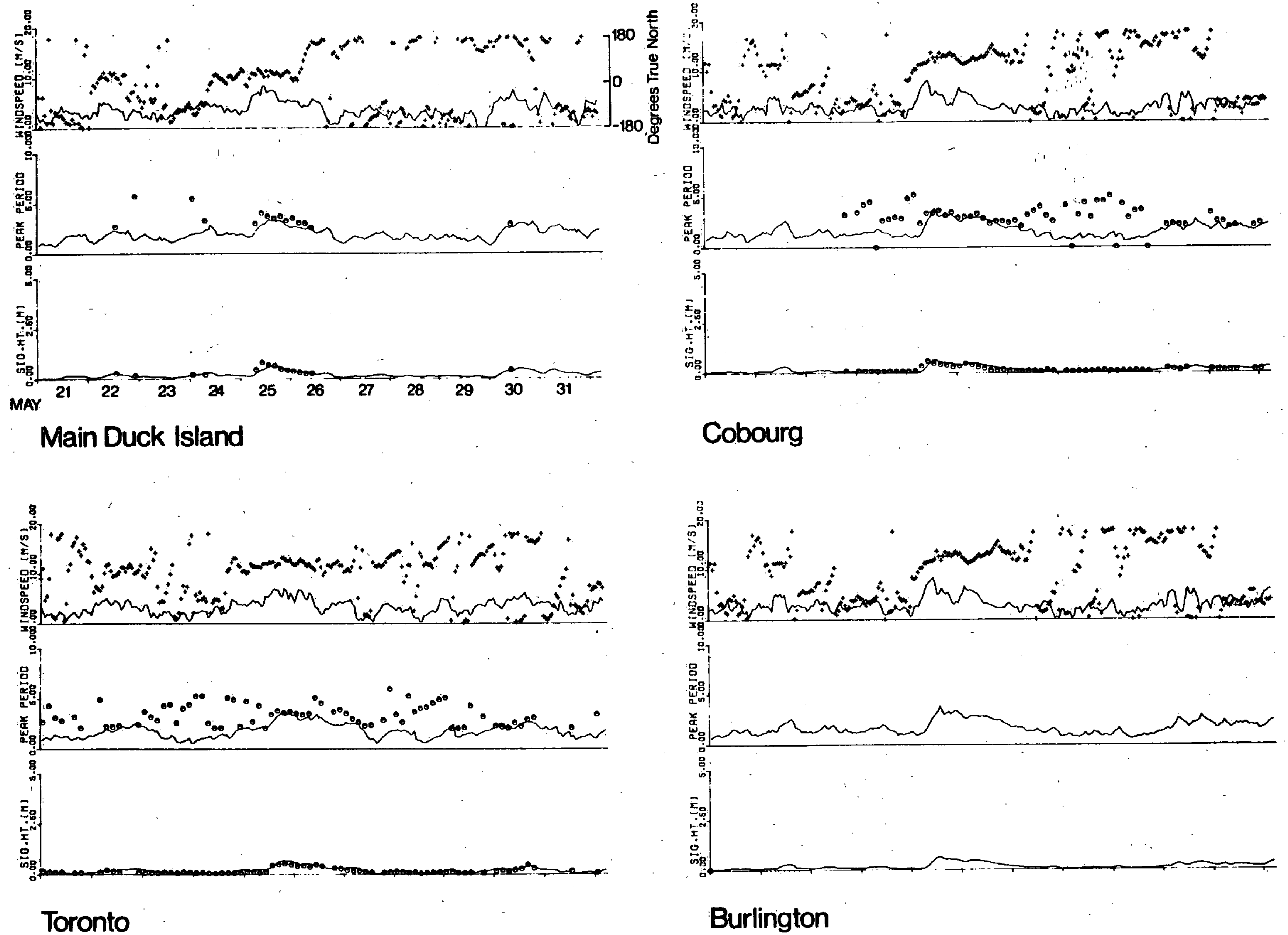


Figure A5 May 21 to 31, 1972

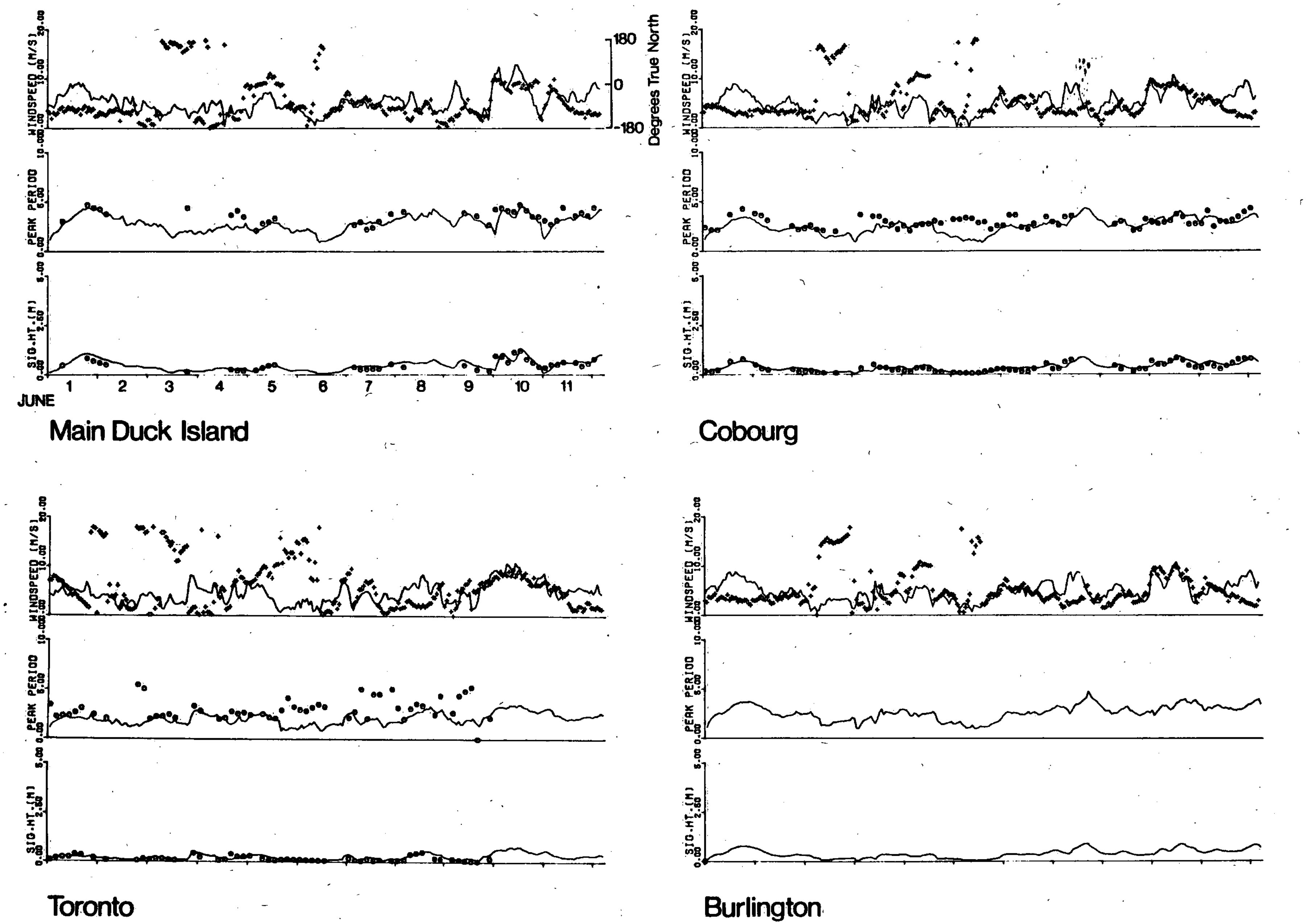


Figure A6 June 1 to 11, 1972

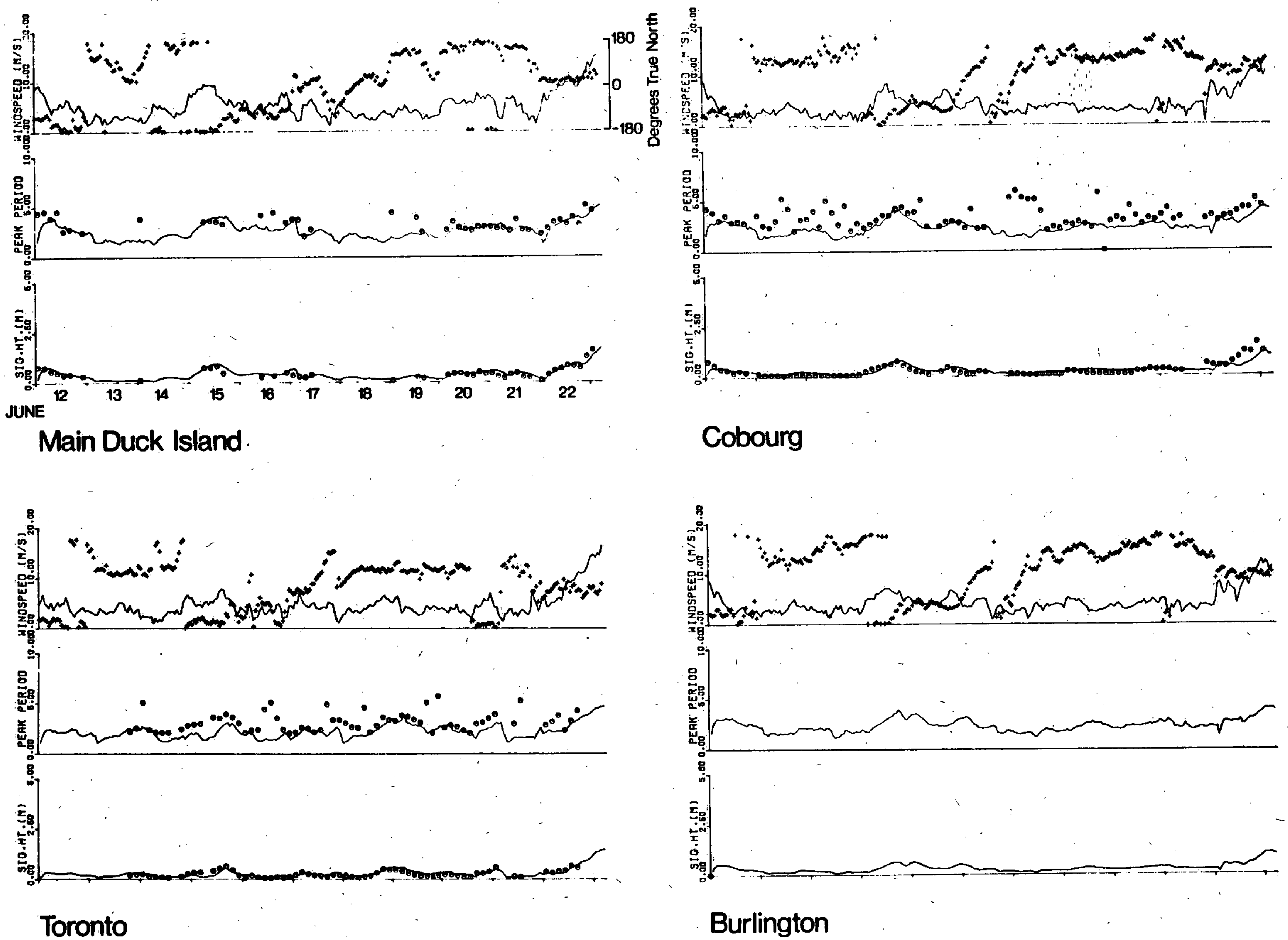


Figure A7 June 12 to 22, 1972

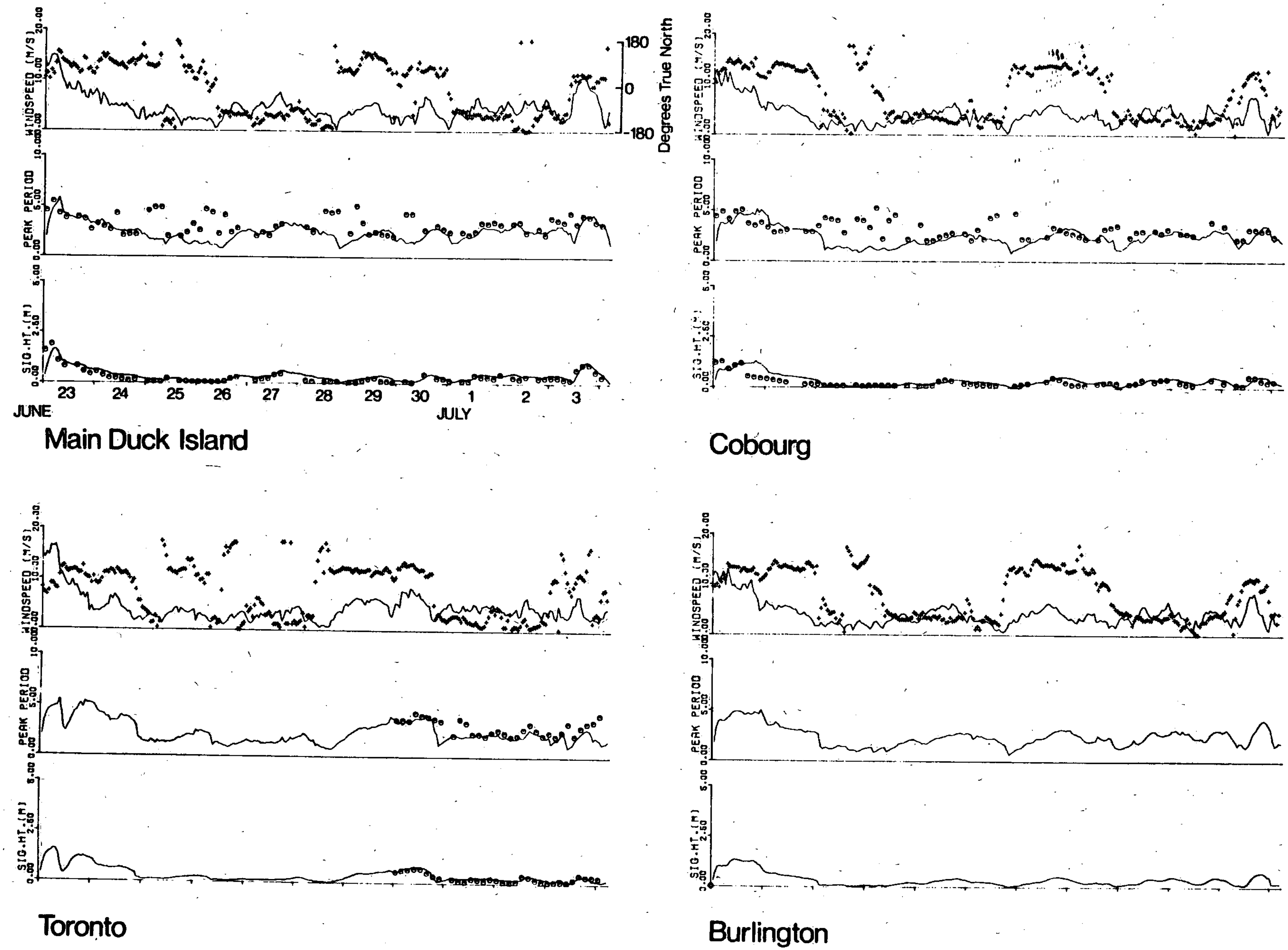


Figure A8 June 23 to July 3, 1972

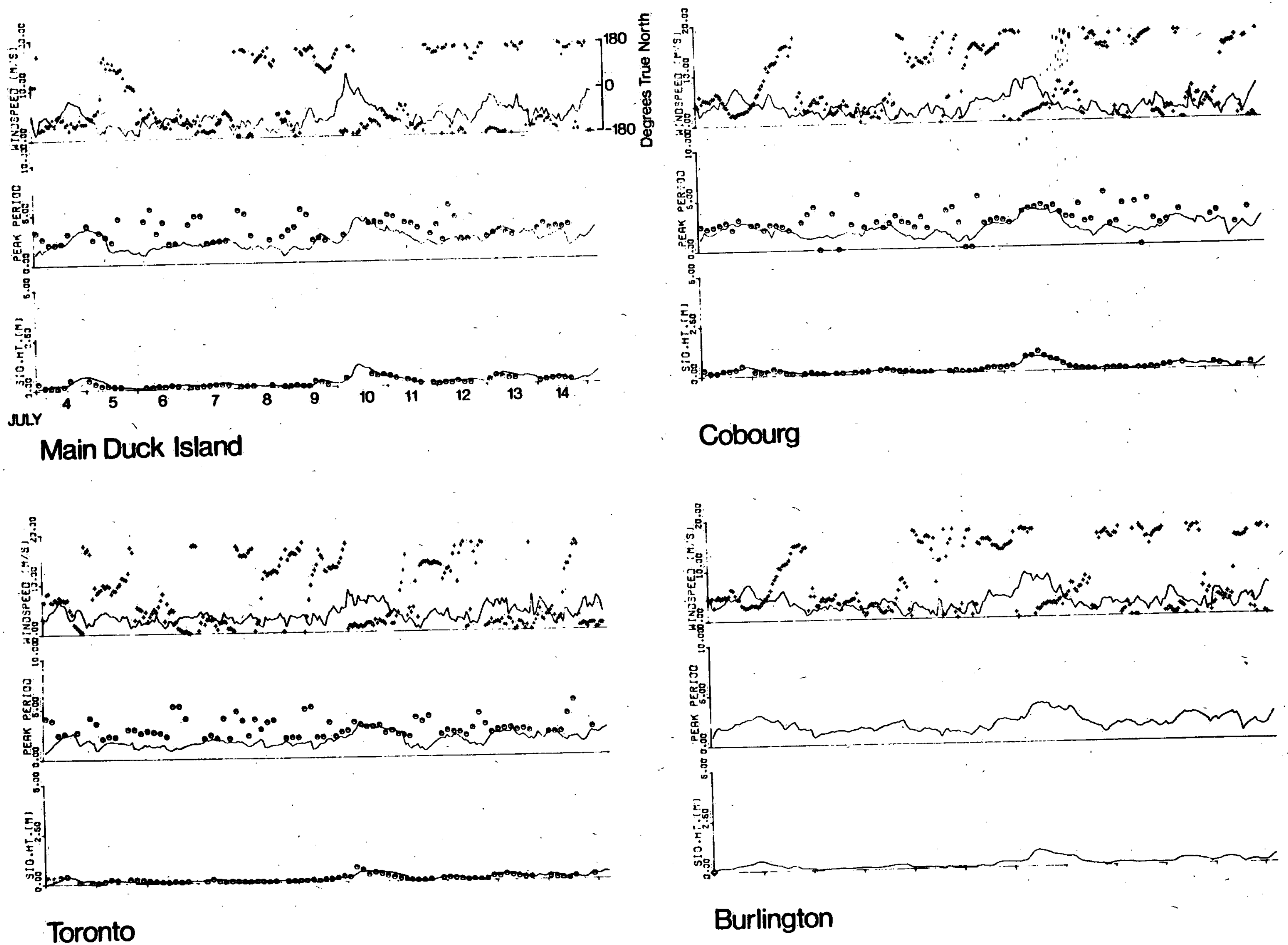


Figure A9 July 4 to 14, 1972

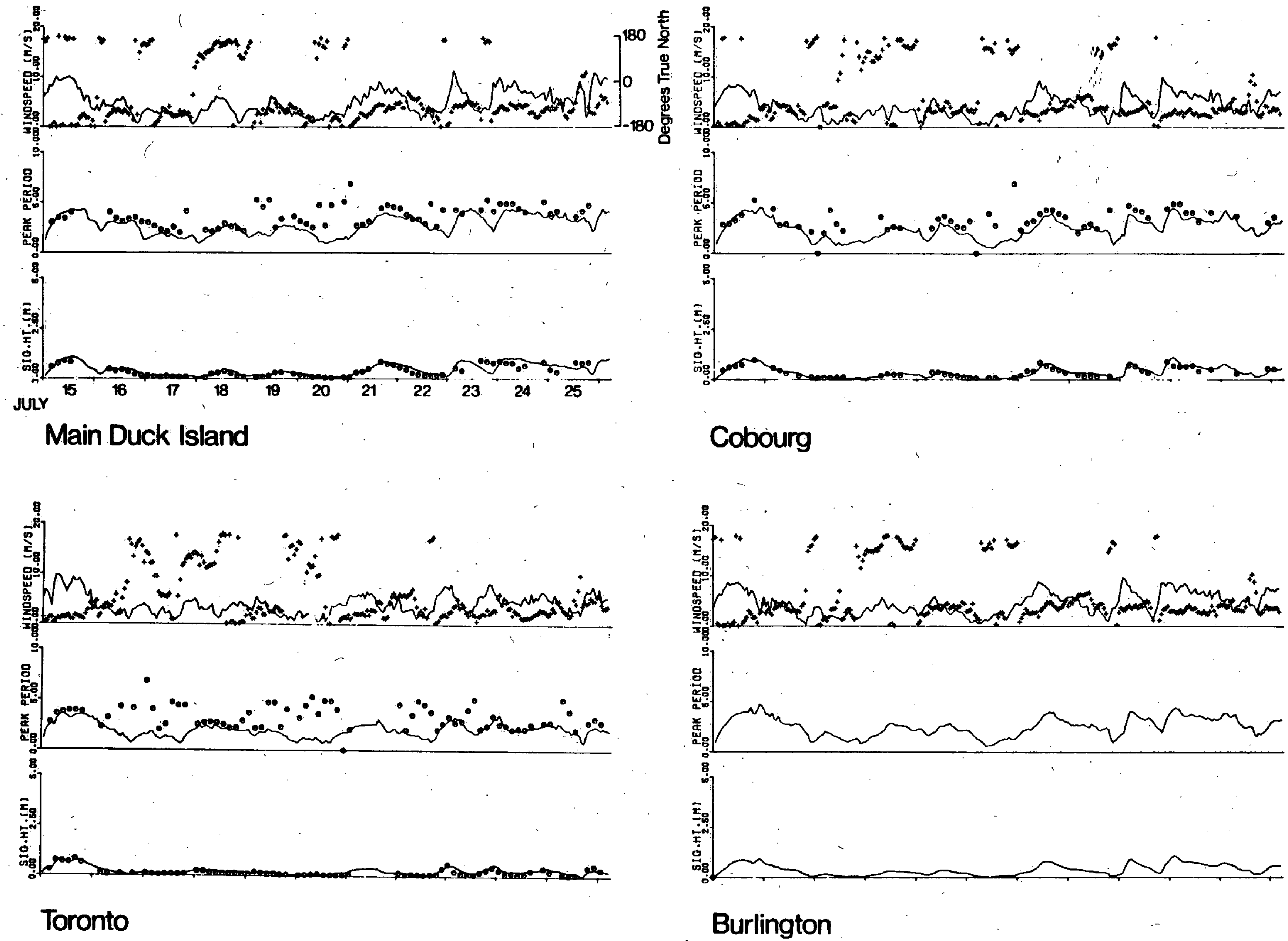


Figure A10 July 15 to 25, 1972

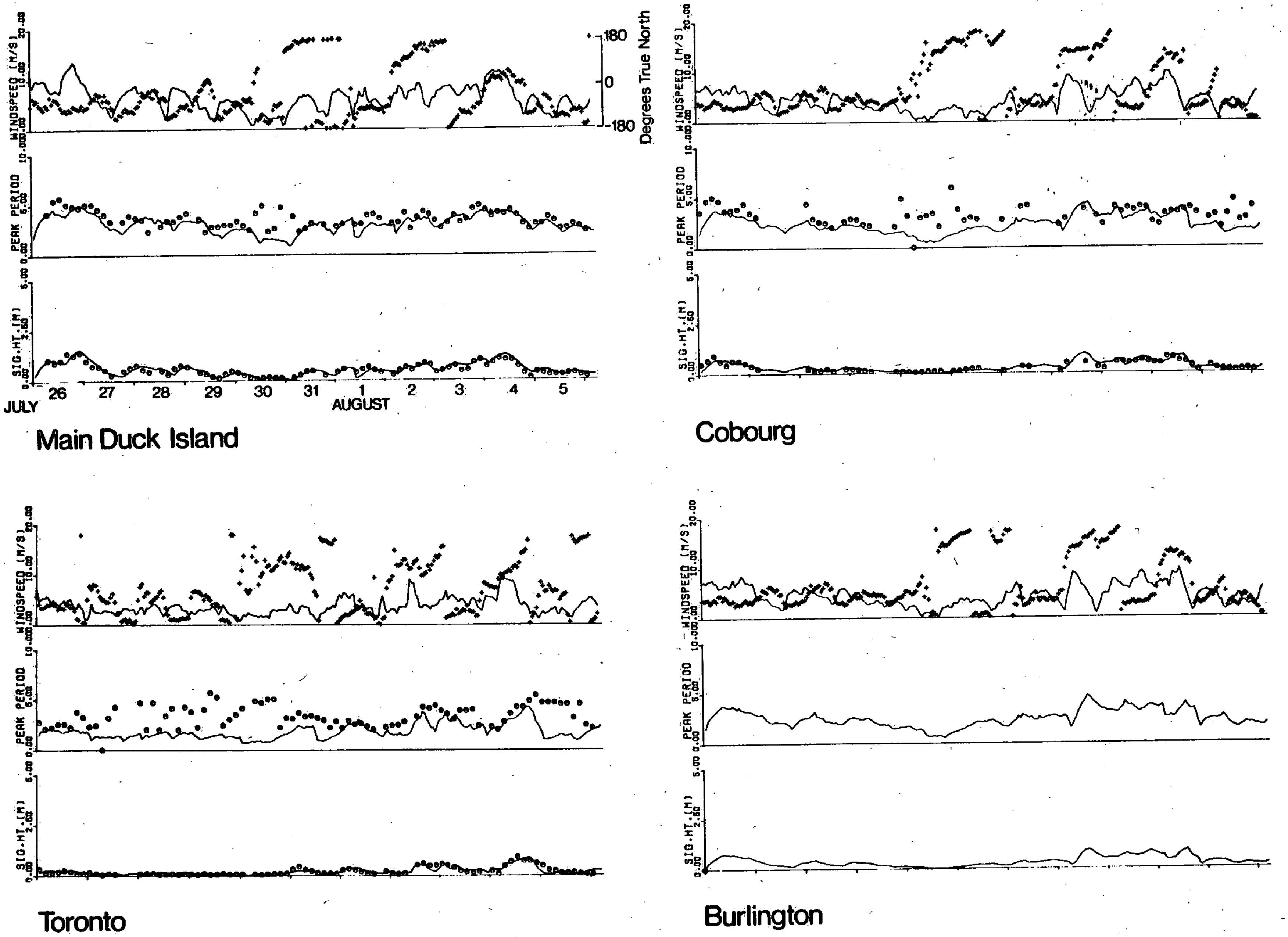


Figure A11 July 26 to August 5, 1972

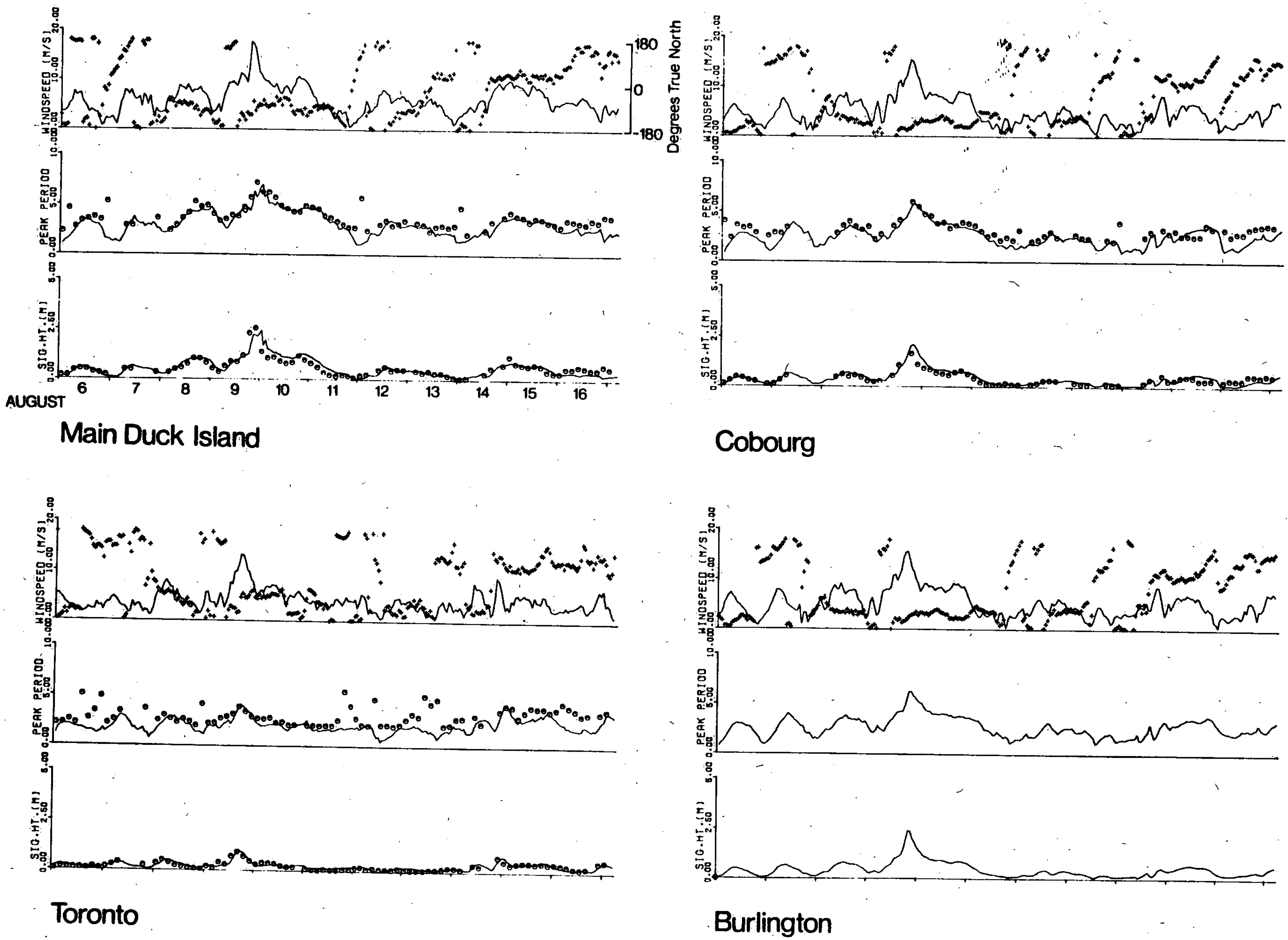


Figure A12 August 6 to 16, 1972

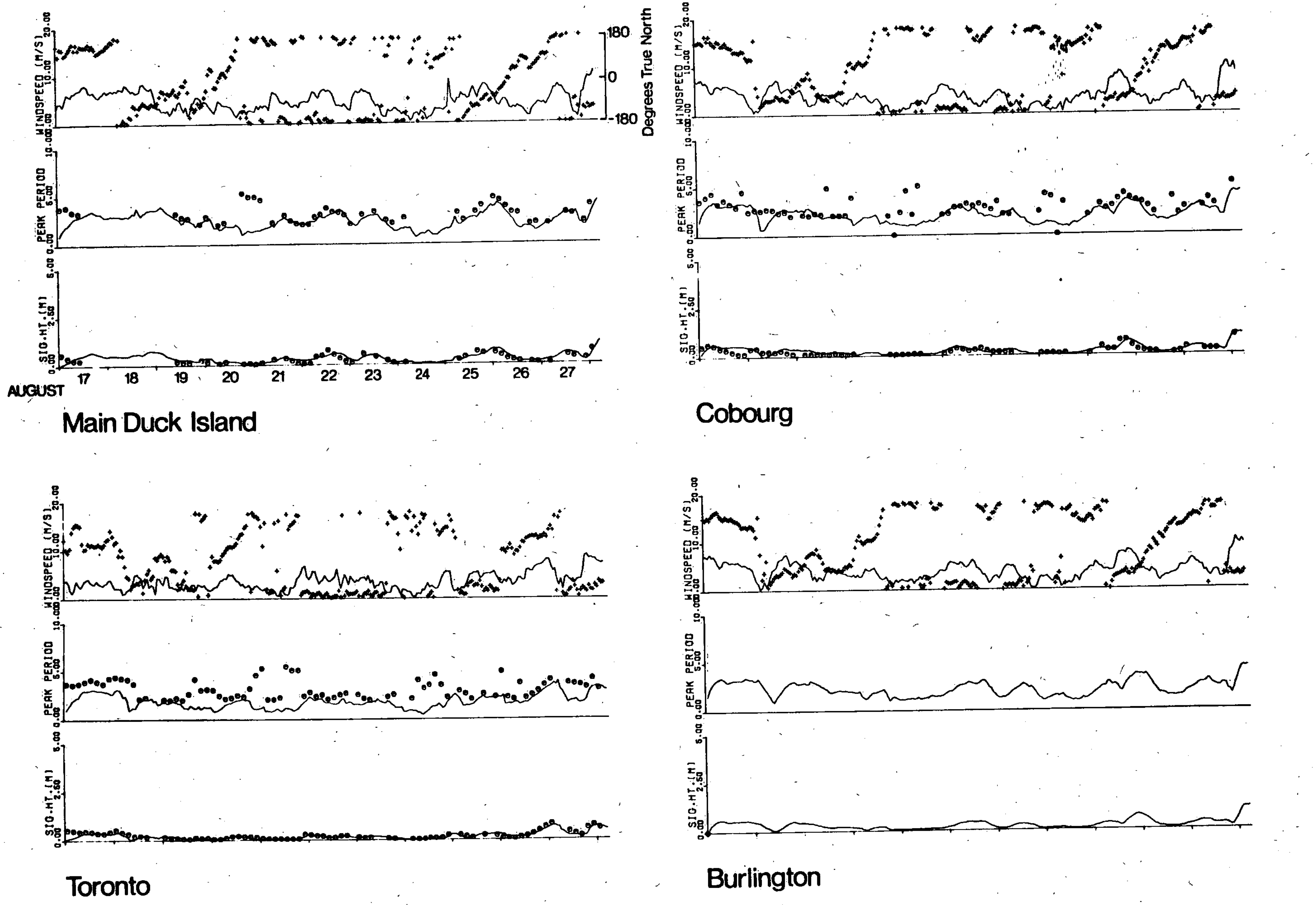


Figure A13 August 17 to 27, 1972

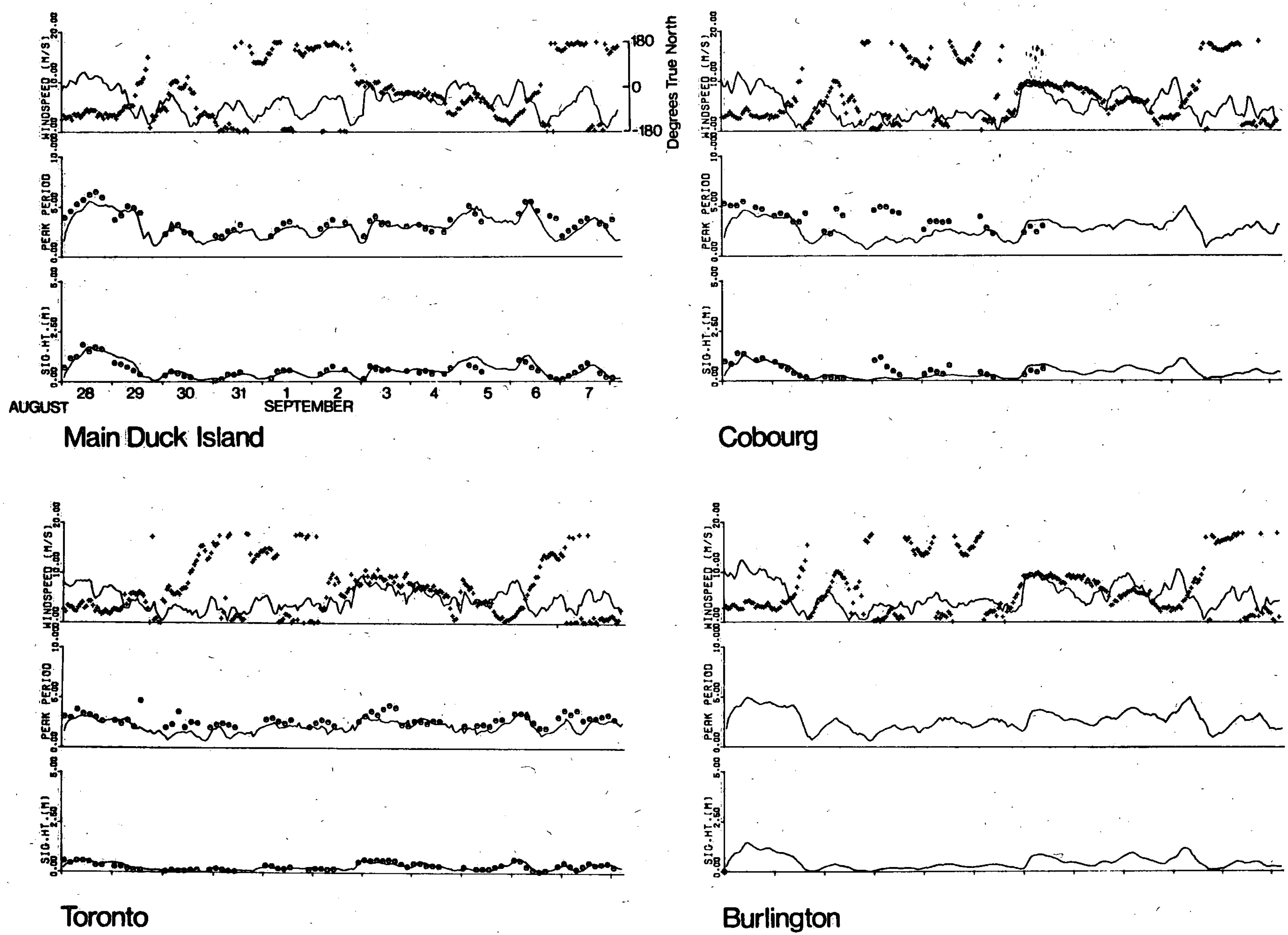


Figure A14 August 28 to September 7, 1972

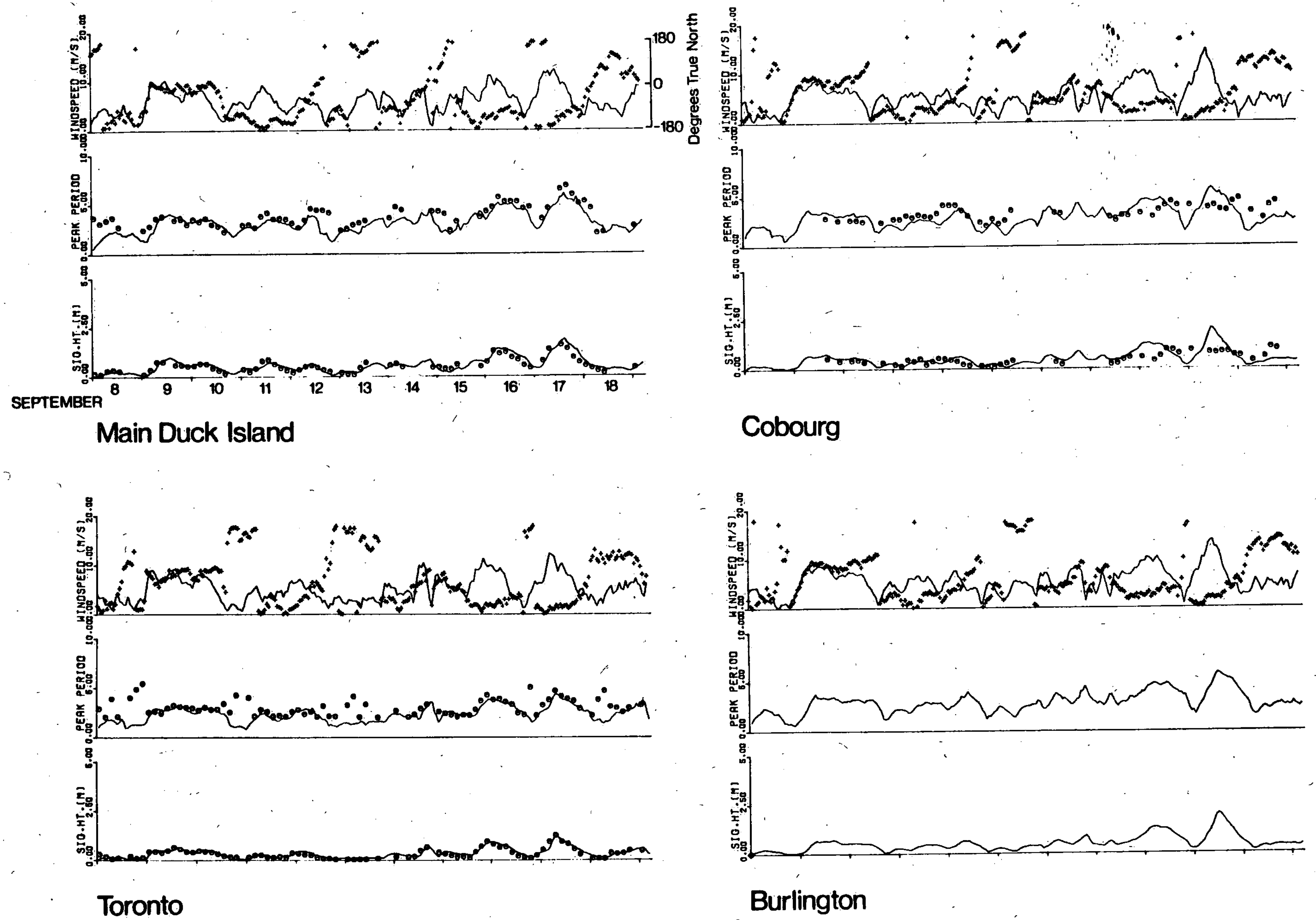


Figure A15 September 8 to 18, 1972

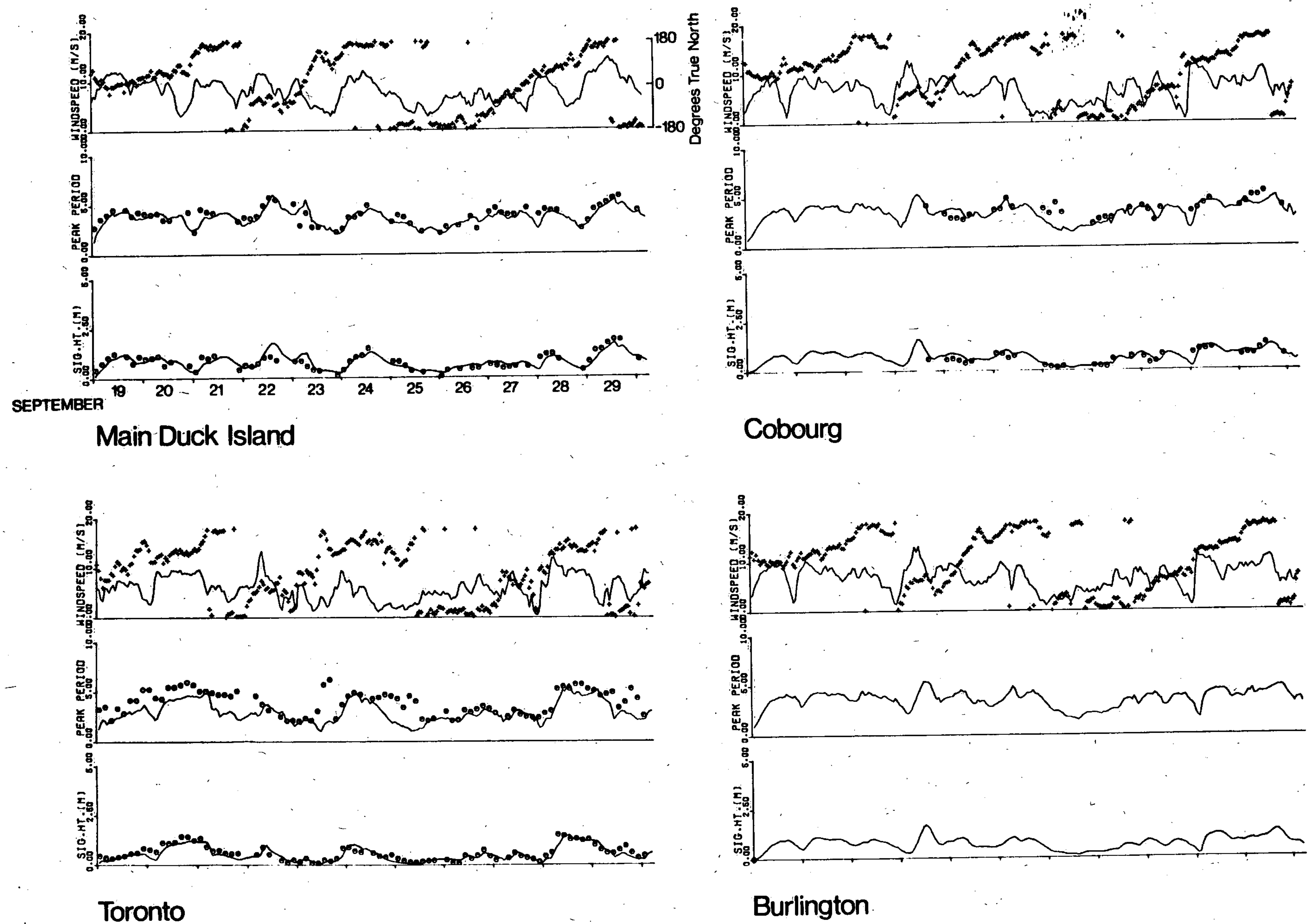
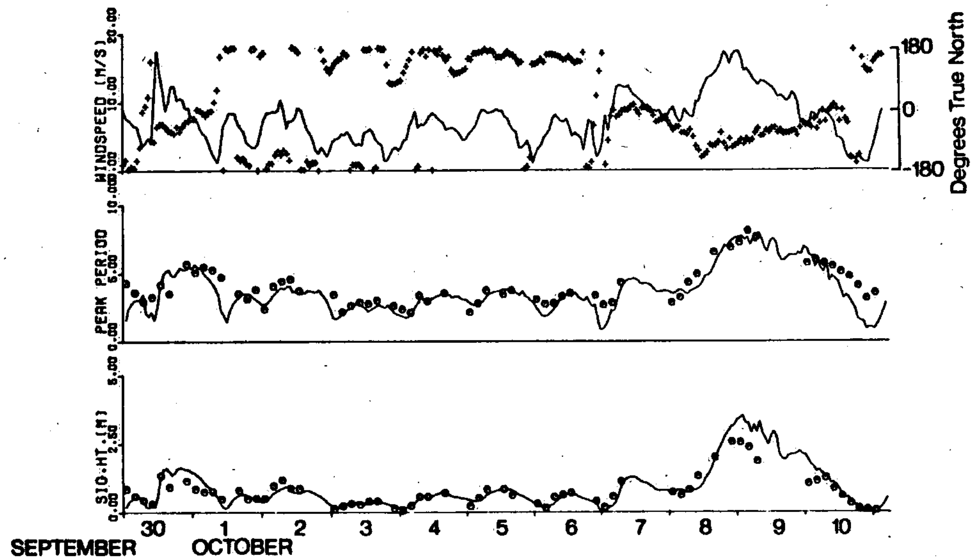
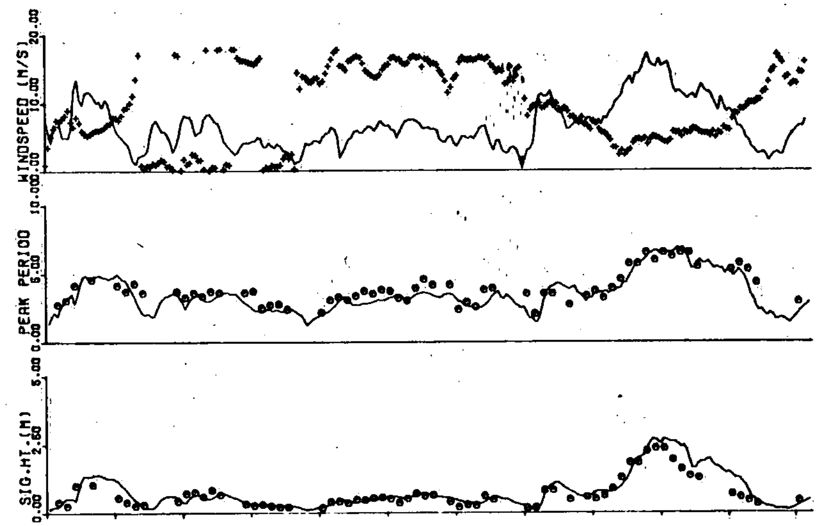


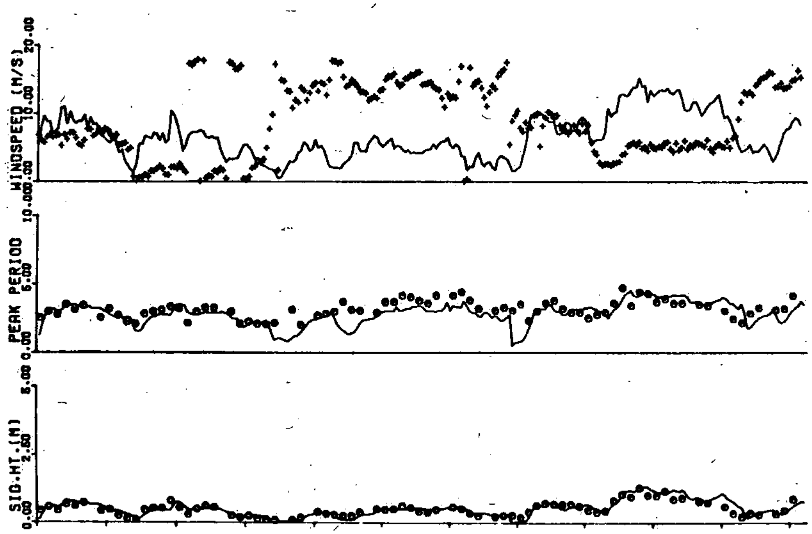
Figure A16 September 19 to 29, 1972



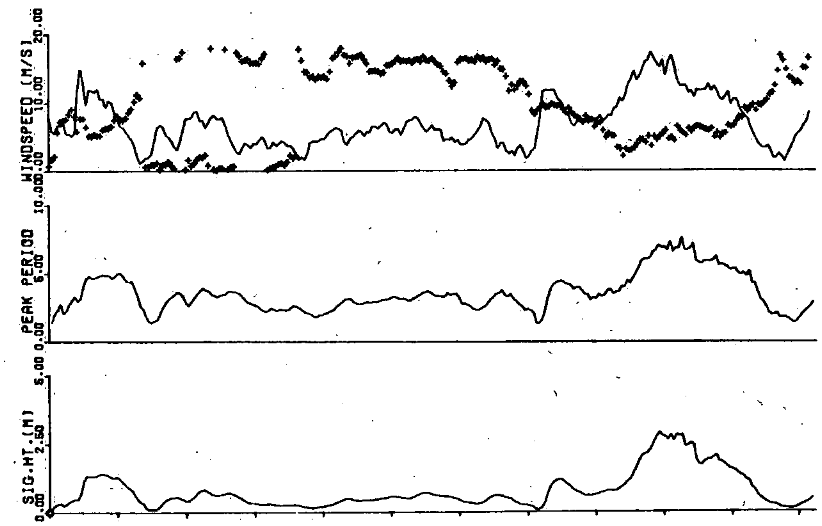
Main Duck Island



Cobourg

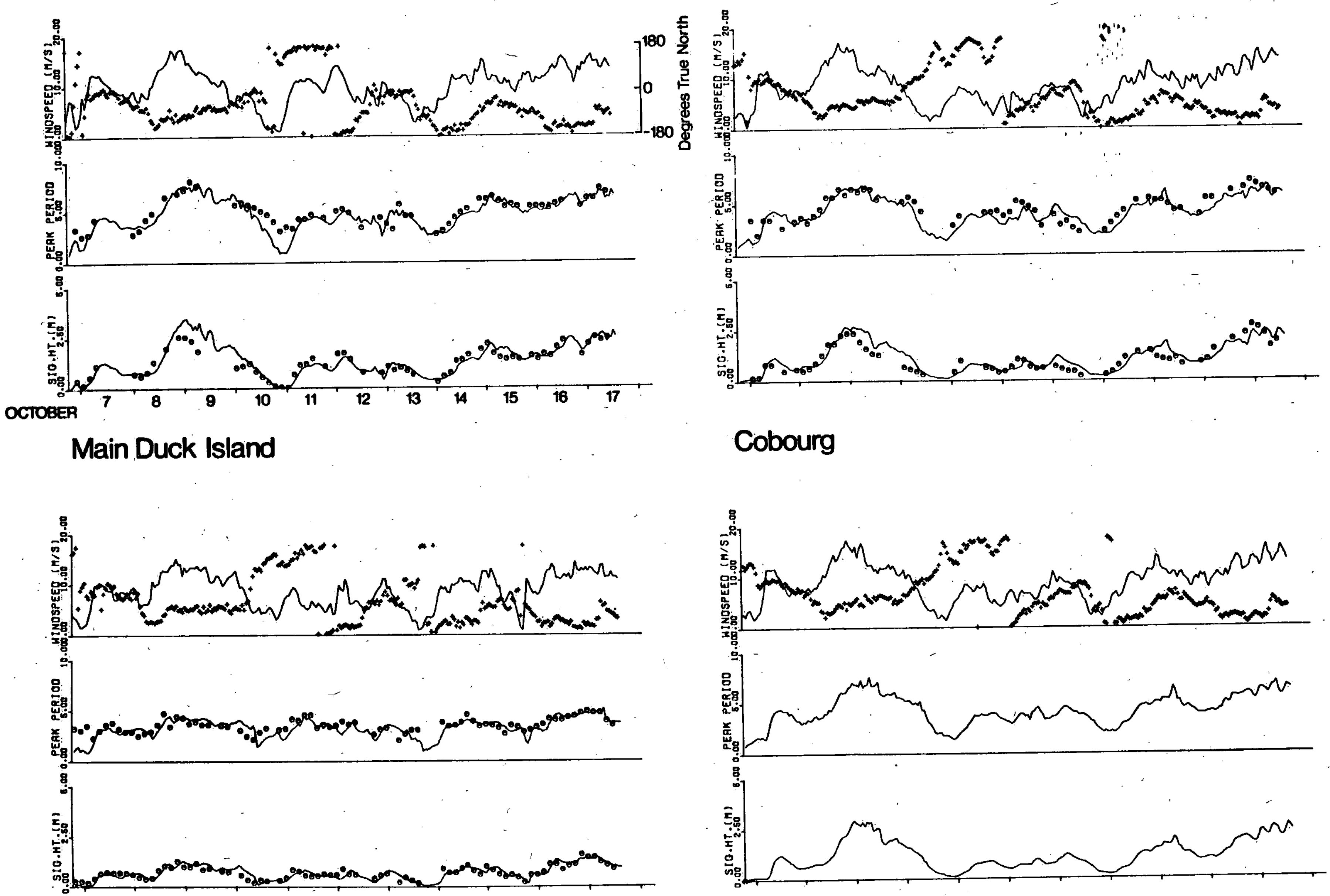


Toronto



Burlington

Figure A17 September 30 to October 10, 1972



Main Duck Island

Cobourg

Toronto

Burlington

Figure A18 October 7 to 17, 1972

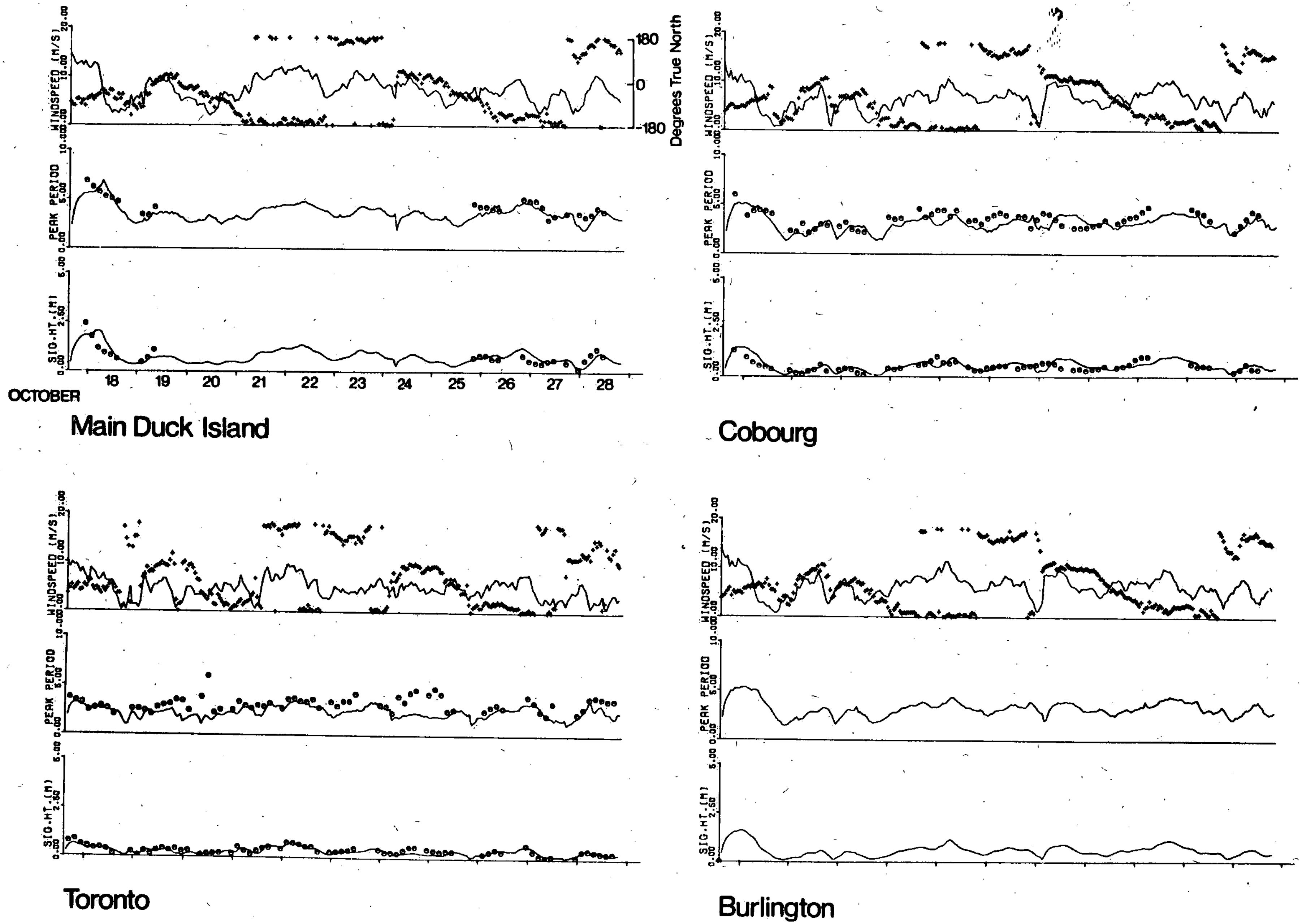
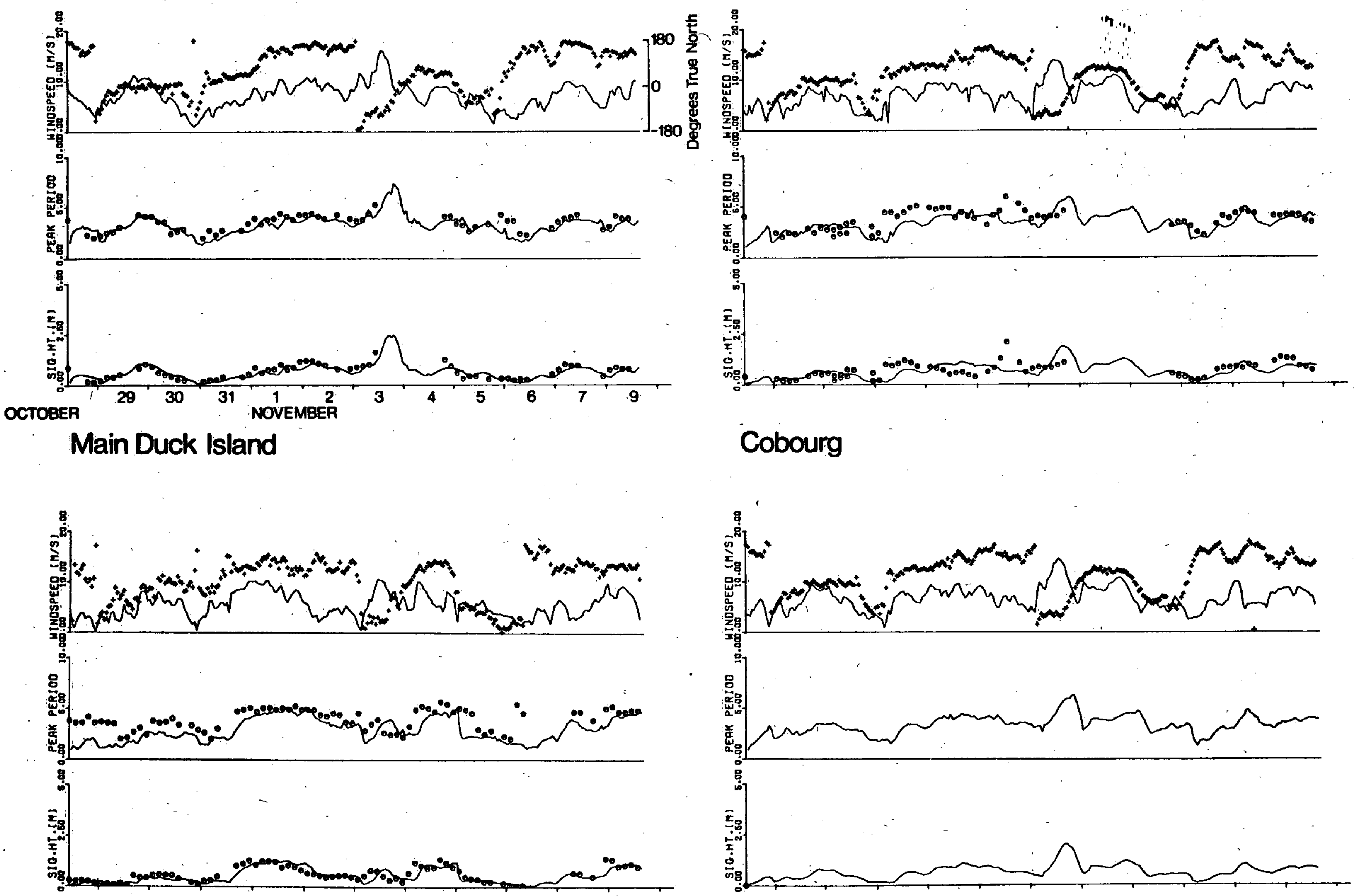


Figure A19 October 18 to 28, 1972



Main Duck Island

Cobourg

Toronto

Burlington

Figure A20 October 29 to November 9, 1972

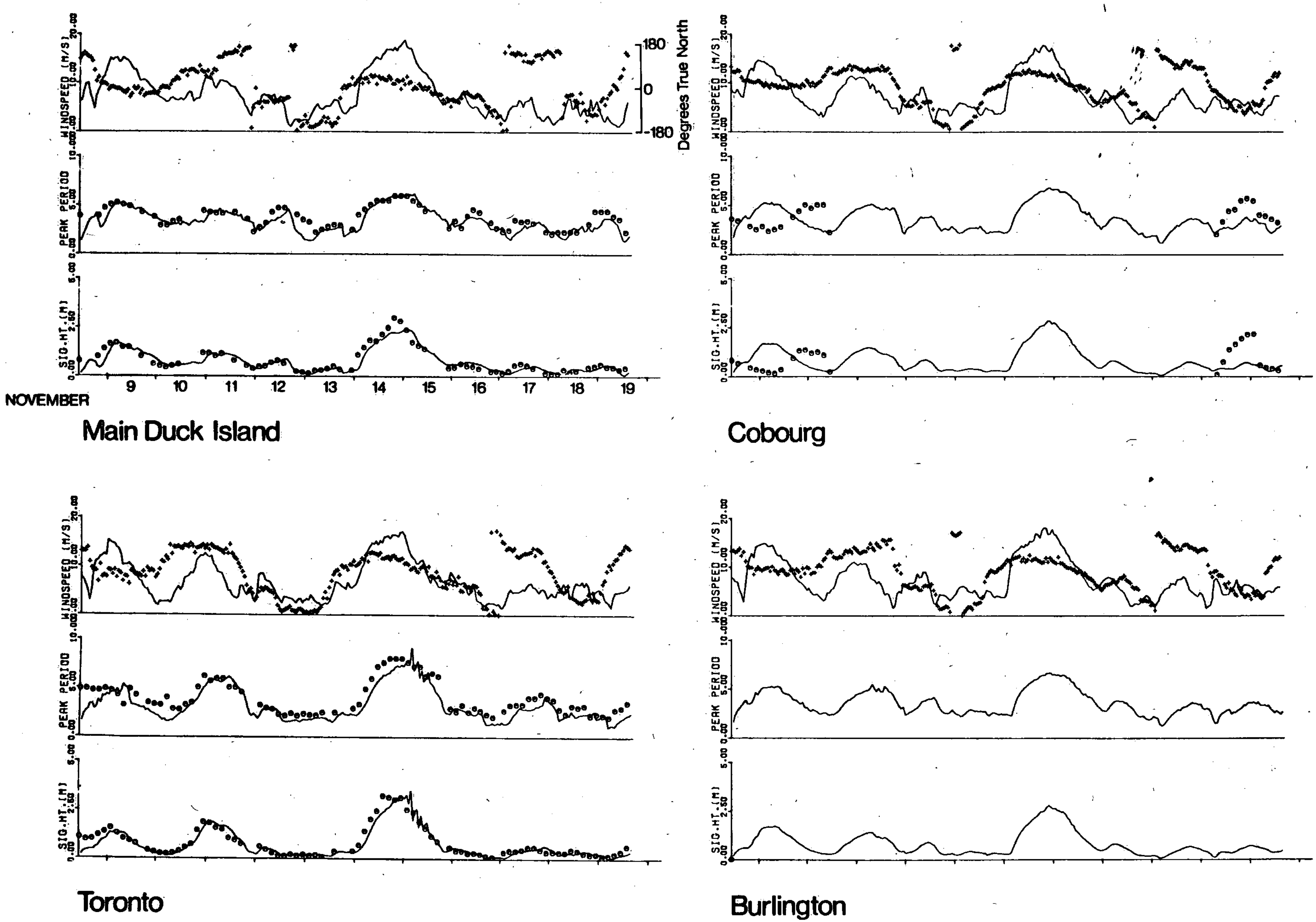


Figure A21 November 9 to 19, 1972

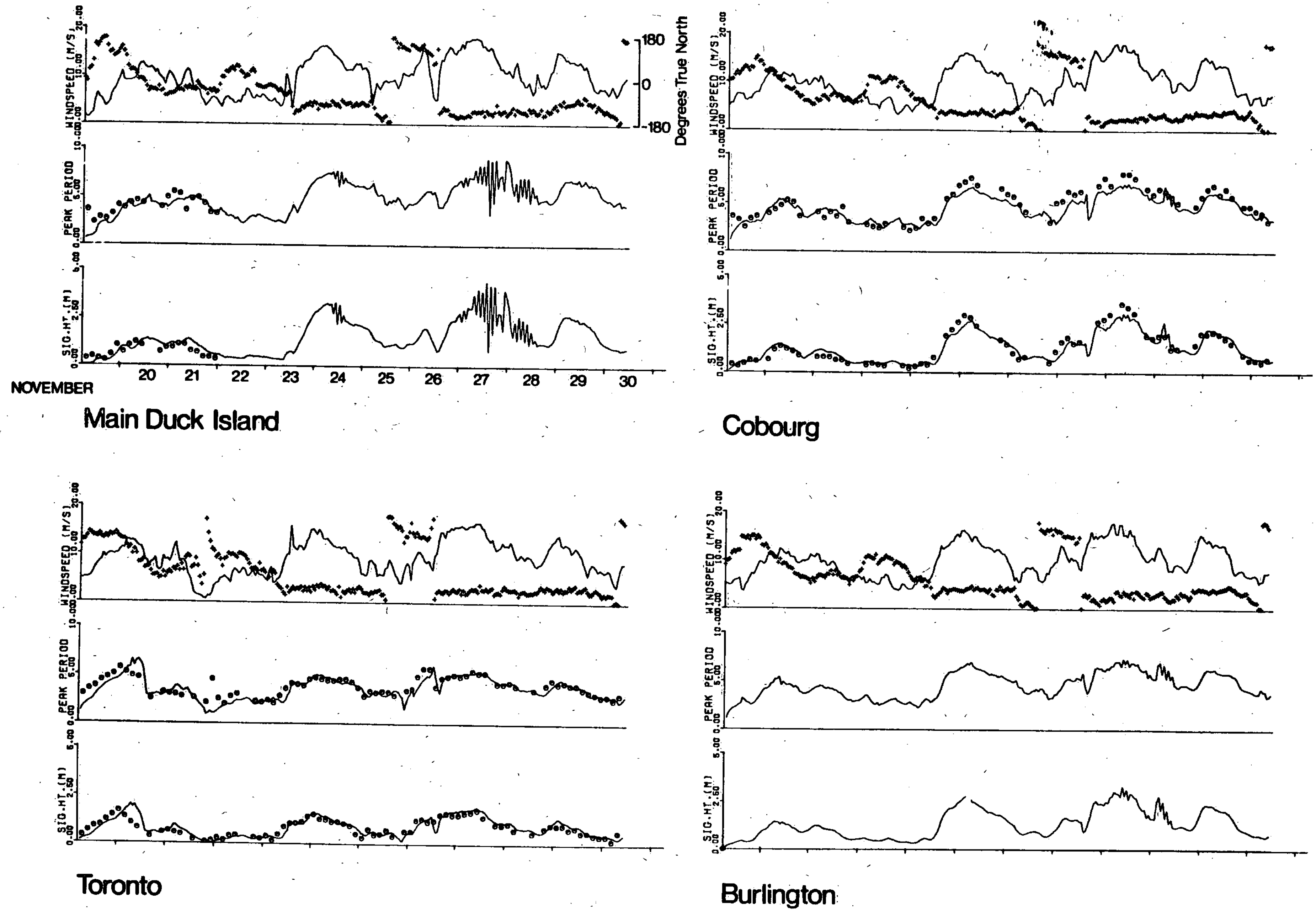


Figure A22 November 20 to 30, 1972

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