

THE METEOTSUNAMI OF JUNE 10, 2020, ON THE NORTHERN BRUCE PENINSULA

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SUMMARY

At 4PM on June 10, 2020, a strong and locally damaging seiche was initiated in Baptist Harbour and continued for 6 hours. The seiche onset was abrupt and coincided with the arrival of a storm front from the southwest. One minute resolution water level measurements were ongoing in Baptist Harbour throughout, and at two other locations located 4km apart along the storm front's path. The data from these two suggest that the seiche was initiated by a meteotsunami wave traveling under the storm, with amplitude of 10-20cm, period roughly 20 minutes and a wavelength of several kilometres. Its success in initiating a severe seiche in Baptist Harbour was due to (1) its direction coinciding with the harbour axis and (2) its period closely matched the resonance period of that harbour.

INTRODUCTION.

On rare occasions a dramatic water level rise and fall occurs in one or more embayments - harbours, inlets, bays - on the Bruce Peninsula. The period - that is the time between two successive highs - is on the order of minutes to tens of minutes, very slow compared to normal waves but fast compared to tides. In severe instances harbours can be almost drained of water, dropping boats onto the bottom, only to lift them up onto the dock minutes later.

These events are believed to be often caused by meteotsunamis, tsunamis waves resulting from abrupt barometric pressure changes. While meteotsunamis can cause seiches within the embayments they impact, they are not themselves seiches. One of the best and by far the most lyrical descriptions of a major meteotsunami event can be found in chapter 7 of Sherwood Fox's wonderful book "The Bruce Beckons".

"The straight at the bridge was beginning to boil and foam in an unusual manner. Each incoming seiche was rising higher and with more commotion than the one before, and each ebb sank lower and more noisily than the ebb that had just preceded it. The span between high water and low water was now at least a foot and was increasing with each reversal of the current which had now the volume of a stream after a thaw. Though we were standing at the summit of the island 200

yards from the turmoil the roar of it tingled in our ears. The whole scene touched every nerve within us. Even the birds were behaving oddly.”

The full Wikipedia entry for meteotsunamis is as follows.

A **meteotsunami** or **meteorological tsunami**^[1] is a *tsunami*-like *sea wave* of *meteorological* origin. Meteotsunamis are generated when rapid changes in *barometric pressure* cause the displacement of a body of water. In contrast to "ordinary" impulse-type tsunami sources, a traveling atmospheric disturbance normally interacts with the ocean over a limited period of time (from several minutes to several hours).^[2] Tsunamis and meteotsunamis are otherwise similar enough that it can be difficult to distinguish one from the other, as in cases where there is a tsunami wave but there are no seismic records of an earthquake.^{[2]:1036} Meteotsunamis, rather, are triggered due to extreme weather events including severe thunderstorms, squalls and storm fronts; all of which can quickly change atmospheric pressure. Meteotsunamis typically occur when severe weather is moving at the same speed and direction of the local wave action towards the coastline. The size of the wave is enhanced by coastal features such as shallow continental shelves, bays and inlets.^[3]

The Sources of Knowledge Forum (SOK) maintains a small network of water level monitoring stations in the Tobermory area whose purpose is to intercept meteotsunami events and document their characteristics. Previous SOKF studies¹ have concentrated on cataloguing the resonant frequency spectra of the small, continuous water level oscillations (seiches or “harbour oscillations”) of local inlets and harbours. If these harbour oscillations can be thought of as the ringing of a bell hit continuously with a very light touch, then the incoming meteotsunami events are, under the right circumstances, the

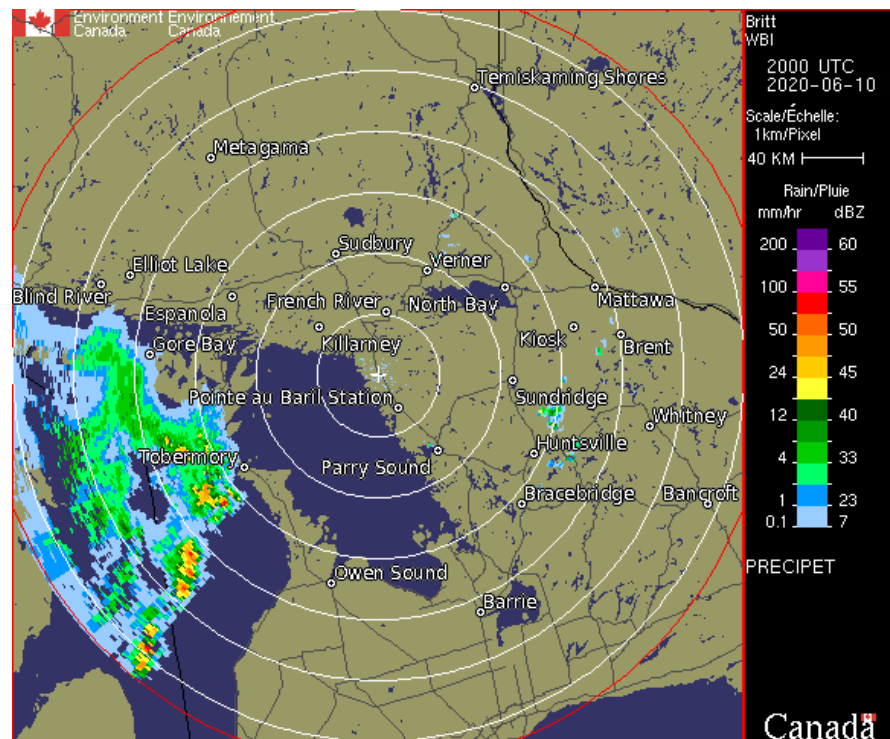


Figure 1. Radar representation of the storm front approaching the Northern Bruce Peninsula at 1600hrs, June 10, 2020.

¹ <https://www.sourcesofknowledge.ca/wp-content/uploads/2019/06/TIDES-O-THE-BRUCE..pdf>

equivalent of hitting the bell with a sledge hammer. What is not clear is the nature of these circumstances. Why do some meteotsunamis have no damaging effects at all, or produce violent reactions in some harbours but not in others? Nor are the characteristics of these meteotsunamis well documented. What is the amplitude of these waves, their frequency, their wavelength and their speed of travel.

On Wednesday, June 10th, of this year our data suggest that a moderately strong meteotsunami arrived on our coastline at 4PM. It arrived simultaneously with a strong storm front (Figure 1) traveling from southwest to northeast at roughly 100 km/hr. It produced a violent seiche in Baptist Harbour, which “rang” every 17 minutes for several hours with water level variations approaching two metres. At least one dock was swept off its concrete footing, and the foundations of houses close to the water were threatened. Other harbours along the west coast suffered unusual damage (Appendix A). The storm was followed by wind stress over the next two or three days which raised water levels by 15 cm in Tobermory but, while related to the meteotsunami event, wind stress effects are a distinct phenomenon.

The SOKF water level stations are located in Baptist Harbour, in the lee of Devil Island and in the outer Tobermory Harbour (Figure 2). The Devil Island location was chosen on the assumption that it would provide a record of an incoming meteotsunami event uncontaminated by harbour oscillations. (Ideally the measurement would be made well off-shore, but there are logistical problems with doing that beyond our capabilities.) The stations record water levels every minute, and the station in Tobermory Harbour also measures barometric pressure every minute. Water levels were measured using Hobo pressure sensors placed on the lakebed at Devil Island and Tobermory harbour, while an inverted tube arrangement with pressure sensors inside and out was attached to a dock in Tobermory harbour.



Figure 2. SOKF network locations, showing the general direction of the storm front on the afternoon of June 10th

Water levels are also available from the Tobermory Little Tub Harbour operated by the Department of Fisheries and Oceans but only at 3 minute intervals. Barometric pressure recordings are available from Environment Canada, but only at 1 hour intervals.

It must be emphasized that this article is not peer-reviewed science. I hope it is more than the delusional ravings of one retired scientist, but that possibility should be kept in mind!

THE DATA

Tobermory harbour.

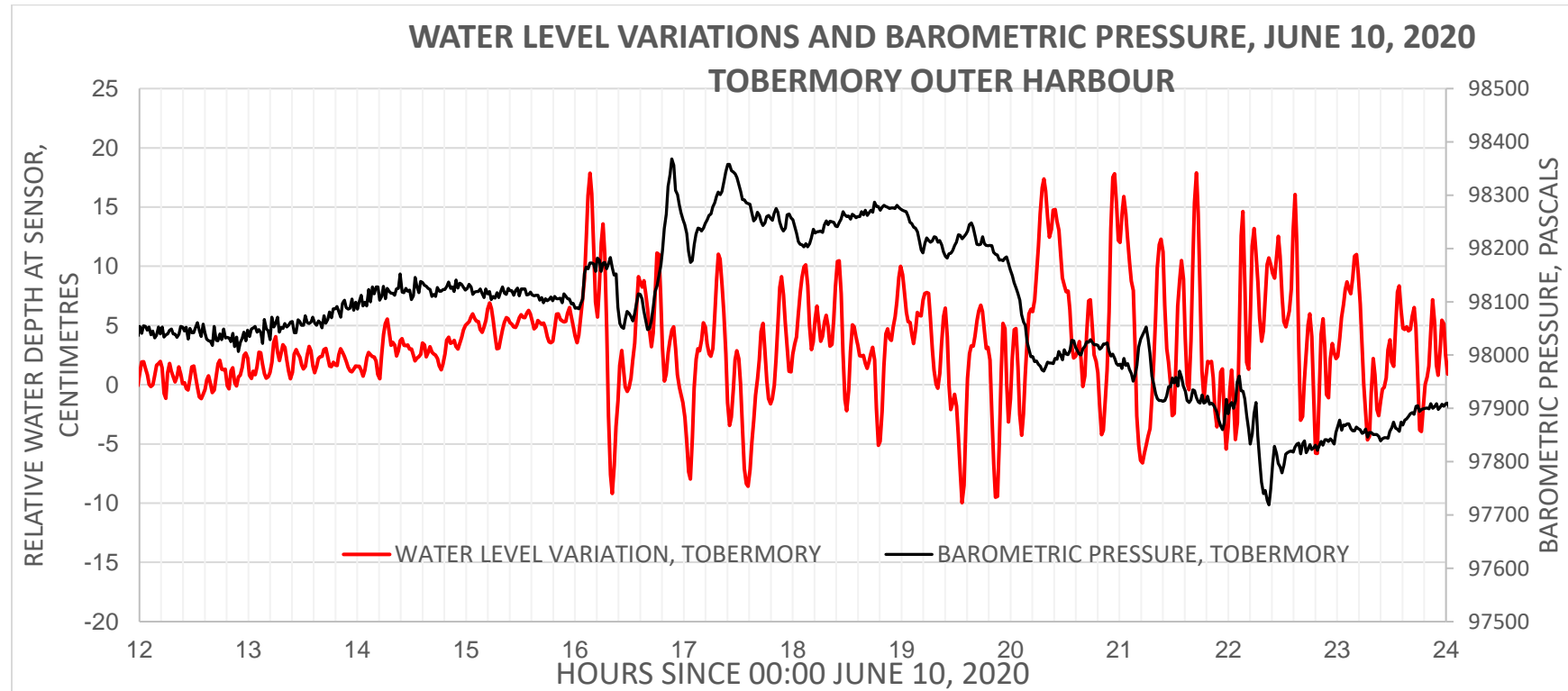


Figure 3a. Water level and barometric pressure variations in Tobermory outer harbour from noon to midnight on June 10, 2020.

Figure 3a shows the water level variation and barometric pressure at Tobermory outer harbour for the hours from noon to midnight on the 10th. The water level record has been offset so that the pre-storm level is roughly zero. Figure 3b gives detail of these records in the one hour period 15:30-16:30 hours. Some notable aspects of Figure 3a and 3b follow.

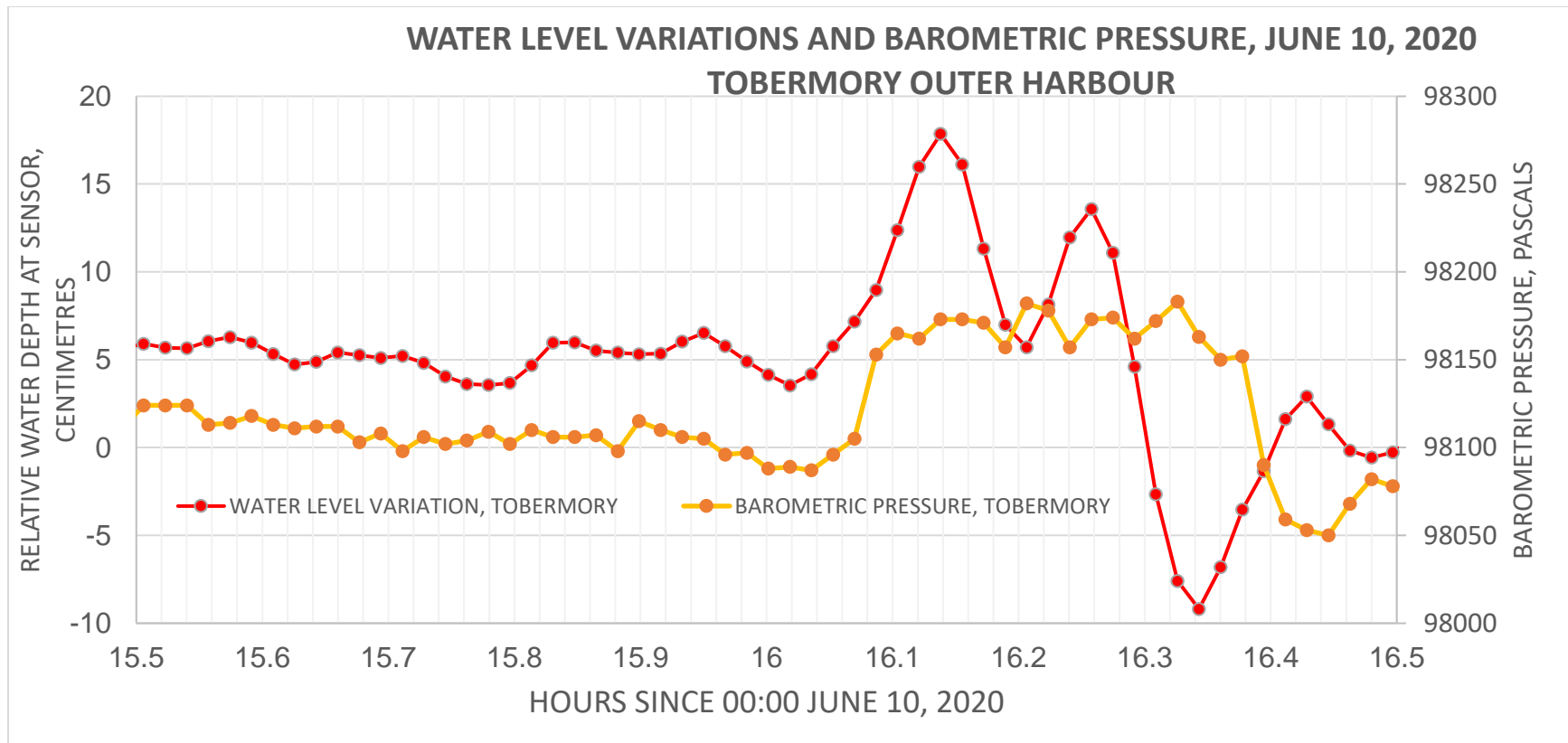


Figure 3b. Detail of the records in Figure 3a for the one hour period bracketing the storm arrival at 16:00hr. The symbols indicate readings made every minute.

- a. The storm arrival at 16:05 in Tobermory Harbour is very sharp, an increase in barometric pressure of 80 Pascals in one minute. The atmospheric disturbance as a whole lasts roughly 6 hours, coinciding with the weather radar image's passage over the peninsula.

- b. An abrupt water level increase of 15 cm over a 5 minute period coincides with the abrupt pressure increase, suggesting a cause and effect relationship.
- c. The “chatter” or noise observed on the water level record prior to the storm in Figure 3a arrival prior is not system noise. Figure 3b shows that the short period variations of 1-2 cm are well resolved, not one reading blips.
- d. The water level record following the sharp onset is reminiscent of the wake of a boat – in this case a barge with length and width measured in tens of kilometres! The bow wave is very sharp followed by trailing waves with wavelengths comparable to the length of the “boat”. The physics of this analogy may not hold up well, but the mental image is useful.
- e. The increase in barometric pressure at the storm’s onset would be expected to depress the water level. Instead we see an increase! Apart from the onset there is little correlation in the fine structure of the two records. The sharp pressure decrease at 20:00 does, however, appear to re-energize the water level oscillations. As will be seen in Figure 5, it is following 20:00 that the major water level swings – and damage – occur in Baptist Harbour. Spectral analysis of these records (shown in Appendix 3) shows a dominant periodicity of 37 minutes. This manifests itself in Figure 3 through the interval between some major highs and lows, for example the first three lows following the onset, or the two highs between 20:00 and 21:00 hours. This is a property of the site, not the storm. Devil Island.
- f. The 37 minute periodicity is a property of the site and not the storm. It is present consistently in multiple spectra taken there in non-storm times. Compared to non-storm spectra, the storm appears to add energy at 10 and 20 minute periodicity, with the effect of broadening the 37 minute peak.

Figure 4a shows the water level variations at Devil Island and compares them to those at Tobermory harbour. Figure 4b shows more detail of this record highlighting the offset between the two measuring stations. The two records are very similar but offset by 5 minutes, representing storm travel time over the 3.75 km the two locations are offset along the storm’s southwest to northeast path. Most of the points made above in connection with Figure 3 apply here as well but also ...

- a. The similarity of two records and the consistent offset of 3-5 minutes tends to confirm that this wave pattern is moving with the storm from southwest to northeast. Once again the dominant energy in the spectrum of interest centres on 37 minutes but there is a superimposed shorter period and lower amplitude oscillation of around 4 minutes.
- b. There is, however, the question of timing offsets between clocks in different instruments. All three clocks had been synchronized 5 days earlier. The Hobo loggers at Devil Island and Baptist Harbour have clock accuracy rated at +/-1 min/month, while the DS 3231 clock at Tobermory Harbour has accuracy of +/- .08seconds per day. There seems no reason to doubt the time offsets observed.
- c. Examining just the initial onset in Figure 4b, the black vertical line is located to coincide with the onset of the sudden rise at Tobermory harbour. At that time the onset at Devil Island has reached its peak. Assuming the two stations are 4 km apart the lake surface between them might look something like shown in Figure 5.

- d. The concept of a very small amplitude, very long wavelength wave is not easily imagined, but there is a lot of water being moved up and down (roughly 9000 cubic metres in a 1 metre cross-section of 15 cm high wave!). Figure 5 is a conceptualization of what this wave might look like along the storm path.
- e. The storm spectrum at Devil Island, like that at Tobermory Harbour, shows additional energy at 10 and 20 minutes.

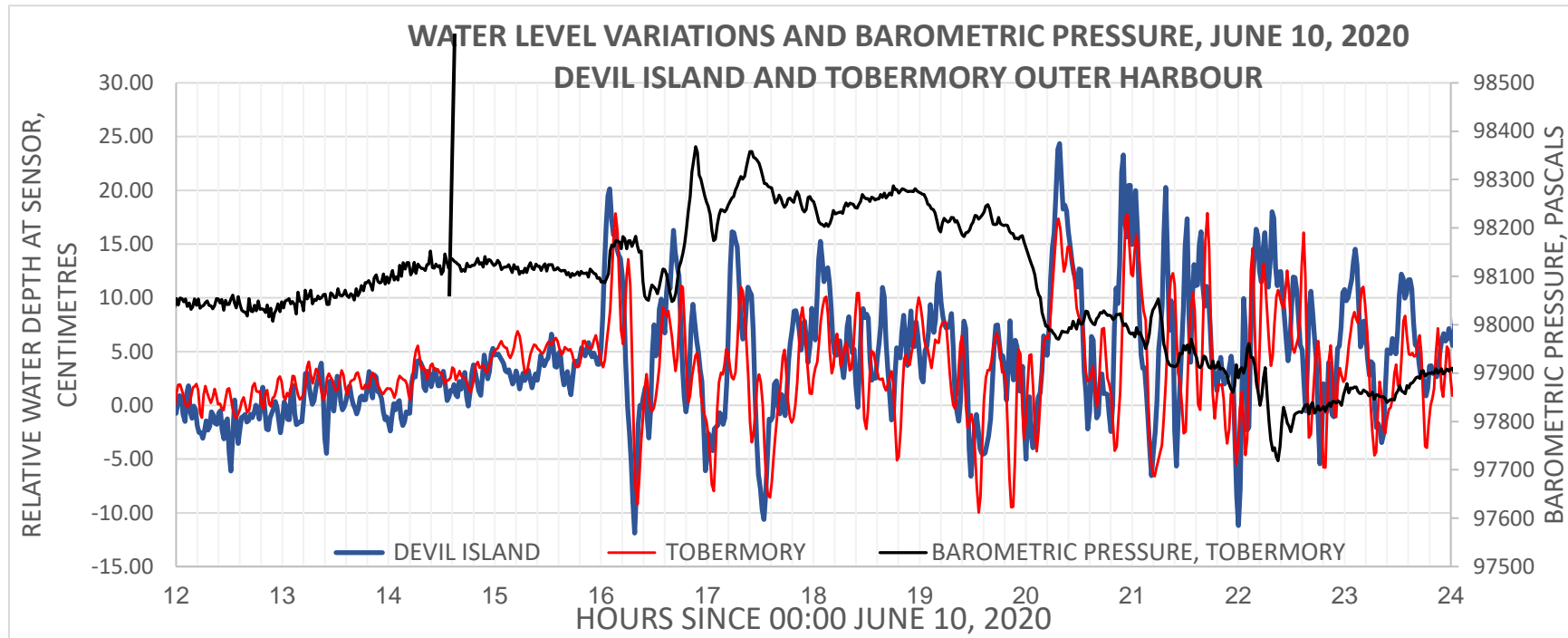


Figure 4a. The water level variations at Devil Island compared to those at Tobermory outer harbour, and to the barometric pressure. Vertical grid lines are spaced by 12 minutes.

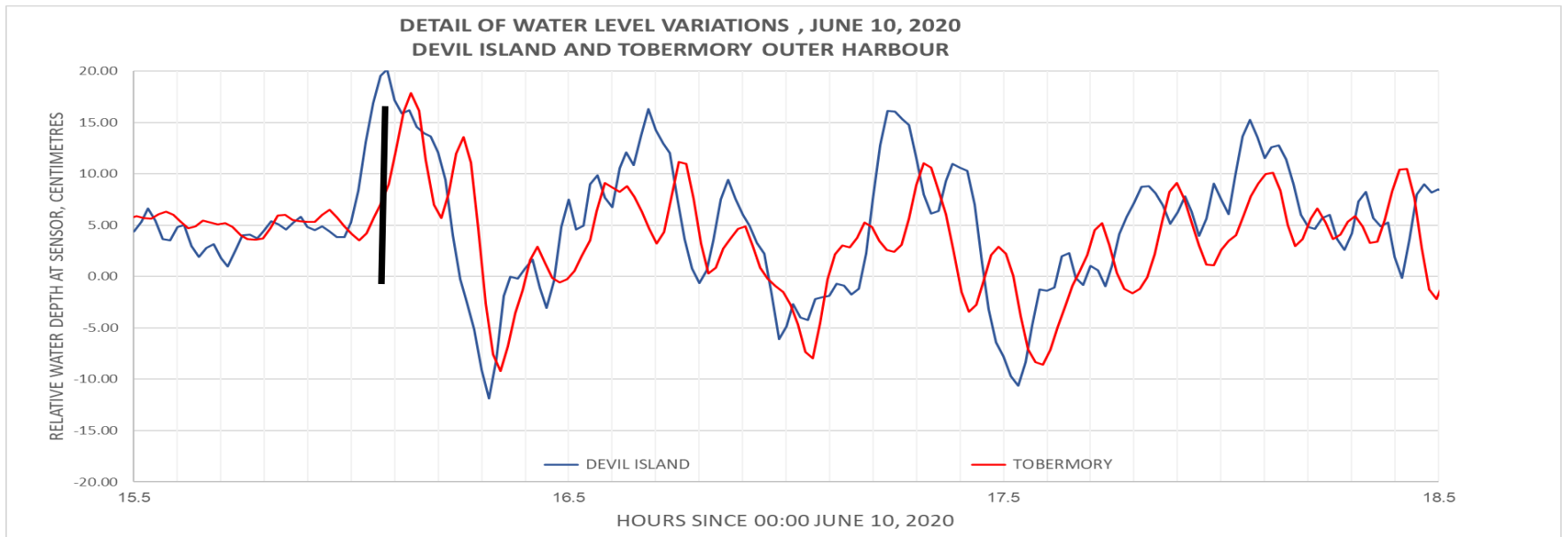


Figure 4b. Detail of the water level records of Figure 4, for the time period 15:30 to 18:30. Vertical grid lines are spaced by 3 minutes.

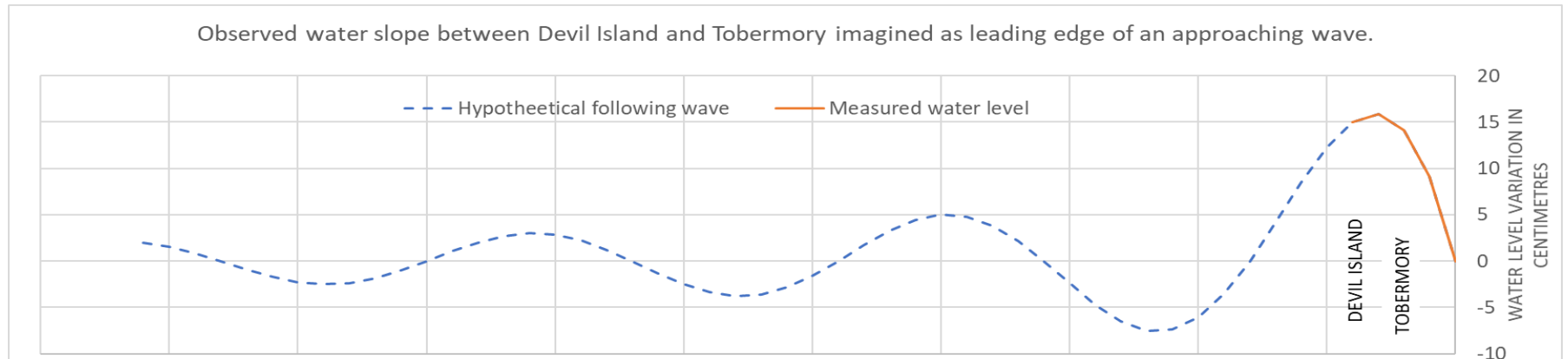


Figure 5. A depiction of a meteotsunami wave approaching shore with a periodicity that would coincide with the time difference in arrival at Devil Island and Tobermory. The amplitude of the wave is shown increasing as the wave shoals in the shallower water of the coast.

Baptist Harbour.

Figure 6 compares the water level response at Baptist Harbour with those of the other two stations. Baptist Harbour has a long and narrow morphology that makes it particularly responsive to harbour oscillation. The difference in Figure 6 is striking; Baptist rings like a bell struck by the onset of the storm, a true seiche with this harbour's resonance periodicity of 16-18 minutes. The initial swings are of about 1 metre, but the sudden drop in pressure at 20:00 (Figure 4) almost doubles that swing. At 21:30 the current sweeps away the dock to which the sensor had been tethered and drags it into deeper water.

This seiche in Baptist Harbour has been described by residents there as the longest and largest they have observed. Baptist Harbour is easily "rung"; the water can be observed at any time to be flowing back and forth every 16-18 minutes. However, this storm seems to have been

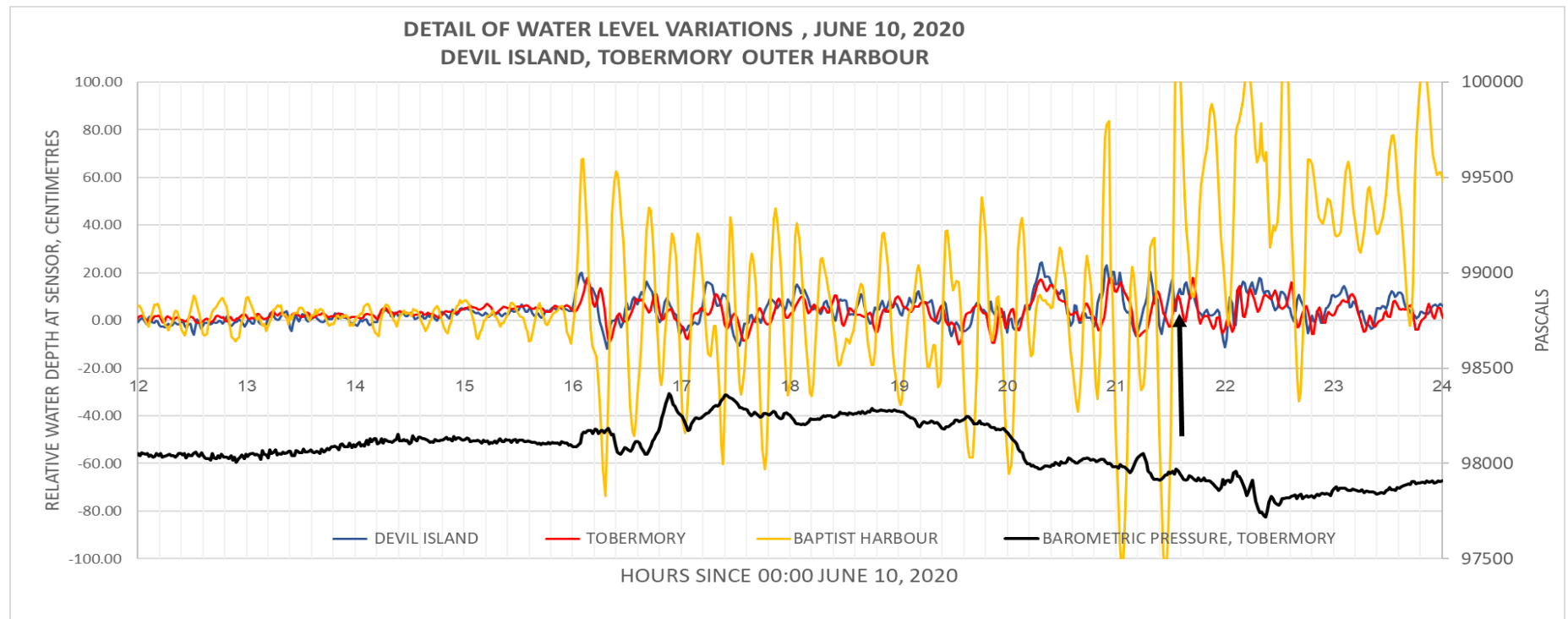


Figure 6. Baptist Harbour water levels compared to Devil Island and Tobermory harbour, noon to midnight on June 10, 2020. The black arrow indicates the time that the dock left its foundation.

particularly effective in transferring its energy to this inlet. One obvious factor is that the storm's direction of travel aligns extremely well with the axis of the inlet. This is a common direction for storms to approach the coast, however, so that is probably not the only factor.

More striking is the way the period of the incoming wave matches the resonance period of Baptist Harbour in Figure 6. This is better illustrated in Figure 7 in which the Devil Island trace has been plotted to a smaller scale so as to more nearly match amplitudes with Baptist Harbour. Looking only at the first cycle of the blue trace, as indicated by the black double arrow, and assuming that this represents the incoming tsunami wave, we see that it is remarkable similar to the dominant oscillation of Baptist harbour (yellow trace). After that initial pulse the two traces diverge, Baptist oscillating at its resonance period and the Devil Island record reacting to storm variations as well as local bathymetry.

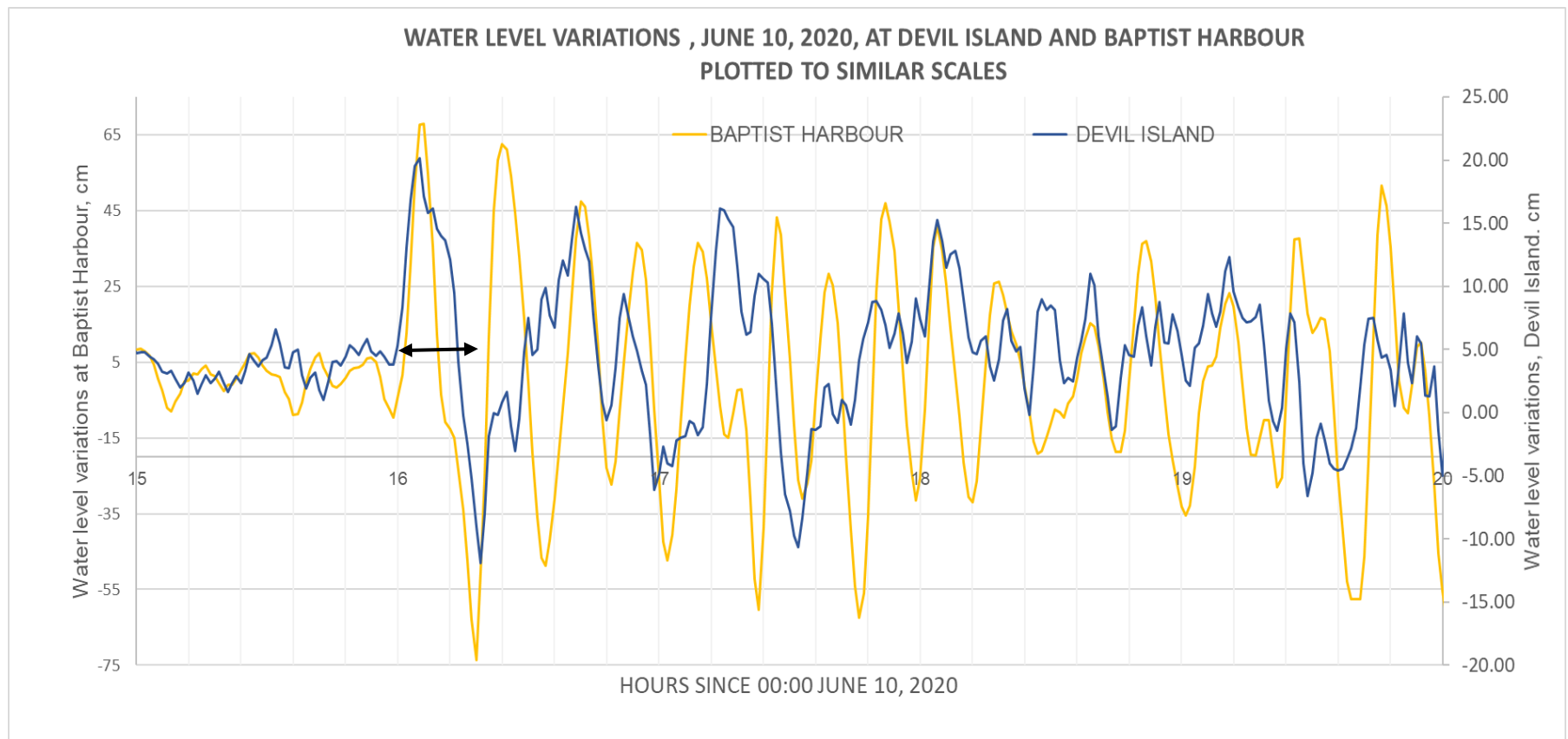


Figure7. The records at Devil Island from Figure 6 has been scaled on the right axis so as to better match the amplitude of oscillations at Baptist Harbour (left axis).. The black arrow emphasizes the similarity of the first cycle of the incoming wave with the resonant oscillation of Baptist Harbour.

SPECTRA.

Water level spectra are the fingerprints of harbours, or in fact any location, their shapes being largely independent of the time at which measurements are taken. A storm from outside can overprint this spectrum, and when storm and non-storm versions are compared the differences help characterize the energy distribution of the storm. Not everyone is familiar with spectra, and since in this case they do not add much to the central concept, they have been relegated to Appendix C.

DISCUSSION.

These data provide an unusually detailed picture of what is with reasonably certainly a meteotsunami. Our interpretation of these measurements suggest that the event approaches the coast with an amplitude of as much as 15 cm, has dominant periods in the range 10-20 minutes, travels with the storm at 100 km/hr and has a wavelength of tens of kilometres.

We suggest that its effectiveness in initiating a seiche in Baptist Harbour is the result of (i) the orientation of the storm path along the axis of the harbour and (ii) the match between the harbour resonance period and that of the incoming wave. There is a hint of a prediction strategy here; if the weather radar shows a storm front bearing down directly on your harbour it would be wise to pull the boats up! Experience shows that waves can arrived unannounced in this way, however, from distant sources and even by reflection from an opposite shore.

It must be acknowledged, too, that this June 10th event and its morphology may or may not be typical. The picture would be a lot clearer if there were more measurements. Perhaps one day there will be enough interest to install a larger network and leave it in place for several years. Unfortunately meteotsunami events of any size rarely occur more than twice a year and the damage they do can be annoying but seldom of much consequence. They are of minimal concern to commercial shipping or recreational boating. They are interesting as scientific phenomena, certainly, but unlikely to attract significant research funding.

That said, a citizen-led program to study meteotsunamis is not difficult to implement. The Hobo data loggers borrowed from Fathom Five Park (thanks Cavan) are only about \$400. Their storage capacity is unfortunately limited to 64k, meaning that for 1 minute readings they must be downloaded at least every 25. Their battery life is sufficient for several field seasons. The home-made device used at Tobermory Harbour (Appendix B), costs less than \$100. Storage capacity on an SD card is huge but battery power (currently a 12volt lead acid marine battery) would have to be replenished on a regular basis. Solar panels might work for this in the right circumstances. .

Devil Island data have here been assumed to represent the incoming wave but this is a stretch! The wave has shoaled in the shallow waters around the island and is undoubtedly amplified as a result. A deep-lake observatory would provide a much better reference point for embayment studies.

Finally, the earlier study by SoK "Tides of the Bruce" has suggested there are other ways to study meteotsunamis. When pressure detectors in two or more different embayment detect a small sudden increases simultaneously it indicates that the source is outside rather than within the individual harbours. In "Tides of the Bruce" we have identified two such events, and suggested that they represent weak meteotsunamis, which nonetheless have characteristics of their larger and more dramatic versions. Experiments with a LIDAR sensor is underway, and initial results show that in a suitable still environment it can obtain sub-millimetre accuracy. This might allow the study of these smaller and presumably more frequent events.

ACKNOWLEDGEMENTS

Thanks to the staff of Fathom Five National Marine Park for entrusting me with the Hobo pressure transducers, and to Deb and Jamie Crowley for the use of their dock in Tobermory Harbour. Tracy and Tony Edwards have been very generous over the years with access to their dock on Baptist Harbour. Daryl Cowell provided some very insightful editing, and discussions with Lawrence Beagan helped refine the approach and the scope. Many thanks to them both. The Sources of Knowledge Forum have allowed me to use their name to give these investigations some legitimacy, a leap of faith which I greatly appreciate.

Thanks too to the readers who responded to a Tobermory Press article on this topic with their experiences of the June 10th event, in particular to Dorothy Harris and Bill Dwyne who were very helpful.

APPENDIX A. Reports from other harbours.

A short notice in the local paper asked for other experiences down the west coast of the peninsula. The following responses were received. It is clear that there was a significant rise and fall in the water level. It is hard to get detailed cycle times but some estimates are given.

Baptist Harbour.

Cecile Eadie, east end of the harbour, south side.

I live on the Lake Huron shore south of Baptist Harbour.

When the water was so high in 1986 we had a cement wall built to hold back the waves. Behind the wall was backfilled and sodded so we now had a lawn we never planned to have....

On June 10 the water and waves splashed over the wall and the run off came 15 feet over the lawn.

There was no damage to speak of but a huge slab of slate that we used as a table at our fire pit was lifted off its cement blocks and is now flat on the sand.

There was a bridge to a small island in front of my neighbour's place and it is finally all gone, the huge sections floating on by.

I wish I had seen the event but then I might have started running.

Cele Eadie
Topsy Lane

Tony and Tracy Edwards, location of SOK sensor, midway down the harbour, north side.

On Wed., Jun. 10, 2020, 11:17 p.m. Tracy Edwards, <wearediving@yahoo.ca> wrote:

Oh I guarentee you will have the recordings you've been waiting for.....if your equipment survived. Our dock is completely trashed and your block is about 50 meters down the harbour. We've never seen seiche activity like this since we lived here. We are waiting for morning to survey the damage....it was just too rough out there this evening to try to save anything. It's pretty heartbreaking....our house just sold today so I'm not sure what's going to happen with that.

Tracy



Figure A1 The Edwards' dock at Baptist Harbourn after the seiche of June 10.

Whiskey Harbour.

Hi,

This event was remarkable at my residence in Whiskey Harbour. There was no significant damage, but my entire yard was covered in at least 13" of water (see photos, taken shortly after the first wave pulled back out). Filled both my boots with it! I also had to park my car higher up the driveway for 2 days while the water receded. It reached my garage door which is about 150' from the lake on a slightly sloped lot.

Regards,
Peter Payne
311 Whiskey Harbour Road

Hi John,

I know the sustained level is often due to the wind, but the event on June 10th was a rapid rise that took less than two minutes to flood



Figure A2. Flooding at Whiskey harbour.

my yard, so was not the sustained level caused by the wind. We had a similar occurrence here one week ago on the 19th, but not quite as high a surge as the one on the 10th.

The first time I noticed this phenomenon was on the long weekend in May last year. The lake level rose about three feet in about 1 minute, dropped about 5 feet, then surged back in again, rising about 4 feet on the second wave. There were successive lower waves until the water settled down again over the next few hours.

It seems to me that these meteo tsunamis were once relatively unusual, but like everything else related to the climate, seem to be becoming more common.

Regards, Peter.

Eagle Harbour.

Hello John

I do have times for all my pictures/videos that day. I took a couple earlier that day at around 12:35 as it was blowing waves in but not like later! It was up about 3ish not as high. Didn't take any pics then. Pics I sent you started at 4:06 with highest water at 4:10. Back to normal at 5:10 and up again at 7:35pm but not quite as high. We think it went up and down about 4 times over about 4 hours starting around 3:00 ish.

Hope this is helpful!
Dorothy

This was also sent by Dorothy on July 19. A major roll cloud came over Tobermory at 19:20, but this appears to have started earlier. "Yesterday July 18th I marked down one cycle from 3:47-4:06 another started at 4:44. We went to see what happened at the neighbors as they had brought in stones and sand. That didn't work"



Figure A3. Flooding at Eagle Harbour.

Warner Bay.

Jim Greig, 434 Warner Bay Road, reported significant damage. I talked to him at the dock in Tobermory but he was not at home when the event hit and he had no photos.

APPENDIX B. Design of a simple water level recorder.

The recording device installed at Crowley's dock was a home-made one, incorporating an Arduino micro-computer, BME280 pressure detectors, a clock and a data logger using a micro-sd card writer. The host was an inverted 2" ABS tube, sealed at its exposed upper end and open to the water pressure through a small aperture at its lower end (see diagram). The BME280s record pressure, temperature and humidity every 60 seconds. The temperature can be used to estimate the density of water in the very basic equation for depth of water h ...

$$h = \rho g / (P_2 - P_1)$$

where ρ is the density of water adjusted for temperature and g is the universal force of gravity, 9.8 m/sec^2

Both BME280s and the clock were run with I2C protocol and the sd card reader under SPI. Ideally the P2 cabling would be run through the top cap or the side of the tube above the water line, but it proved very difficult to get a long lasting seal there. Bringing the cable through the bottom orifice worked well. After about 6 weeks the P2 BME280 did start to give strange results, seemingly the due to increased

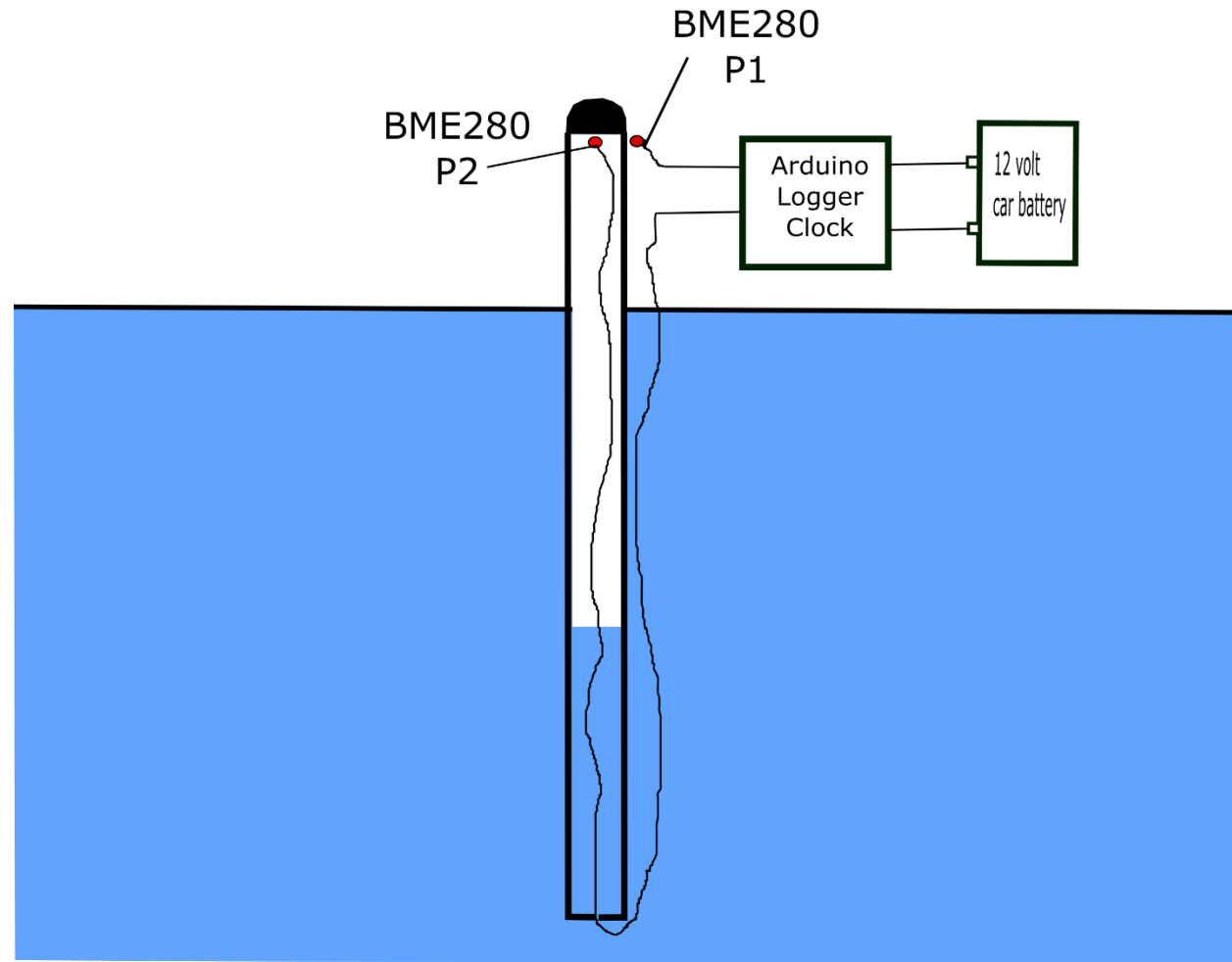


Figure B1. Schematic of the water level detector used at Crowley's dock, Tobermory Harbour.

temperature sensitivity. Still it survived the high humidity until then.

The Arduino, a 5volt device, is remarkable in being able to run on as much as 13.5 volts. A car battery could run this setup for at least two weeks; solar charging would extend that.

The tube does not have to be vertical, so it could be run on an angle from shore in a more remote location. Some sort of wax or epoxy “potting” might have avoided the effects of high humidity in the tube. Also , the tube should have been made from white instead of black ABS plastic, and shaded.

As temperature drift is generally quite long-term compared to the water level variations we are looking for, that drift is not a major problem.

A LIDAR version is currently being tested.



APPENDIX C. THE SPECTRA².

Spectra of their water level variations are the fingerprints of harbours! The wiggles on water level records will change from day to day but the shape of their spectrum stays remarkably the same. The genius of Joseph Fourier, an 18th century mathematician, was to show that a series of N measurements such as these water level records can be reproduced as the sum of N sine waves having distinct amplitudes and time periods of oscillation. Water movement is naturally wave-related, so this representation of the data as the amplitude³ versus the period of these constituent sine waves – a spectrum - gives a measure of the energy at each wave period, which could range from tides (12.48 hours) to ripples (<1 second). In practice the range of periods that can be examined is limited by the measurement frequency and the length of the record.

The water level variations in harbours and inlets tend to have uniquely shaped spectra, with properties related to their dimensions and their depth. Figures 8, 9 and 10 show period spectra over 2 to 100 minutes for the measuring stations during the storm (15:40 on June 10 to 03:00 on June 11⁴, orange traces) and compare them with the spectra of the five days prior to the storm (12:00 June 5-12:00 June 10, blue trace) and one other spectrum recorded for a period of several days at some earlier time (grey trace) at each station. In each case the storm spectra are referred to an amplitude scale on the left vertical axis of the graphs while the two earlier spectra are referred to a scale on the right side of the graphs⁵. Note that the range of the left scale is ten times that of the right scale, reflecting the much larger energy in the storm water level variations compared to more normal times. The horizontal axis shows the period in minutes, on a logarithmic scale which better represents the sampling of the spectrum by the Fourier transform.

Figure B2. The water level detector on Crowley's dock.

June

² We do not have access to very sophisticated spectral analysis tools, relying on an add-in to MS EXCEL for basic Fourier Analysis. These spectra have been smoothed and in some cases flattened to make comparisons easier.

³ Amplitude and phase to be more precise.

⁴ At Baptist Harbour the water level detector was abruptly moved off its base at 21:30 so the spectrum in Figure 9 is for only the 6 hours from 15:00 to 21:00.

⁵ The units of the left and right hand scale are cm-sec, and can be thought of as the contribution of each frequency to the overall signal.

Baptist Harbour spectra.

With reference to Figure C1, the two non-storm examples, made over made over 5 day intervals 3 years apart, are strikingly similar. There is a broad peak with centre at 17 minutes and a half-width of about 5 minutes, consistent with the ringing of the Baptist record in Figures 6 and 7. There are minor peaks at 10 and 30 minutes, again consistent over many samples. The origin of these minor peaks is not understood.

The storm spectrum preserves the general shape of the previous two, but with more than 10 times the amplitude and a broadening of the peak. Because it is made from only 6 hours of data it lacks the resolution of the other two, particularly at longer periods. The broadening of the peak may be the influence (overlain fingerprint) of the storm.

Devil Island spectra (Figure C2).

While this measurement site is not a harbour it has a distinctive spectrum shape characterized by a broad peak centred on 37 minutes. The storm spectra, orange trace, retains that 37 minute peak while overprinting the earlier spectra with a peak at 21 minutes and a broad peak between 6 and 11 minutes.

Areas where the storm and background spectra differ are presumably the fingerprints of the meteotsunamis. In our study of harbour spectra it has always been difficult to separate peaks that are characteristic of the harbour and those that are characteristic of the large lake outside. In

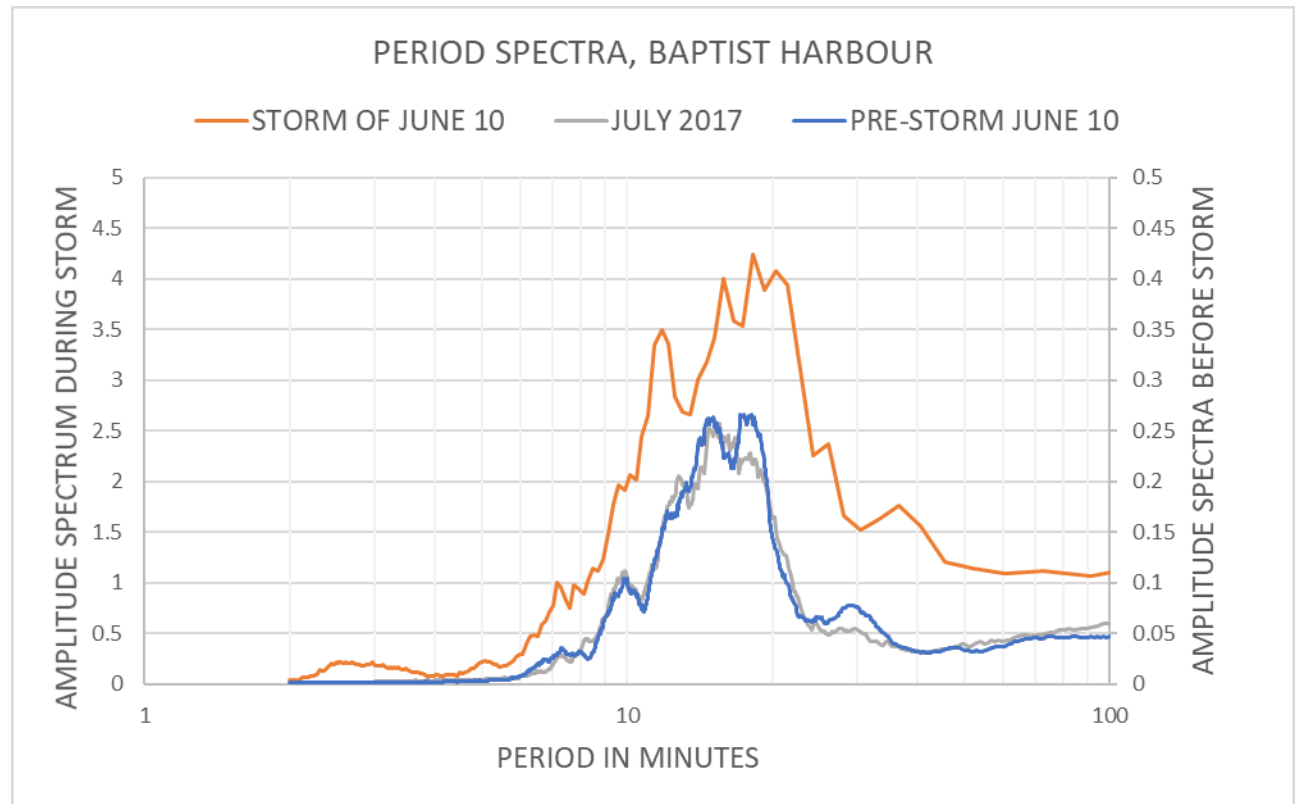


Figure C1 Spectra of water level data at Baptist Harbour during and before the storm of June 10. Note that the “before” spectrum scale on the right side is one tenth of the “storm” spectrum scale on the left side, reflecting a 10 fold increase in activity during the storm relative to more normal times. The gray trace is from a recording made over 5 days in July 2017.

“Tides o’ the Bruce” the assumption was that periods greater than 60 minutes, and are common to several harbours, probably originate outside.⁶ The 37 minute peak is common to two previously occupied sites along the channel linking Georgian Bay and Lake Huron, Eversley Point (at 65 Grant Watson drive, opposite Middle Island and the Little Tub Harbour. Its origins are not clear⁷, but in this case it should be considered a property of the Devil Island location and not the incoming meteotsunami.

Tobermory Harbour spectra (Figure C3).

Just as the storm records of Devil Island and Tobermory Harbour (Figure 4a,b) show a degree of resemblance, their spectra are also similar. The narrow peak at 21 minutes, and the broad enhancement from 6-11 minutes are the primary differences between the storm and background spectra, suggesting again that they are the spectral fingerprints of the incoming meteotsunami.

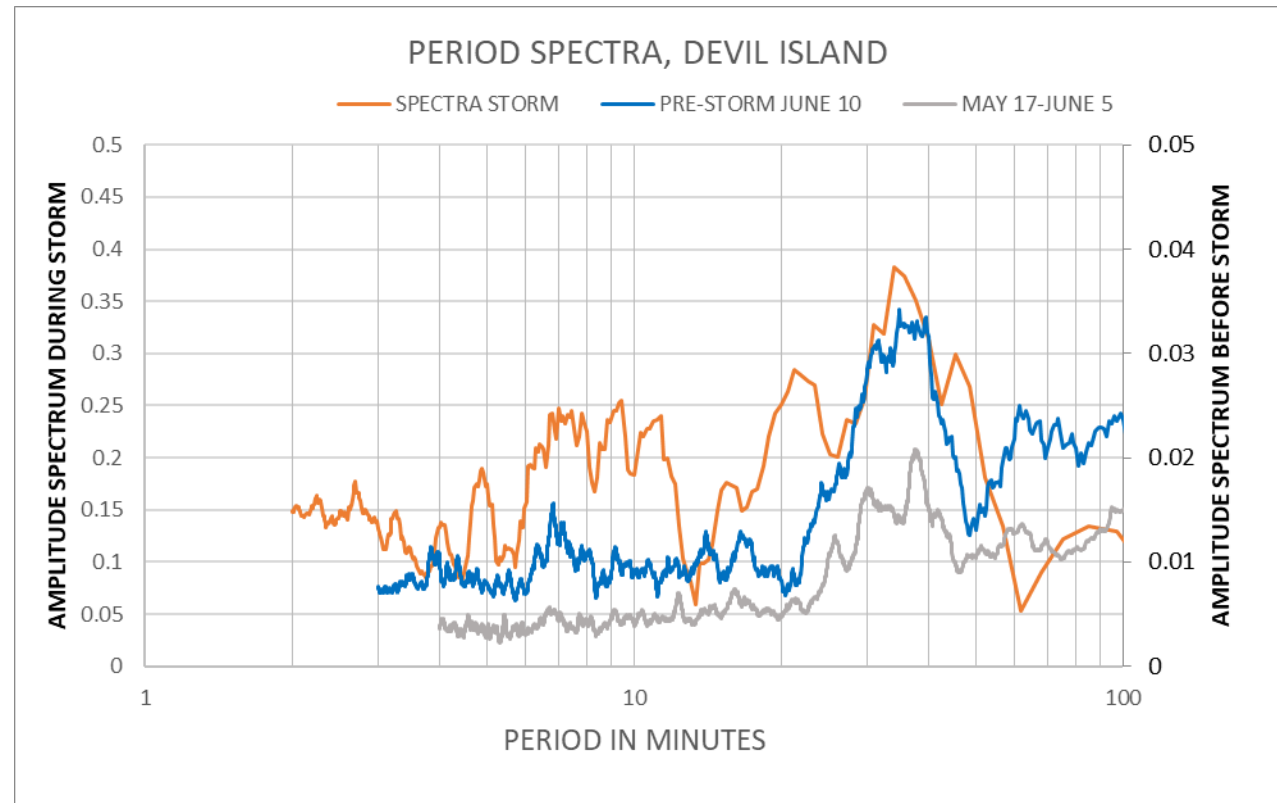


Figure C2. Storm and pre-storm spectra at devil island.

⁶ Stokes Bay, being large and relatively shallow, has a predicted and observed period greater than 60 minutes.

⁷ Possibly, along with a common peak seen down the coast at 62 minutes, a multiple of the 139 minute 5th mode of Lake Huron (Schwabb and Rao, 1977) but this is a stretch!

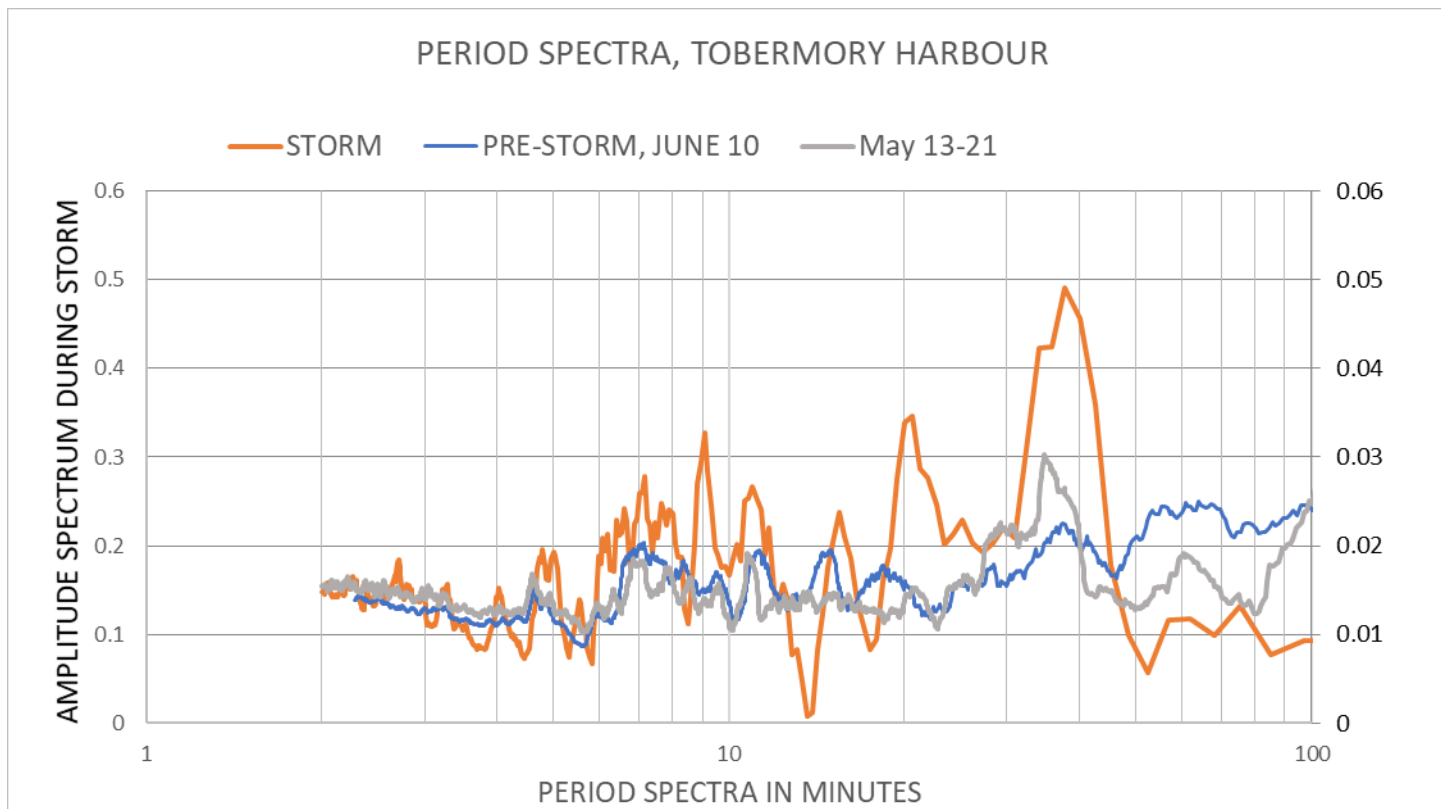


Figure C3. Storm and pre-storm spectra, Tobermory Harbour.