The Role of Underflows and Weather on Sediment Distribution in Glacial-Fed Lake Linné, Svalbard, Norway

By:

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Chapter 1: Introduction

1.1 Relevance and Objective

Climate change is without doubt one of the most problematic issues that society will need to find a solution in the future to prevent further damage. According to the IPCC's fourth assessment report in 2007, recent climate change has been due to an increase in greenhouse gases caused by humans. Some parts of the world have and will further experience an increase in temperature; this might trigger catastrophic events such as the extinction of polar bears in the arctic regions or desertification in Southwestern US. One way to understand how the Earth will react to this abrupt change is to find out how she has reacted in the past. These past-climate reconstructions are an important key to understand and predict future climatic variations.

The High Arctic is currently a vulnerable area being largely affected by climate change. It's an excellent place to reconstruct past climates due to of its small human population and because it's completely driven by natural forces. The High-Arctic, especially areas such as Svalbard, will have an increase in temperature of about 8°C by the end of the 21st century (Øseth, 2011). This warming will likely have a huge impact on both local and global plant, animal, and human populations due to the decrease of ice sheets, ice caps, glaciers and snowpack (Øseth, 2011).

One of the various proxies presently used to reconstruct past climates are arctic varved lacustrine sediments (Bradley et al., 1996; Overpeck et al., 1997; Lamoureux et al., 2002). Sediments deposited by glacial-fed lakes in the Canadian High-Arctic have received a lot of attention since the late 70s and remain a currently used proxy

(Carmack et al., 1979; Smith, 1981; Gilbert and Church, 1983; Smith and Ashley, 1985; Snyder et al., 2000; Lamoureux et al., 2002; Lewis et al., 2002; Cockburn and Lamoureux, 2008, among others). Linnévatnet is an arctic lake monitored by the Svalbard REU since 2003 and contains lacustrine sediments that have laminations which seem to be strongly influenced by season; coarse silt to fine sand in the summer and clay during the winter (Svendsen and Mangerud, 1997; Snyder et al., 2000, McKay, 2004; Motley, 2006; Roop, 2007; Cobin, 2008; Arnold, 2009). Young laminated sediments can be calibrated using current weather data to see how it's affecting the sediment distribution and use this relationship in older sediments to reconstruct past climate.

One factor that influences where and how much sediment will be deposited in an area of a lake is the frequency of different lake processes such as overflows, interflows, underflows and homopycnal flows (described in section (1.3). In Linnévatnet the spring melt occurs during late-June to mid-July. As in other lakes in the Canadian High-Arctic, it is the most important event of the year due to the high input of discharge of nival melt and sediment (Braun, et al. 2000; Gilbert and Butler, 2004; Cockburn and Lamoureux, 2008). The purpose of this project is to determine the frequency of underflows and how they may influence sediment distribution in Linnévatnet. Another goal is to see how underflows are related to weather patterns and inflow temperature during the spring melt. This will be done by using different sets of data gathered from the lake during and a weather station near Linnévatnet during July 2010.

1.2 Study Site

Linnévatnet

Svalbard is a Norwegian archipelago inside the Arctic Circle (Figure 1.1 and 1.2) that is currently 60% glaciated and was affected by the last ice age (Werner, 1998; Svendsen and Mangerud, 1992). Linnévatnet, or Lake Linné, (78° 3'N, 13° 50'E) is a glacial-fed lake (Figure 1.3 and 1.4) located in the largest island of Svalbard, Spitsbergen (Bøyum and Kjensmo, 1978). It's about four meters above sea level and has approximate dimensions of 4.7 km in length, 1.3 km in width and, at its deepest point, 37 m in depth (Bøyum and Kjensmo, 1978). Linnévatnet is located about 7 km east of where the largest fjord of Spitsbergen, Isfjorden and the Atlantic Ocean meet. This is important fact since during a greater period of glaciation Linnévatnet deposited marine sediments since it was connected to the Isfjorden (Bøyum and Kjensmo, 1978, 1980; Svendsen and Mangerud, 1997; Snyder et al., 2000).

Bathymetry

Linnévatnet has a lake surface of about 4.6 km^2 and has a catchment zone of 27 km^2 (Bøyum and Kjensmo, 1978; Snyder et al., 2000). It also has three basins (Figure 1.4); the main basin, east basin and west basin (Snyder, 2000). The main basin comprises all of the central and northern areas of Linnévatnet; it also contains the deepest parts of the lake. The west basin is the shallowest part of the lake and a big part of the sediment deposited in this area comes from the Little Ice Age moraine about 1 km west as shown in Figure 1.5 (Snyder, 2000). The east basin is directly influenced by incoming discharge and sediments coming from Linnébreen, but also from a carbonate alluvial fan located about 1 km southeast of the lake (Figure 1.5). This basin might also be under the influence of Kongressvatnet (Figure 1.3), a meromictic (doesn't mix), smaller version of Linnévatnet about 94 meters above sea level (Guilizzoni, 2006) and is further discussed in the results section.

Bedrock

Svalbard is considered a mecca for geologists due to its extensive geologic history (Ingólfsson, 2006). In Linnévatnet, the Grieg Aksla mountain ridge contains some of the oldest sediments in the world (Figure 1.5). These sediments are part of the Precambrian-Ordovician Hecla Hoek formation, which consist of metasediments such as schists, quatzites, phyllites, and tillites, (Åkerman, 1984). On the east side of the lake, in the Starostin Aksla mountain ridge (Figure 1.5), there are limestones, dolostone and gypsum of Carboniferous and Permian age (Ingólfsson, 2006).

Sediment Deposition

The lake is part of a glacial sedimentation system with most of the sediments supplied by Linnébreen, or Linné Glacier, which is located 8 km south of the lake. This glacier was created about 4,000 to 5,000 years ago and has been retreating rapidly these past few years; about 17.7 m/yr (Svendsen and Mangerud, 1992; Schiff, 2004). The sediments are transported through streamflow in Linnéelva, or Linné River, and deposited in the lake. Linnébreen is the major contributor of water discharge and sediment to Linnévatnet, but there are other sources of discharge and sediment (Bøyum and Kjensmo, 1978) such as the Grieg Aksla mountain ridge to the west and the Starostin Aksla mountain ridge to the east (Åkerman, 1986).

Previous Glaciation

According to Ingólfsson, Svalbard has gone through major glaciation phases during the Quaternary. As shown in Figure 1.7, during the Last Glacial Maxima (LGM) in the Late Weichselian (Mangerud et al., 1998), glaciers covered most of the area inside the Arctic Circle, including Svalbard (Ingólfsson, 2006). About 12 ka, this ice sheet began to melt (Mangerud and Svendsen, 1992) and at about 9 ka, Linnédalen started to rise in altitude due to isostatic rebound, or the decrease in pressure from the heavy ice sheets which leads to the uplift of that area, and led to the separation of the valley from the Bering Sea (Svendsen and Mangerud, 1997). Linnédalen was then ice free for a few thousand years (Figure 1.8) and very little sediment was deposited during this time as shown in Figure 1.9 (Svendsen and Mangerud, 1997). About 4 ka, Linnébreen seems to have started forming (Figure 1.8), and since “size of the glaciers upstream of the lake seems to be the most important factor regarding the sedimentation in Linnévatnet”, it lead to an increase in laminated sediment deposition in Linnévatnet as shown in Figure 1.9 (Svendsen and Mangerud, 1997).

Figure 1.1: Location of Svalbard in the Northern Hemisphere

From: Google Earth

Figure 1.2: Map of Svalbard

From: http://www.russia.no/regional/svalbard

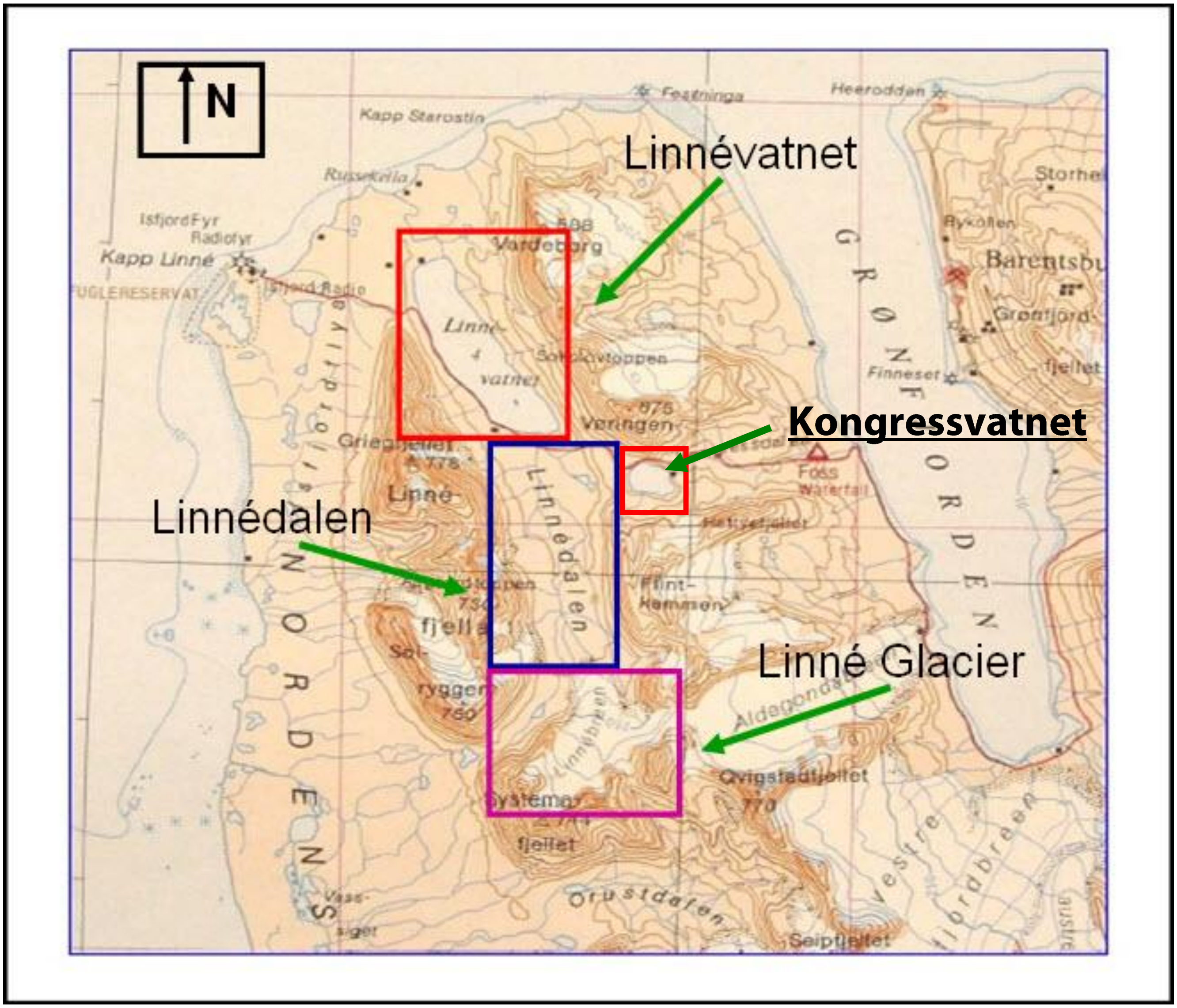


Figure 1.3: Map of Linnédalen and Kongressvatnet

Modified from: Leon, 2007

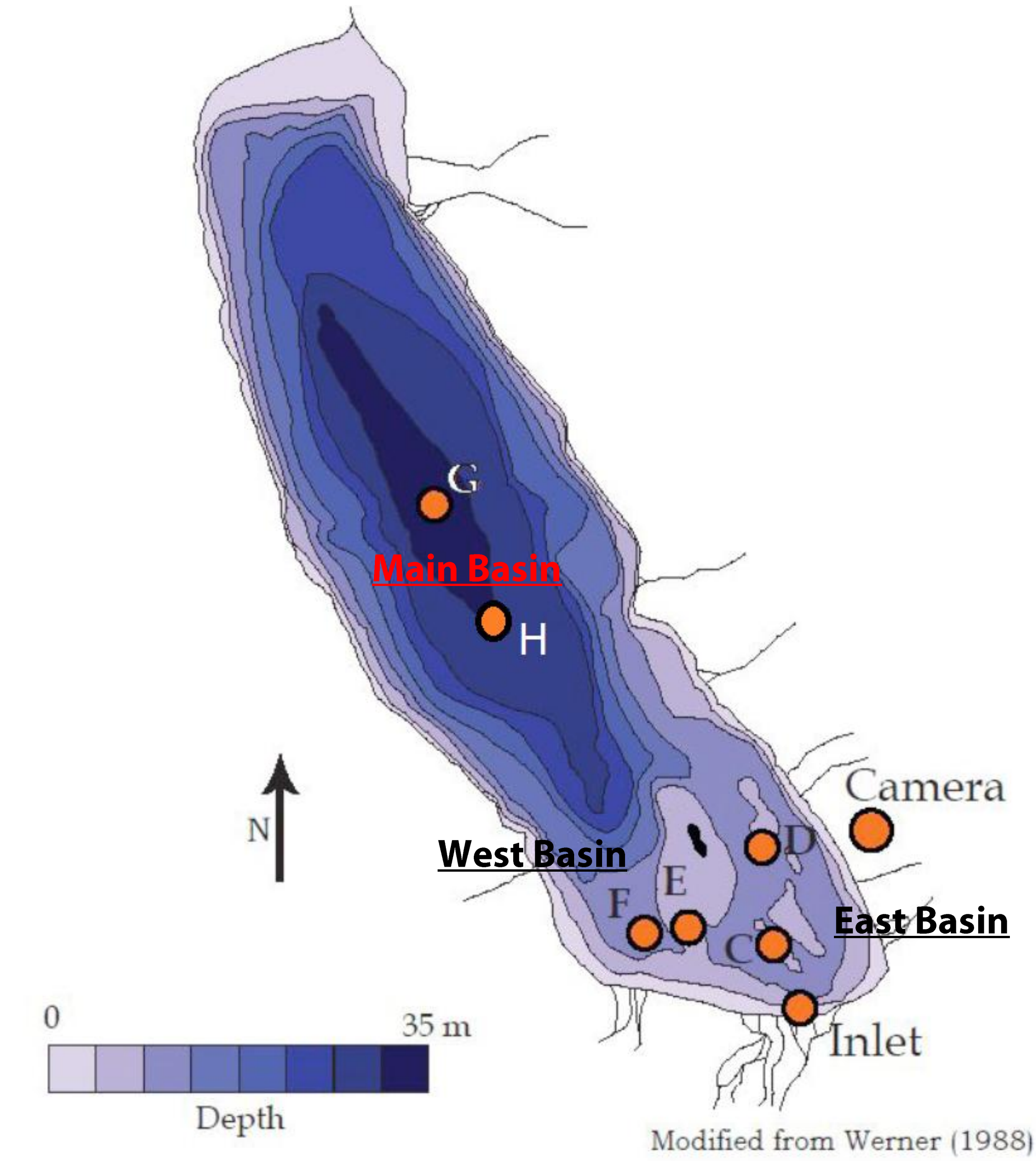


Figure 1.4: Bathymetry Map of Linnévatnet with Mooring Sites, Time-Lapse Camera and Inlet Locations

Modified from: Schupack, 2004

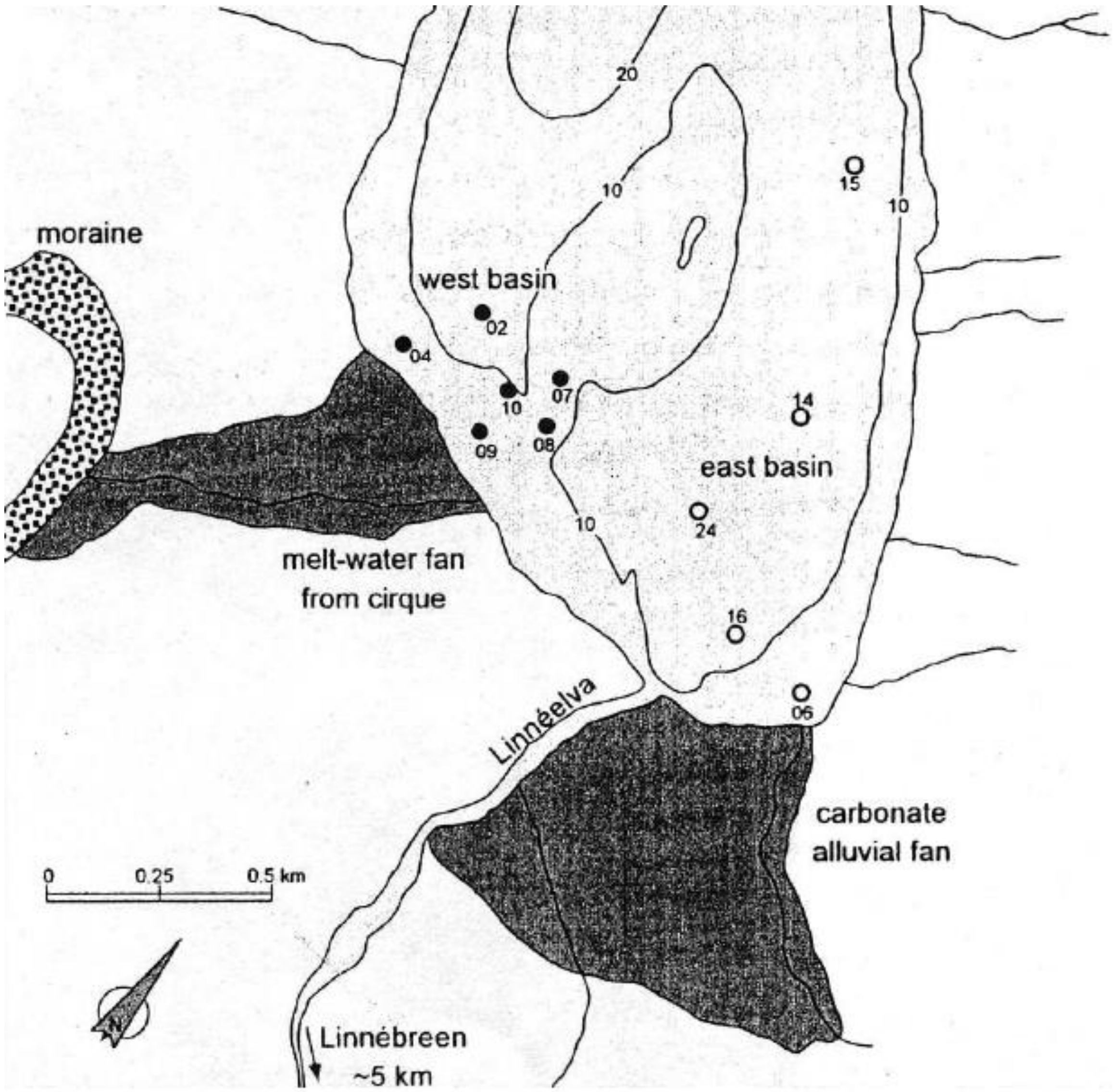


Figure 1.5: Map of proximal area of Linnévatnet showing the different areas of sediment sources aside from Linnébreen

From: Snyder et al., 2000

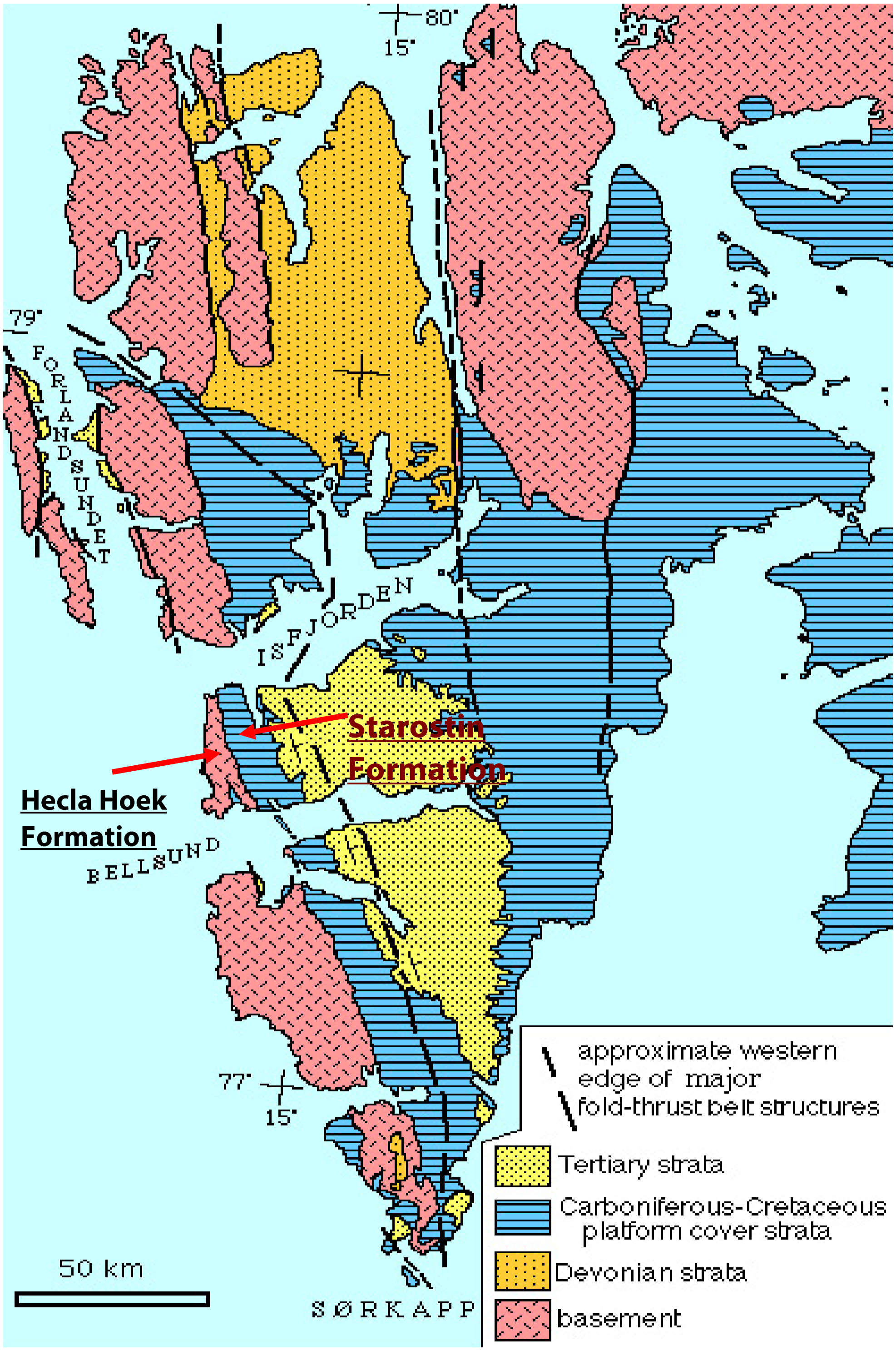


Figure 1.6: Geologic Map of Svalbard

Modified from: Ingólfsson, 2006

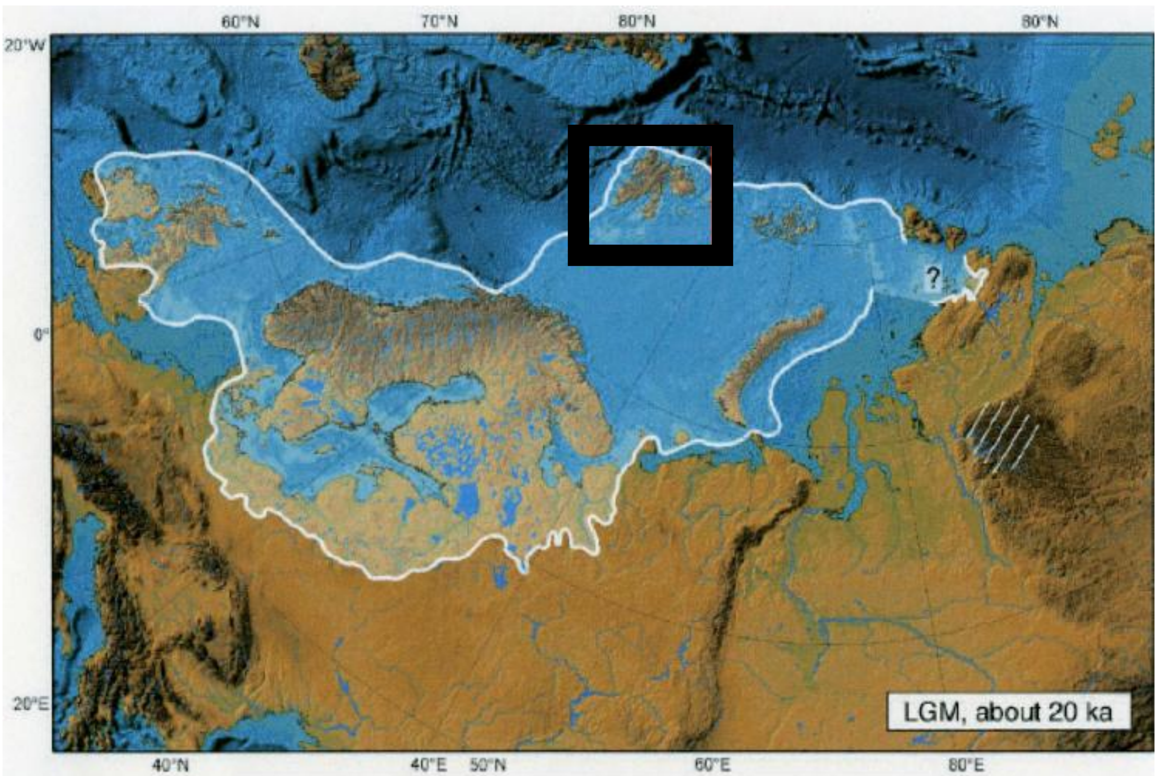


Figure 1.7: Last Glacial Maximum ice sheet covering Scandinavia; including Svalbard (shown in black rectangle).

From: Svendsen et al., 2004

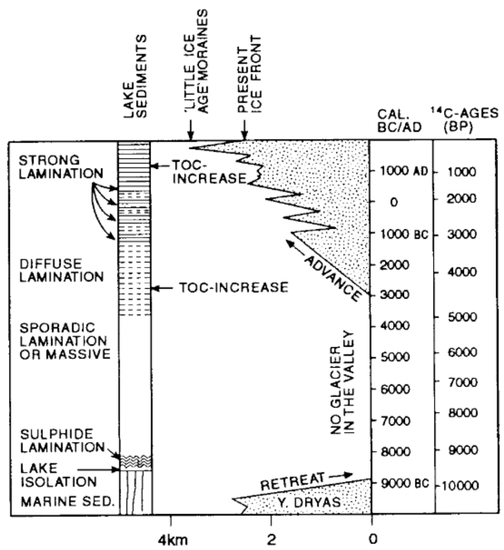


Figure 1.8: Timeline of Glacial advances at Linnédalen including types of lamination and age

From: Svendsen and Mangerud, 1997

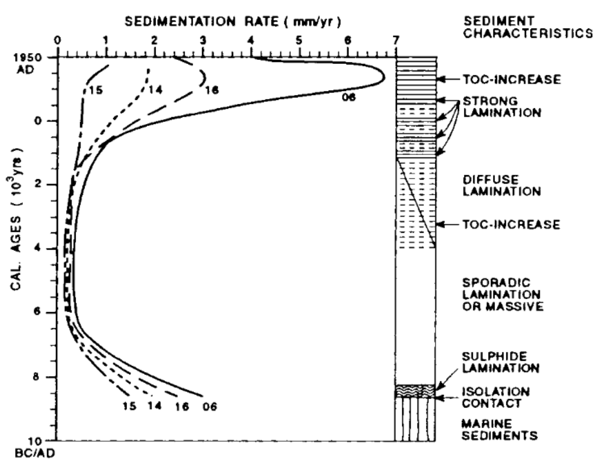


Figure 1.9: Timeline of Sedimentation Rates at Linnévatnet including types of lamination and age

From: Svendsen and Mangerud, 1997

1.3 Limnology

Lakes have a thermal vertical structure that changes through the season. The thermal stratification of a lake is due to the different densities throughout the water column. As Figure 1.10A depicts, if a lake was only influenced by solar radiation, the thermal profile would be parabola-like, since the surface of the lake would receive larger amounts of solar radiation than the bottom. A more realistic depiction of a lake would be Figure 1.10B, since the lake will not only be influenced by solar radiation, but also by wind direction and wind speed. Due to these added factors, the lake will adopt a more complex thermal structure. For example, during the summer the bottom, or the hypolimnion, of the lake will contain cold water. The surface of the lake, or the epilimnion, will contain the warmest water. Finally, the area of transition between the hypolimnion and epilimnion is called the metalimnion or thermocline. During the early phases of the spring, this thermal stratification will be very weak and continuous mixing is expected until the temperature in the epilimnion increases well above 4°C (Smith and Ashley, 1985).

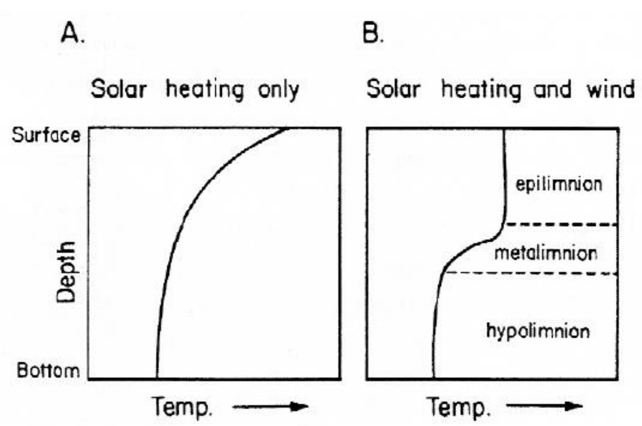


Figure 1.10: A. Thermal vertical structure of a lake by solar radiation only; B. Thermal vertical structure of lake by solar radiation and wind

From: Smith and Ashley, 1985

Inflow water entering Linnévatnet can be distributed in four different ways: overflow, interflow, underflow or homopycnal flow (Figure 1.12A and 1.12B). These different flow types are dependent on the relative density of the inflow water and the lake water; water's highest density is around 4°C (Figure 1.11). Density varies due to temperature and suspended sediment concentration (Smith, 1985; Werner, 1985).

Overflow occurs when the inflow water is less dense than the lake water. It is the least effective form of sediment deposition due to its low sediment concentration and is relatively uncommon (Figure 1.12A).

Interflow occurs when the inflow water is denser than the surface lake water, but less dense than the bottom waters. This process deposits minor amounts of sediment (Figure 1.12A).

Underflow occurs when the inflow water is very dense, due to temperature at or near 4°C or high concentration of sediment, and is thus a dominant deposition process. Inflow water velocity will be very fast and will last long periods of time (up to a few days) (Figure 1.12A).

Homopycnal Flow occurs when the inflow water is the same density as the lake water and is uncommon especially in deep lakes. Due to its low density, this process will not deposit large amounts of sediment (Figure 1.12B).

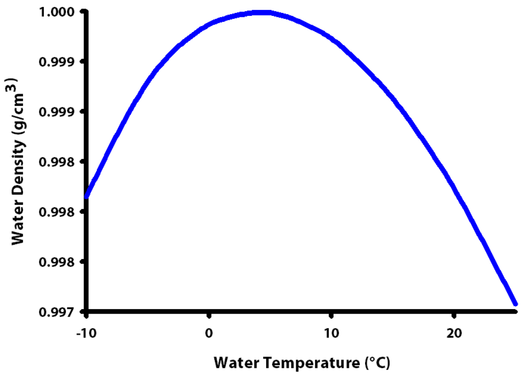


Figure 1.11: Water Density Curve with Highest Density at 4°C

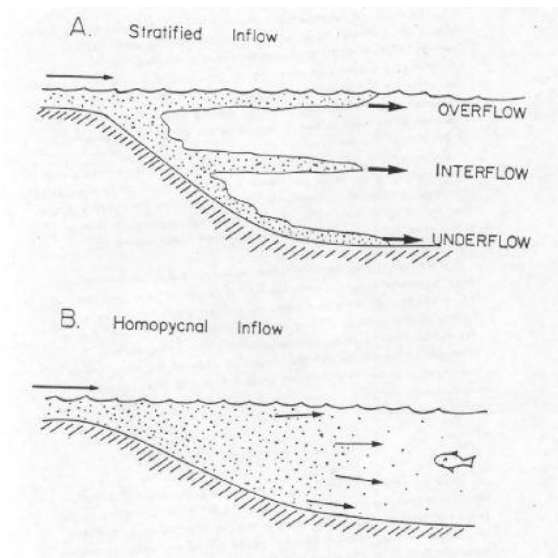


Figure 1.12: Lake Processes driven by differences in density of incoming water and lake (From: Smith and Ashley, 1985)

Linnévatnet's thermal stratification changes throughout the year. From around late October to around late-June, the lake has an ice cover of about 1.5 to 2 meters (Svendsen and Mangerud, 1997). After that, inflowing water starts to warm up and as it gets near 4°C it will sink to the bottom as an underflow (Figure 1.13), since it will have the highest density as shown in Figure 1.11. As the lake water warms up, the inflow water will mix with the lake water and sink again as an underflow (Figure 1.14). In the late spring/summer, the lake water will be >4°C and the inflowing water will pass as an overflow (Figure 1.15).

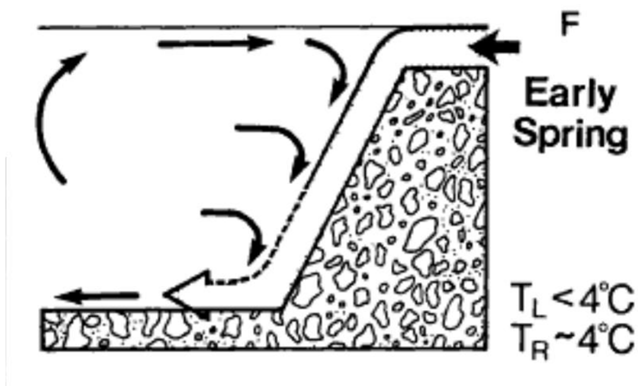


Figure 1.13: Distribution of inflowing water to ambient lake during the early spring (Carmack, 1979)

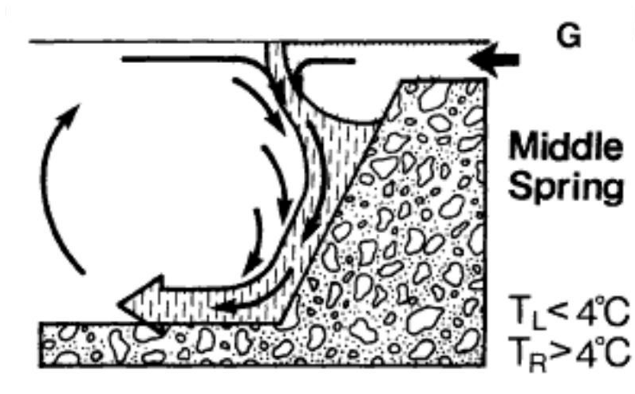


Figure 1.14: Distribution of inflowing water to ambient lake during the middle spring (Carmack, 1979)

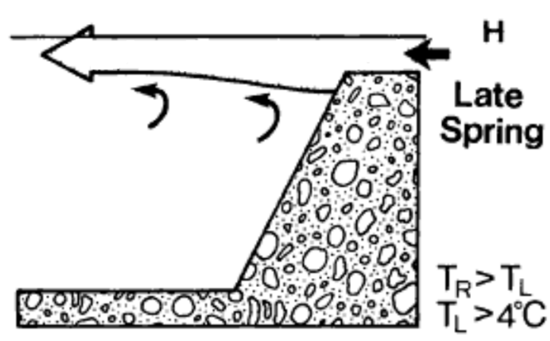


Figure 1.15: Distribution of inflowing water to ambient lake during the late spring (Carmack, 1979)

1.3 Climatology

According to data gathered at Longyearbyen, the largest settlement in Svalbard, the average air temperature is about -6°C. The coldest month during the year is February (-15.2°C) and the warmest month is July (6.2°C) and the annual precipitation is around 200 mm in central area of Spitsbergen and 400 mm in the eastern areas (Ingólfsson, 2006). Linnévatnet's climate is mild, compared to other areas of Svalbard and of the same latitude, due to its contact with the North Atlantic Current (influenced by the warm Gulf Stream in the south) as shown in Figure 1.16 (Svendsen and Mangerud, 2000, Guilizzoni, 2006).

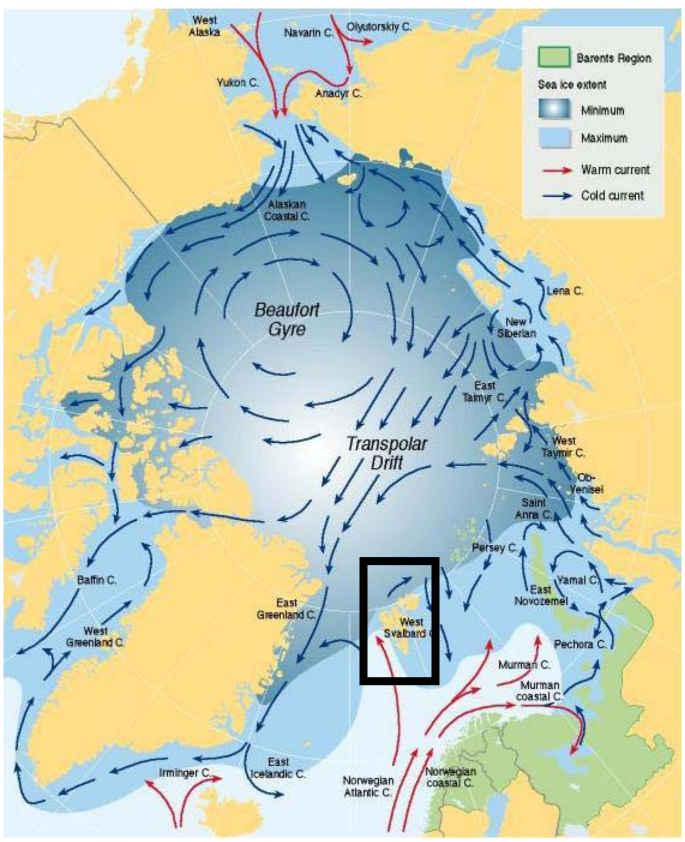


Figure 1.16: Currents in the High Arctic Latitudes; Svalbard is located inside the black rectangle

From: Rekacewicz, UNEP/GRID Website

1.4 Previous Work

Most of the work done in Linnévatnet has been to calibrate sediment cores with instrumental data and use them as a past-climate proxy. Such work was recently made by Pratt (2006), Leon (2007), Nelson (2010), Nereson (2010), Wei (2011) and Parker (2011). The last type of work done has been with sediment traps in the lake by McKay (2005), Motley (2006), Roop (2007), Cobin (2008), Arnold (2009), Gorcynski and Coleman (2010) and de Wet (2011) in order to understand the physical characteristics of sediment deposited through the year and the weather parameters affecting sedimentation. No work has been done in order to understand how lake processes are influencing sedimentation in the lake, or how these lake processes are being influenced by weather patterns.

1.5 Purpose of Study

The purpose of this study is to understand the lake's complexity during the spring melt. This includes the frequency of underflows (since it's the most frequent form of sediment distribution in the lake bottom) using temperature logger data from the lake using three different types of methods. The study is also going to decipher how weather patterns might or might not affect underflows. Finally, sediment distribution will be interpreted using the relationship between underflows and weather patterns.

Chapter 2: Methodology

2.1 Field Methods

Temperature Loggers

Sixty HOBO temperature loggers (examples of these loggers are shown in Figure 2.1) were recovered from the six different sites in Linnévatnet shown in Figure 1.4 from July 18, 2010 to July 22, 2010. However, this study will only use loggers obtained from mooring lines in C and D. These two sites contained two different mooring lines with temperature loggers; year long mooring lines (YL) which were deployed in July 2009 (recorded every 30 minutes) and spring mooring lines (S) which were deployed in May 2010 (recorded every 10 minutes). S mooring lines had loggers at almost every meter, while YL mooring lines had them every two meters.

Figure 2.1: HOBO temperature loggers recovered from site G

At S mooring C (recovered 7/18 at 12:30 p.m.), temperature loggers were collected from the following depths, measured from bottom: 0.1m, 0.85m, 2m, 2.9m, 3.9m 4.95m, 6m, 7m, 8.05m, 9.1m, 10.1m, 11.15m, 12.2m and 13m. At S mooring D (recovered 7/18 at 2:54 p.m.), temperature loggers were collected from the following depths, measured from bottom: 0.2m, 1m, 2.08m, 3.15m, 4.22m, 5.3m, 6.38m, 7.44m, 8.48m, 9.51m, 10.55m, and 11.6m.

At YL mooring C (recovered 7/18 at 11:30 a.m.), temperature loggers were collected from the following depths, measured from bottom: 0m, 0.2m, 1m, 5.1m, 9.2m and 12.2m. At YL mooring D (recovered 7/19 at 6:30 p.m.), temperature loggers were collected from the following depths, measured from bottom: 0m, 0.22m, 1.1m, 4m, 8.18m, and 11m.

Figure 2.2: Mooring Line with both a Temperature logger and a sediment trap

Both S and YL mooring lines contained temperature loggers and sediment traps (Figure 2.2). Sediment traps were not located at every place where a temperature logger was located. Data collected by the temperature loggers was downloaded using a HOBO Optic USB Base Station adapter (Figure 2.3). The battery on the temperature loggers was checked to see if it needed new batteries and the memory was erased in order to reassemble the mooring line and launch into the lake.

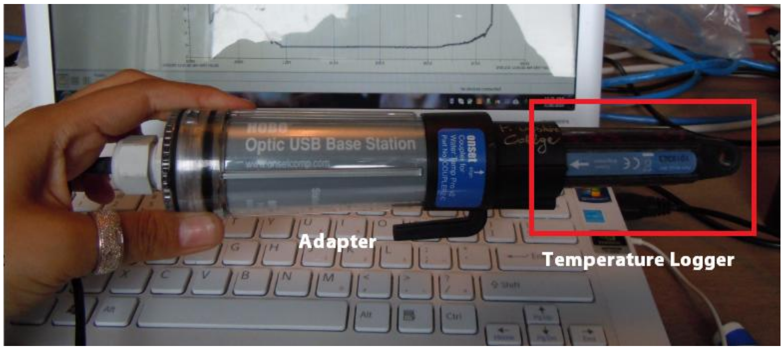


Figure 2.3: HOBO Optic USB adapter used to collect data stored in loggers

Weather Data

Weather data was recorded from Linné's Main Weather Station, which is about 0.5 km south of the lake. It recorded air temperature, precipitation, wind speed, wind direction, barometric pressure, and solar radiation every 30 minutes.

Intervalometer

A Cook intervalometer (Figure 2.4A) was placed in site C from July 2009 to July 19, 2010 and recorded sediment accumulation at the bottom in the lake in a test tube (Figure 2.4 B). The intervalometer is a custom-made piece of equipment that is related to a sediment trap (Arnold, 2009), although it contains LED lights located on one side (Figure 2.4C) which help to record sediment accumulation. If enough sediment is deposited, these lights will be blocked from their receivers, which increase the voltage (Arnold, 2009). Every two millimeters of sediment accumulation and are shown as a “jump” in the graphs. This is a very important piece of equipment in this study, since we’ll be inferring how underflows are depositing sediment using this data.

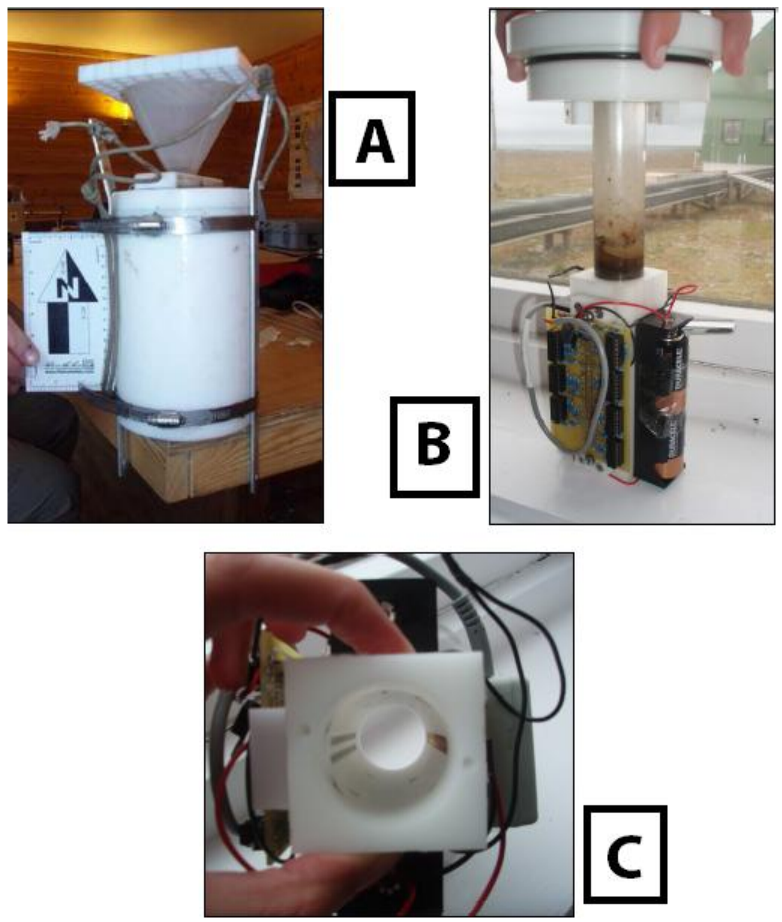


Figure 2.4: Cook intervalometer; A. Un-dismantled equipment, notice sediment trap at top; B. Dismantled intervalometer with sediment tube showing sediment accumulation; C. LED lights and receivers

From: Arnold, 2009

Xylonz 9000 ZX

This equipment was developed by Steve Roof and is meant to record currents passing by using a data logger (Figure 2.6). The Xylonz was placed in the bottom of S mooring line C and D and when a current places by, it will lift the sensor which will then record an angle (Steve Roof, personal communication).

Figure 2.6: Xylonz 9000 ZX

Time-lapse pictures

Time-lapse pictures were taken automatically twice a day (11 am and 4 pm) from about 500 m up in Starostin Aksla near the inlet (Figure 1.4). This camera takes pictures from the inlet “plume pictures” as shown in Figure 2.5 (left) and pictures of the north side of the lake “down lake pictures” as shown in Figure 2.5 (right).

Figure 2.5: Time-lapse pictures taken 7/13 at 4 p.m. from right: Plume Camera and left: Down Lake Camera

2.2 Analytical Methods

This study will focus on identifying underflows and three methods will be used in order to correctly identify them. The first is using averages and standard deviations in Microsoft's Excel. The second method will be to use the first method's results as a guide and plot raw temperature data into D-Plot. The third method will be to use the first and second methods results as a guide and plot to see if the Xylonz tilt current data coincide with the underflows from the first two methods.

Underflow Detection Method #1

The first method that was used in order to decipher when and where underflows are happening is to use Excel to take 6-hr averages and use the standard deviation from a particular site in order to determine if the water is either warming or cooling within a six hour period.

The first step taken was to separate sites C and D temperature data into months. The only data considered was from July-August in 2009 (for YL loggers) and May-July in 2010 (for both YL and S loggers). After all the months had their own sheets, averages and standard deviations were taken, and they were all compiled into one sheet to get a new average and standard deviation to be used to identify underflows (Note: Data from different sites was kept separate).

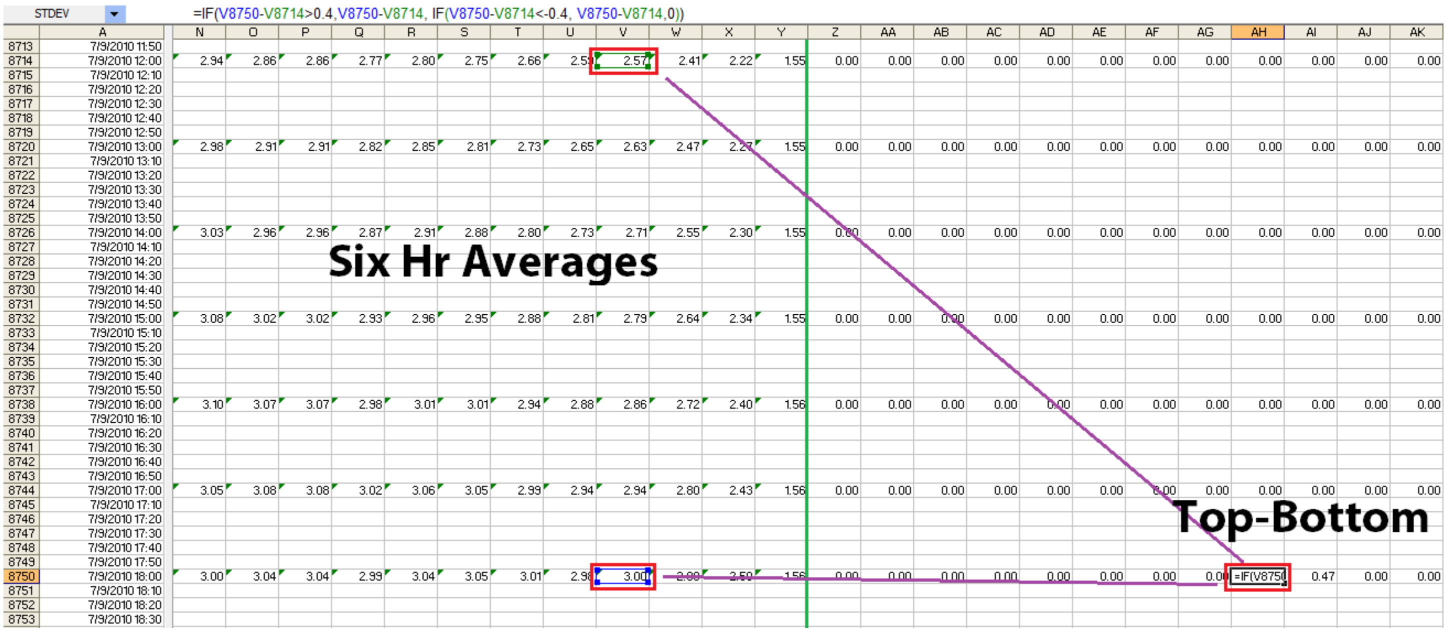
Next, raw data from May 10, 2010 to July 17, 2010 in C and D was copied into a new excel file. Every six hours an average was taken in all of the depths in all the sites. Then, to see if the water has increased or decreased in temperature, every six hours the averages are subtracted and if they were ± one standard deviation, it was considered to be a significant change (an event) as shown in Figure 2.6. Continuous events in the bottom, such as those shown in Figure 2.7 are significant episodes which might be underflows.

Underflow Detection Method #2

The second method used the results of the first method as a guide in order to see if raw data plotted in D-Plot would also show underflows. First, results from the first method were analyzed and a list was made with potential date ranges where underflows might have been happening. Raw data from these potential date ranges is organized into D-Plot Data and plotted into a temperature contour graph.

Underflow Detection Method #3

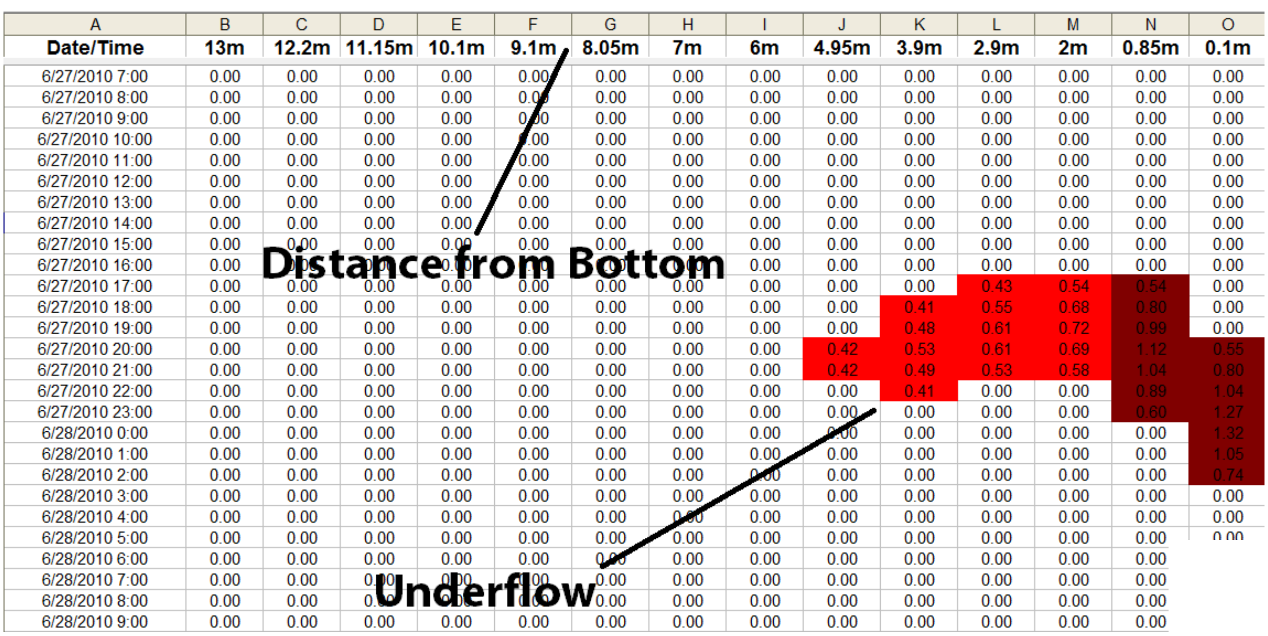
The third method used the results from the first and second method to confirm when underflows are happening. This method used the data collected from the Xylonz in order to see if currents are happening where the other two methods showed them.



	A	N	O	P	Q	R	S	T	U	V	W	X	Y
8713	7/9/2010 11:50												
8714	7/9/2010 12:00	2.94	2.86	2.86	2.77	2.80	2.75	2.66	2.59	2.57	2.41	2.22	1.55
8715	7/9/2010 12:10												
8716	7/9/2010 12:20												
8717	7/9/2010 12:30												
8718	7/9/2010 12:40												
8719	7/9/2010 12:50												
8720	7/9/2010 13:00	2.98	2.91	2.91	2.82	2.85	2.81	2.73	2.65	2.63	2.47	2.27	1.55
8721	7/9/2010 13:10												
8722	7/9/2010 13:20												
8723	7/9/2010 13:30												
8724	7/9/2010 13:40												
8725	7/9/2010 13:50												
8726	7/9/2010 14:00	3.03	2.96	2.96	2.87	2.91	2.88	2.80	2.73	2.71	2.55	2.30	1.55
8727	7/9/2010 14:10												
8728	7/9/2010 14:20												
8729	7/9/2010 14:30												
8730	7/9/2010 14:40												
8731	7/9/2010 14:50												
8732	7/9/2010 15:00	3.08	3.02	3.02	2.93	2.96	2.95	2.88	2.81	2.79	2.64	2.34	1.55
8733	7/9/2010 15:10												
8734	7/9/2010 15:20												
8735	7/9/2010 15:30												
8736	7/9/2010 15:40												
8737	7/9/2010 15:50												
8738	7/9/2010 16:00	3.10	3.07	3.07	2.98	3.01	3.01	2.94	2.88	2.86	2.72	2.40	1.56
8739	7/9/2010 16:10												
8740	7/9/2010 16:20												
8741	7/9/2010 16:30												
8742	7/9/2010 16:40												
8743	7/9/2010 16:50												
8744	7/9/2010 17:00	3.05	3.08	3.08	3.02	3.06	3.05	2.99	2.94	2.94	2.80	2.43	1.56
8745	7/9/2010 17:10												
8746	7/9/2010 17:20												
8747	7/9/2010 17:30												
8748	7/9/2010 17:40												
8749	7/9/2010 17:50												
8750	7/9/2010 18:00	3.00	3.04	3.04	2.99	3.04	3.05	3.01	2.98	3.00	[illegible]	2.50	1.56
8751	7/9/2010 18:10												
8752	7/9/2010 18:20												
8753	7/9/2010 18:30												

	A	Z	AA	AB	AC	AD	AE	AF	AG	AH	AI	AJ	AK
8713	7/9/2010 11:50												
8714	7/9/2010 12:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8715	7/9/2010 12:10												
8716	7/9/2010 12:20												
8717	7/9/2010 12:30												
8718	7/9/2010 12:40												
8719	7/9/2010 12:50												
8720	7/9/2010 13:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8721	7/9/2010 13:10												
8722	7/9/2010 13:20												
8723	7/9/2010 13:30												
8724	7/9/2010 13:40												
8725	7/9/2010 13:50												
8726	7/9/2010 14:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8727	7/9/2010 14:10												
8728	7/9/2010 14:20												
8729	7/9/2010 14:30												
8730	7/9/2010 14:40												
8731	7/9/2010 14:50												
8732	7/9/2010 15:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8733	7/9/2010 15:10												
8734	7/9/2010 15:20												
8735	7/9/2010 15:30												
8736	7/9/2010 15:40												
8737	7/9/2010 15:50												
8738	7/9/2010 16:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8739	7/9/2010 16:10												
8740	7/9/2010 16:20												
8741	7/9/2010 16:30												
8742	7/9/2010 16:40												
8743	7/9/2010 16:50												
8744	7/9/2010 17:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8745	7/9/2010 17:10												
8746	7/9/2010 17:20												
8747	7/9/2010 17:30												
8748	7/9/2010 17:40												
8749	7/9/2010 17:50												
8750	7/9/2010 18:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	=IF(V875	0.47	0.00	0.00
8751	7/9/2010 18:10												
8752	7/9/2010 18:20												
8753	7/9/2010 18:30												

Figure 2.6: Six hour averages in left side of green line; right side of green line are results from the difference between left top red box and left bottom red box.



A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
Date/Time	13m	12.2m	11.15m	10.1m	9.1m	8.05m	7m	6m	4.95m	3.9m	2.9m	2m	0.85m	0.1m
6/27/2010 7:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6/27/2010 8:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6/27/2010 9:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6/27/2010 10:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6/27/2010 11:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6/27/2010 12:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6/27/2010 13:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6/27/2010 14:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6/27/2010 15:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6/27/2010 16:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6/27/2010 17:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.43	0.54	0.54	0.00
6/27/2010 18:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.41	0.55	0.68	0.80	0.00
6/27/2010 19:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.48	0.61	0.72	0.99	0.00
6/27/2010 20:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.42	0.53	0.61	0.69	1.12	0.55
6/27/2010 21:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.42	0.49	0.53	0.58	1.04	0.80
6/27/2010 22:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.41	0.00	0.00	0.89	1.04
6/27/2010 23:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.60	1.27
6/28/2010 0:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.32
6/28/2010 1:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.05
6/28/2010 2:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.74
6/28/2010 3:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6/28/2010 4:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6/28/2010 5:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6/28/2010 6:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
6/28/2010 7:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
6/28/2010 8:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
6/28/2010 9:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	

Figure 2.7: Results from the difference of every six hours; bright red boxes signify >1 std dev, burgundy boxes are >2 std dev

Climatology

Data gathered from Linnévatnet's Main Weather Station from 2003 to 2010 was separated into different sheets. Data was recorded every 30 minutes and 24 hour averages and standard deviations were taken. These daily averages and standard deviations were compiled into one sheet and monthly averages and standard deviations were taken from those results. Finally, the monthly data of all the years was averaged and standard deviation was taken again in order to come up with a climatological history of Linnévatnet using Sigmaplot and Wind Roses with Origin 8.5.

Weather

In order to see if weather patterns might have an affect on underflows, we need to see if the weather significantly changes (±2 Standard Deviations). Raw weather data was copied into a new Excel file and daily averages were taken. Raw daily weather data was subtracted from the 03-10 monthly averages. The resulting value was then compared to the 03-10 monthly standard deviation averages and if the resulting value was ±2 standard deviations, then the weather for that day was considered significant and given either a 1 (for positive significance or >+2 standard deviations) or -1 (for negative significance, <-2 standard deviations).

Chapter 3: Results

3.1 Climatology Results

Data gathered in Linnévatnet from 2003-2010 was averaged and the area receives about 406 mm in precipitation and is about -3.35°C in temperature during the course of a year. As shown in Figure 3.1, the months with the most precipitation are December and January, with about 70 mm in precipitation and the most with the least are April and May, with <15mm. The air temperature is the highest in July and August, with about 6°C and least is in February and March, with -10°C.

Figure 3.1 also shows that during the spring/late-spring season wind speed is relatively low, around 3 m/s and wind direction is more variable compared to the other months, but it seems to be mostly coming from the southeast, south and southwest. Due to the complex nature of wind direction and wind speed, further analysis of these two variables was done in order to determine the frequency and strength of them during the year (Figures 3. 2-3.13). Other parameters are pressure, which reaches its highest in May (about 1016 mb) and decreases steadily, reaching 1008 mb in August and solar radiation which reaches its peak in June (at about 200 W/m^2) and decreases in a parabola-like fashion.

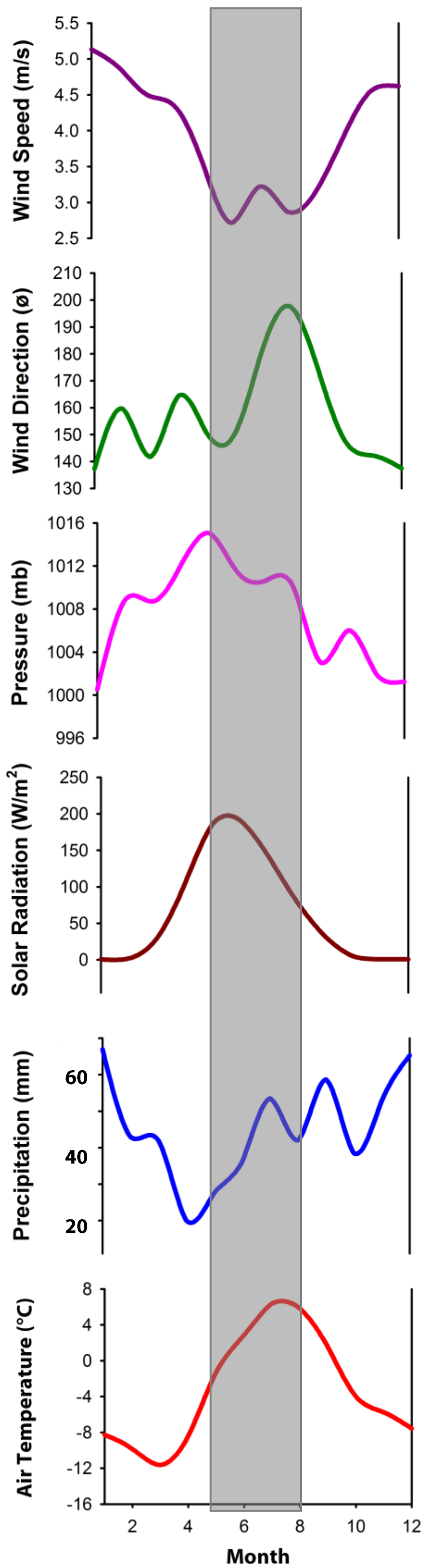


Figure 3.1: Climatology of Linnévatnet with data gathered from 2003-2010; gray rectangle shows spring-late spring averages

Wind Rose

As explained in the section above, wind can be very hard to analyze using simple averaging, since direction and speed are taken into consideration. The software Origin divided wind speeds into different range categories; 0-4, 4-8, 8-12 and 12-16 m/s, and Table 3.1 shows the percentages of when and how frequently those wind speeds are happening throughout the year. Wind speeds <8m/s are the most commonly found winds; most of the year they count for about 90% of all winds. Low winds, 0-4 m/s, are common from the months of May to August and account for about 60% of all winds during those months; December and January have the lowest percentages with about 35% of all winds. Low to moderate winds are, 4-8 m/s, are common in January and February, accounting for about 40% of all winds in those months; June and September have the lowest percentages with about 20% of all winds. Moderate winds, 8-12 m/s, are the highest during the winter from November to February with about 10% of all winds; the lowest occur from June to August and are about 2% of all winds. Finally, high winds are have the highest percentage of occurrence during November to January with about 3%; the lowest occur from June to August with <0.1%.

Range (in m/s)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0-4	34.2	41.7	48.6	49	57.7	69.1	64.2	61.2	52.5	44.4	41.8	37.1
4-8	41.6	41.6	39.5	38	30.6	21.5	30	27.2	25.1	32.2	35.6	38
8-12	13.2	11.1	9.02	9.68	5.32	1.97	2.11	1.87	4.65	7.02	10.5	10
12-16	3.22	1.93	1.42	0.64	0.47	0.04	0.08	0.12	1.02	0.15	2.55	2.9

Table 3.1: Wind speed ranges and their percentage per month; Red boxes signify the highest percentages within the wind range, while aqua boxes signify the lowest percentages

Figures 3.2-3.13 show the monthly wind roses for data from 03-10. Due to the protection from mountain ranges in west and east of the lake, most of the winds would be coming from north or south. In January, winds were mostly coming from the NW, in February from the N, March from N and SW, April from N, May from NW, June S, July S, August N and S, September from NW, October from N, November from N and December from NW. As can be seen in Figures 3.7-3.9, during the spring melt (June to July), the majority of the winds come from the south, with about 40% of all winds coming from that direction. During the other months, most of the winds are coming from either the North or the Northwest. Total percentages table can be seen in Appendix 1.

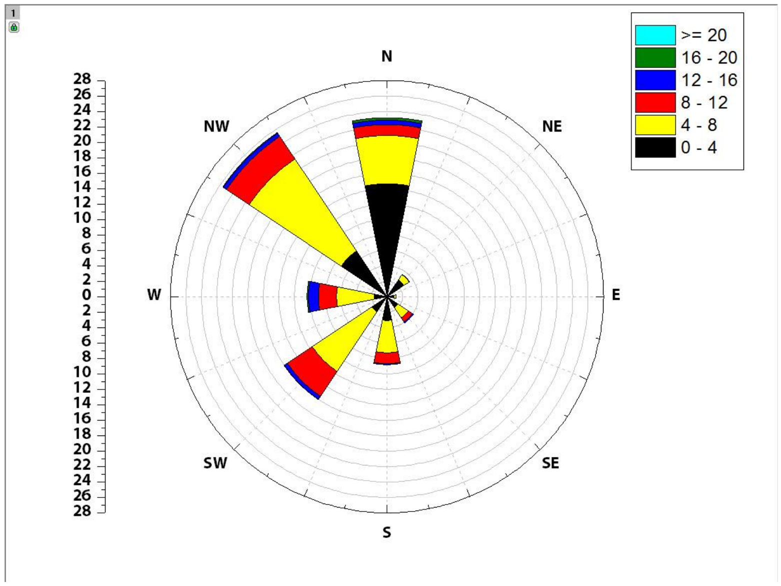


Figure 3.2: January Wind Rose for 03-10; Reoccurring winds are those coming the north/northwest

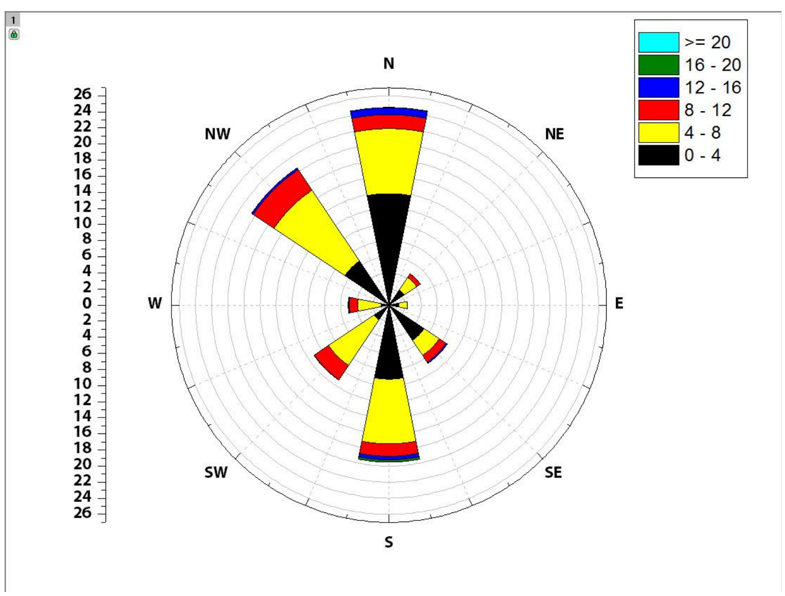


Figure 3.3: February Wind Rose for 03-10; Reoccurring winds are coming from both north and south

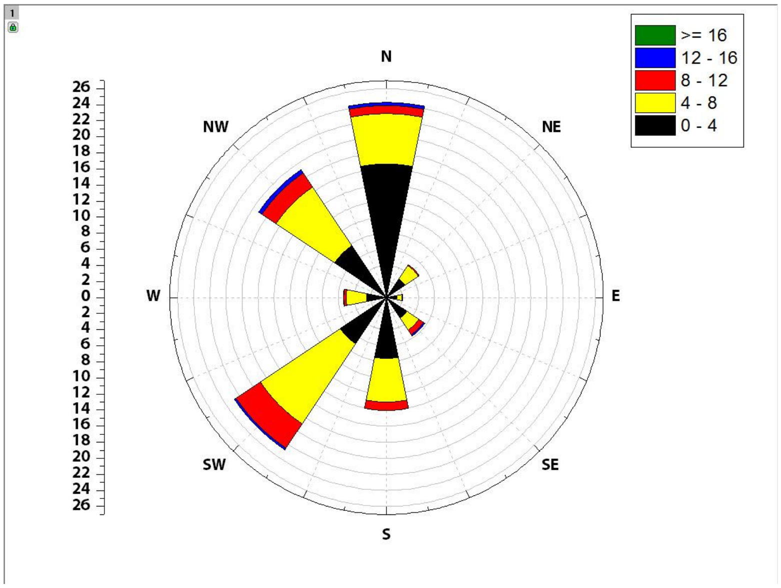


Figure 3.4: March Wind Rose for 03-10; Reoccurring winds are coming from both north and southwest

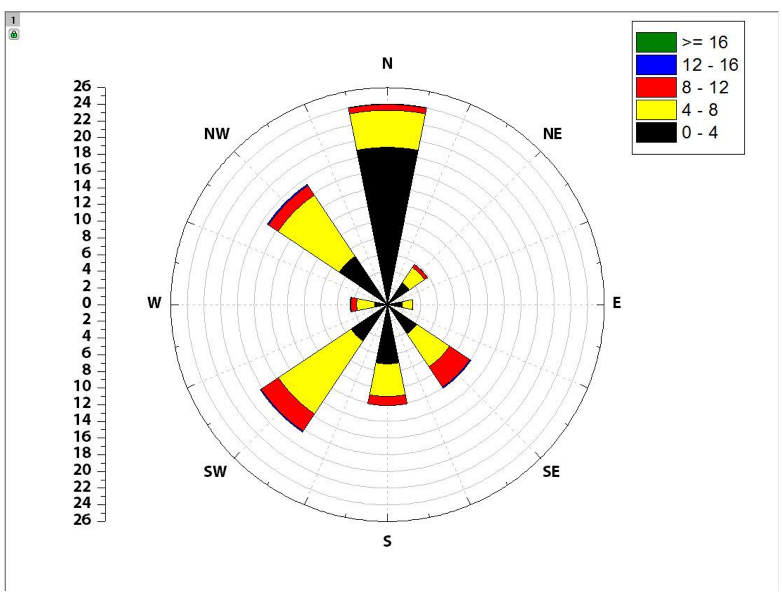


Figure 3.5: April Wind Rose for 03-10; Reoccurring winds are coming from both north

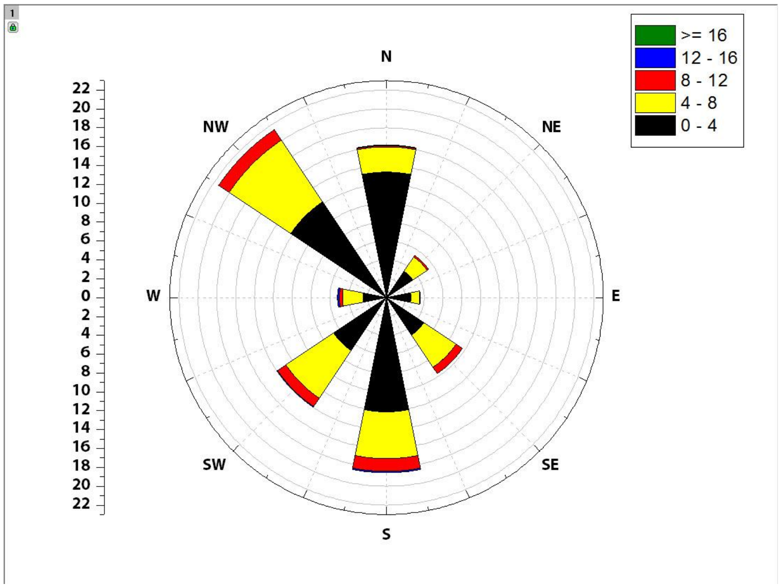


Figure 3.6: May Wind Rose for 03-10; Reoccurring winds are coming from both northwest and south

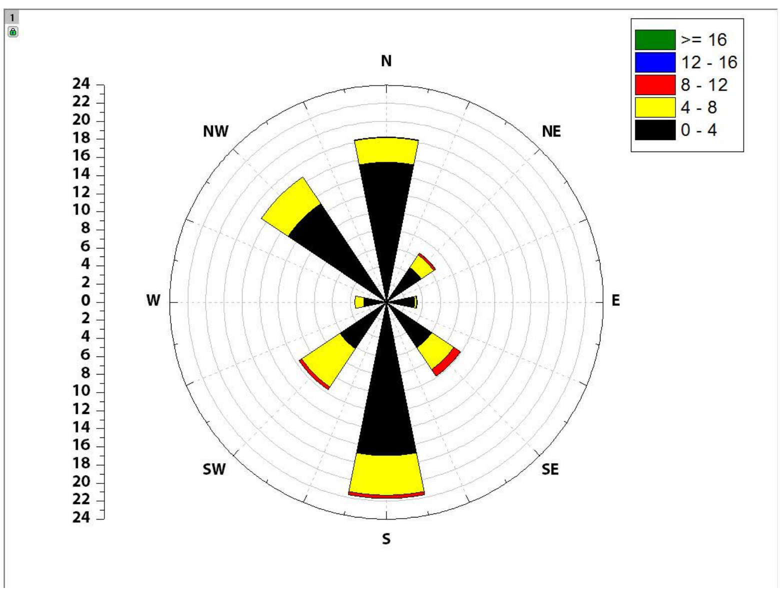


Figure 3.7: June Wind Rose for 03-10; Reoccurring winds are coming from both south and north

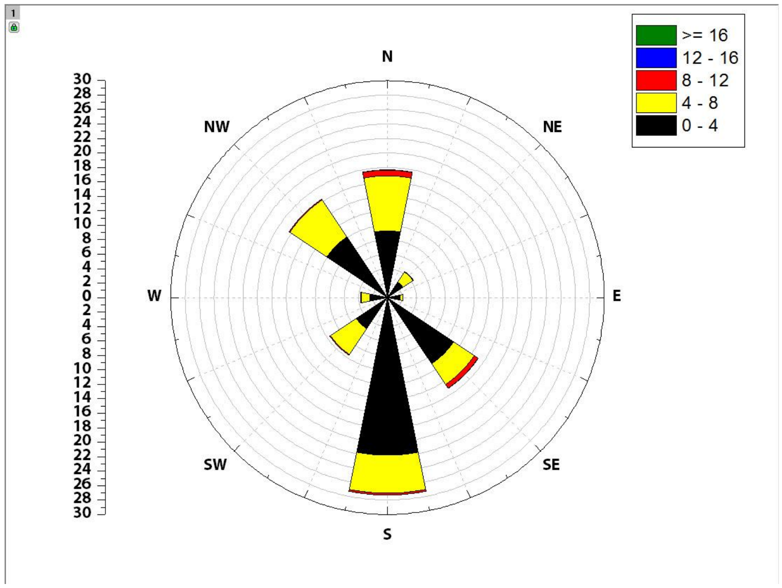


Figure 3.8: July Wind Rose for 03-10; Reoccurring winds are coming mostly from the south

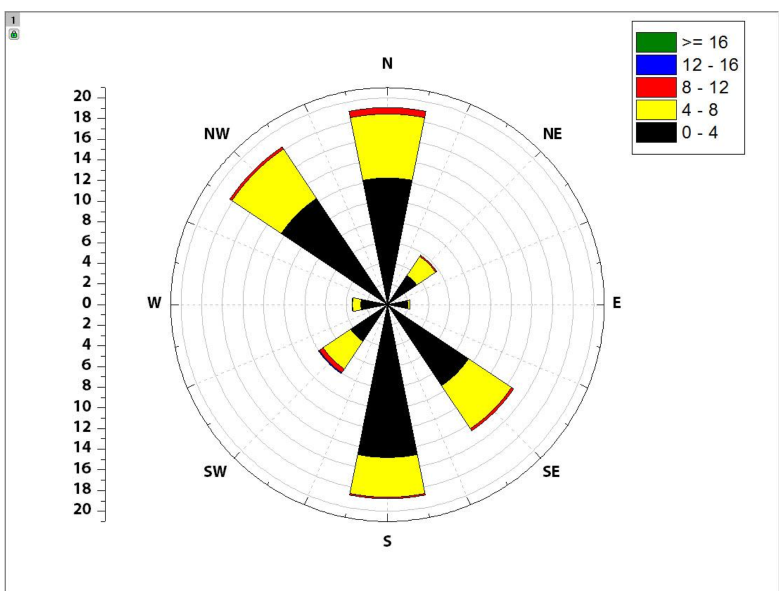


Figure 3.9: August Wind Rose for 03-10; Reoccurring winds are coming from both north and south

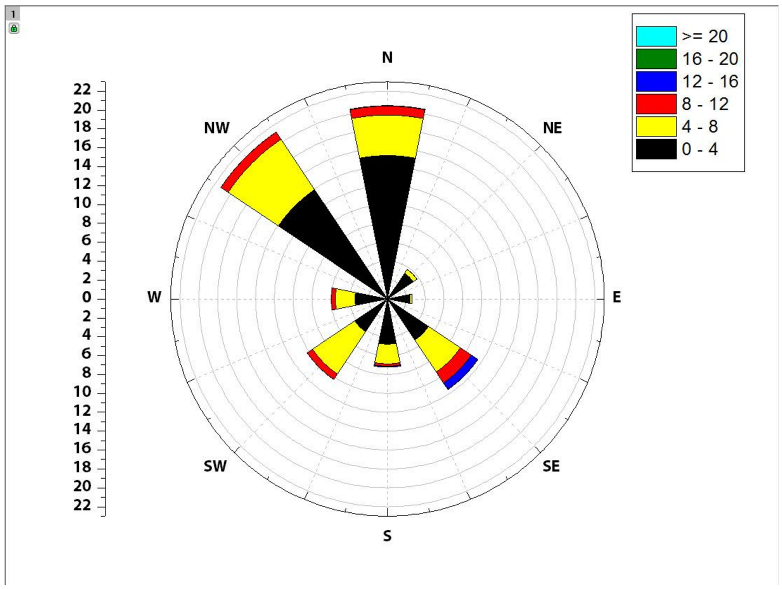


Figure 3.10: September Wind Rose for 03-10; Reoccurring winds are coming from both northwest and north

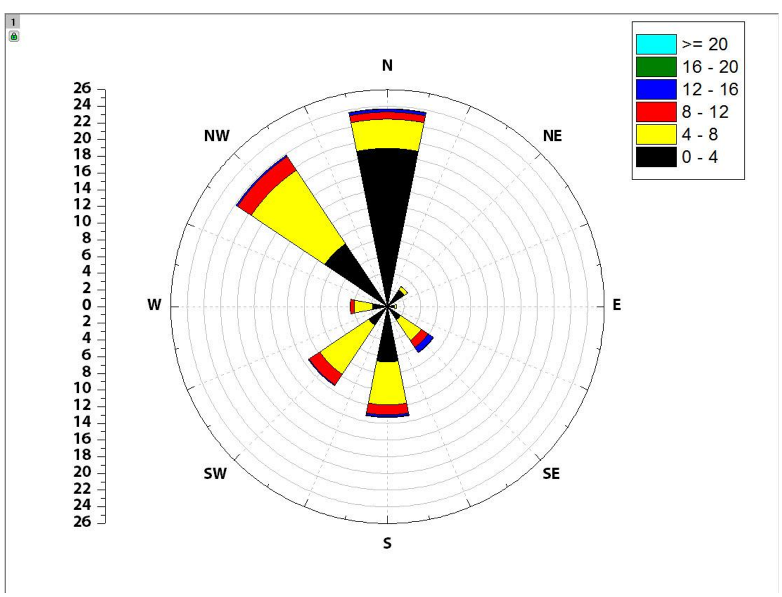


Figure 3.11: October Wind Rose for 03-10; Reoccurring winds are coming from both north and northwest

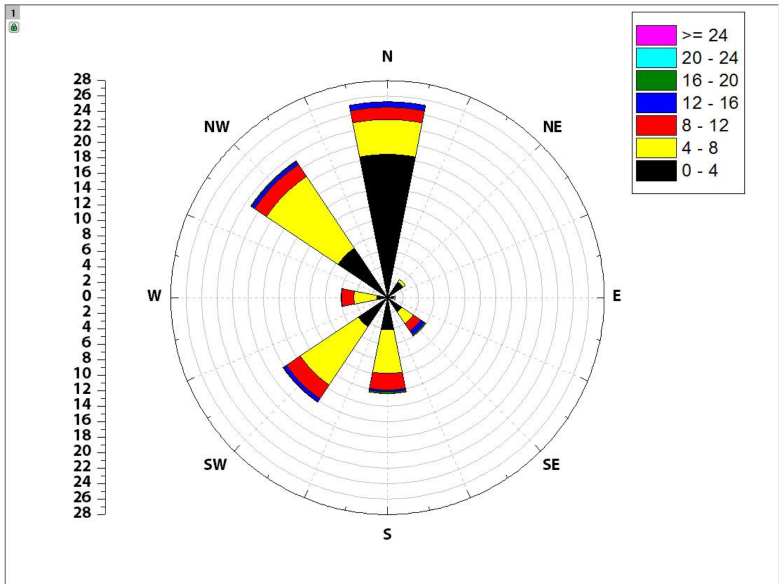


Figure 3.12: November Wind Rose for 03-10; Reoccurring winds are coming from both north and northwest

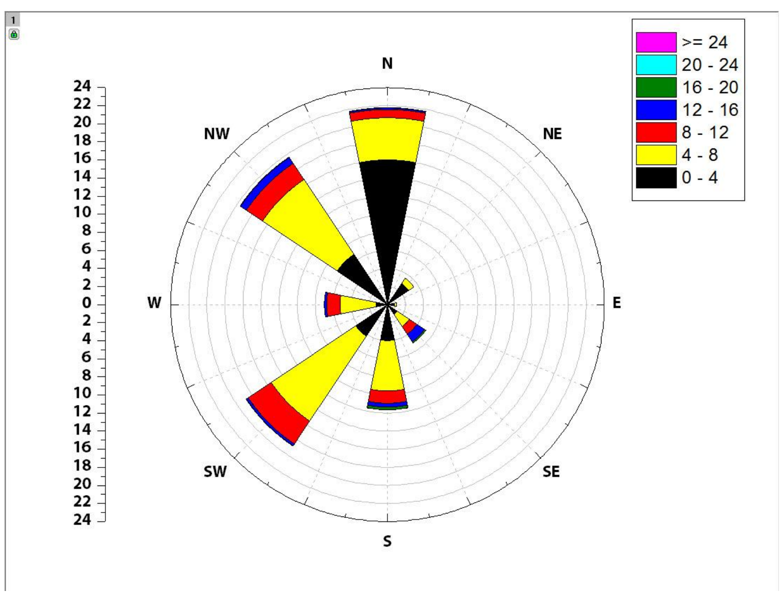


Figure 3.13: December Wind Rose for 03-10; Reoccurring winds are coming from both north, northwest and southwest

3.2 Linnévatnet Events

Preliminary Results Using Excel

Events that were +1 standard deviation were taken into consideration as "Medium Warm" events, -1 standard deviation were "Medium Cold" events, +2 standard deviations were "Warm" events and -2 standard deviations were "Cold" events. Figure 3.14 shows the number of events in Spring and Year Long Mooring Lines C and D. Both Spring and Year-Long C sites had the highest number of events in all categories. The number of events ± 1 standard deviation is much higher than events ± 2 standard deviations. Also, C sites have a higher number of events compared to D.

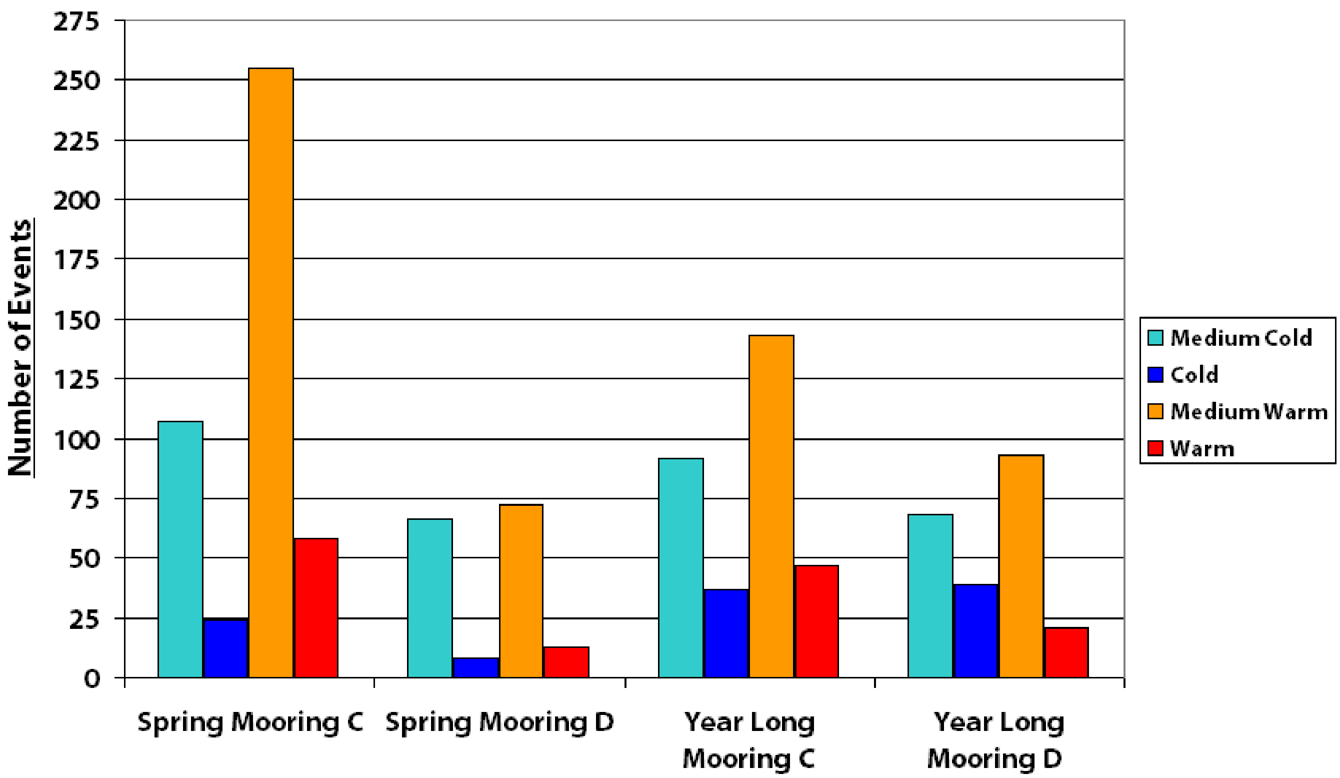


Figure 3.14: Number of Events in Spring and Year-Long Mooring Lines at both C and D

Method #1 Results

Site C: Spring

The first series of medium cold events seen using the first method to look for underflows was seen in May 11 in Spring Line C (Figure 3.15); these events were not seen in Year-Long Line C or at site D and were located a distance of 0.1 m from bottom. The second series of medium cold events was seen on May 19 in both Spring and Year-Long C (Figure 3.16 and 3.17).

Date/Time	13	12.2	11.15	10.1	9.1	8.05	7	6	4.95	3.9	2.9	2	0.85	0.1
5/11/2010 18:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5/11/2010 19:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5/11/2010 20:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5/11/2010 21:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.46
5/11/2010 22:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.58
5/11/2010 23:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.67
5/12/2010 0:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.60
5/12/2010 1:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.49
5/12/2010 2:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5/12/2010 3:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5/12/2010 4:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Figure 3.15: May 11 event happening in bottom of lake at Spring C; aqua boxes signify "Medium Cold" events

Date/Time	13	12.2	11.15	10.1	9.1	8.05	7	6	4.95	3.9	2.9	2	0.85	0.1
5/19/2010 18:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5/19/2010 19:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5/19/2010 20:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5/19/2010 21:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.48
5/19/2010 22:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.49
5/19/2010 23:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.42
5/20/2010 0:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5/20/2010 1:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5/20/2010 2:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Figure 3.16: May 19 event happening in bottom of lake at Spring C; aqua boxes signify "Medium Cold" events

Date	12.2M	9.2M	5.1M	1M	0.2M	0M
5/19/2010 16:00	0.00	0.00	0.00	0.00	0.00	0.00
5/19/2010 17:00	0.00	0.00	0.00	0.00	0.00	0.00
5/19/2010 18:00	0.00	0.00	0.00	0.00	0.00	0.00
5/19/2010 19:00	0.00	0.00	0.00	0.00	-0.45	0.00
5/19/2010 20:00	0.00	0.00	0.00	0.00	-0.56	0.00
5/19/2010 21:00	0.00	0.00	0.00	0.00	-0.67	0.00
5/19/2010 22:00	0.00	0.00	0.00	0.00	-0.68	-0.43
5/19/2010 23:00	0.00	0.00	0.00	0.00	-0.57	-0.49
5/20/2010 0:00	0.00	0.00	0.00	0.00	-0.48	-0.49
5/20/2010 1:00	0.00	0.00	0.00	0.00	0.00	-0.48
5/20/2010 2:00	0.00	0.00	0.00	0.00	0.00	-0.44
5/20/2010 3:00	0.00	0.00	0.00	0.00	0.00	0.00
5/20/2010 4:00	0.00	0.00	0.00	0.00	0.00	0.00
5/20/2010 5:00	0.00	0.00	0.00	0.00	0.00	0.00
5/20/2010 6:00	0.00	0.00	0.00	0.00	0.00	0.00

Figure 3.17: May 19 event happening in bottom of lake at Year-Long C; aqua boxes signify "Medium Cold" events

The second series of events were seen until the end of June through the first days of July. The first events happened around June 27 and 28 and most of the events happened in the bottom of the lake at site C; the "Medium Warm" events happened from 5 m to 2 m (on 6/27) from bottom while the "Warm" events happened at the bottom 1 m (at both 6/27-28) (Figure 3.18 and 3.19). The second events happened on June 30 and July 1, these were "Medium Warm" and "Medium Cold" events, which happened through the whole water column (Figure 3.20).

The third series of events were seen on July 6-7 and they were "Medium Warm" and "Medium Cold"; most of them happened at the bottom 5 m, while the others were seen 9-10 m from bottom (Figure 3.21). More "Medium Warm", "Medium Cold" and "Warm" events were seen on late July 7-8 (Figure 3.22). These events were mostly seen at the surface and intermediate depths. Lastly, "Medium Warm" events seen were on July 11 on the bottom meter (Figure 3.23).

The fourth series of events were seen starting on July 13, and were "Medium Cold" at the bottom 3 m (Figure 3.24). The next events were "Medium Events" and were seen in through the whole water column from July 14-15 (Figure 3.25). Finally, "Medium Cold" and "Cold" events were seen in the surface and intermediate depths on July 16 (Figure 3.26).

Date/Time	13	12.2	11.15	10.1	9.1	8.05	7	6	4.95	3.9	2.9	2	0.85	0.1
6/27/2010 12:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6/27/2010 13:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6/27/2010 14:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6/27/2010 15:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6/27/2010 16:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6/27/2010 17:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.43	0.54	0.54	0.00
6/27/2010 18:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.41	0.55	0.68	0.80	0.00
6/27/2010 19:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.48	0.61	0.72	0.99	0.00
6/27/2010 20:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.42	0.53	0.61	0.69	1.12	0.55
6/27/2010 21:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.42	0.49	0.53	0.58	1.04	0.80
6/27/2010 22:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.41	0.00	0.00	0.89	1.04
6/27/2010 23:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.60	1.27
6/28/2010 0:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.32
6/28/2010 1:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.05
6/28/2010 2:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.74
6/28/2010 3:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6/28/2010 4:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6/28/2010 5:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6/28/2010 6:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.44
6/28/2010 7:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.45
6/28/2010 8:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.41
6/28/2010 9:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6/28/2010 10:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Figure 3.18: "Medium Warm" and "Warm" events at Spring C on 6/27in bottom 5 m

Date/Time	13	12.2	11.15	10.1	9.1	8.05	7	6	4.95	3.9	2.9	2	0.85	0.1
6/28/2010 18:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6/28/2010 19:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6/28/2010 20:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.44	0.45
6/28/2010 21:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.48	0.64
6/28/2010 22:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.47	0.77
6/28/2010 23:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.43	0.72
6/29/2010 0:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.71
6/29/2010 1:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.43	0.00	0.00	0.00	0.00	0.71
6/29/2010 2:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.47
6/29/2010 3:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6/29/2010 4:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6/29/2010 5:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6/29/2010 6:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6/29/2010 7:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6/29/2010 8:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6/29/2010 9:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6/29/2010 10:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6/29/2010 11:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.46	0.45	0.00
6/29/2010 12:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.42	0.48	0.00	0.00
6/29/2010 13:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.40	0.00	0.00
6/29/2010 14:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Figure 3.19: "Medium Warm" and "Warm" events at Spring C on 6/28-29in bottom 1 m

Date/Time	13	12.2	11.15	10.1	9.1	8.05	7	6	4.95	3.9	2.9	2	0.85	0.1
6/30/2010 15:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6/30/2010 16:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.47	0.00	0.00	0.00	0.00	0.00
6/30/2010 17:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.43	0.00	0.00	0.00	0.00	0.00
6/30/2010 18:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.41	0.00	0.00	0.00	0.00	0.00
6/30/2010 19:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6/30/2010 20:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6/30/2010 21:00	0.47	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6/30/2010 22:00	0.53	0.00	0.00	0.00	0.00	0.00	0.00	0.46	0.00	0.00	0.00	0.00	0.00	0.00
6/30/2010 23:00	0.64	0.00	0.00	0.00	0.00	0.00	0.00	0.51	0.00	0.00	0.00	0.00	0.00	0.00
7/1/2010 0:00	0.53	0.00	0.00	0.00	0.00	0.00	0.45	0.49	0.00	0.00	0.00	0.00	0.00	0.00
7/1/2010 1:00	0.43	0.00	0.00	0.00	0.00	0.45	0.51	0.49	0.00	0.00	0.00	0.00	0.00	0.00
7/1/2010 2:00	0.46	0.00	0.00	0.00	0.46	0.53	0.56	0.40	0.00	0.00	0.00	0.00	0.00	0.00
7/1/2010 3:00	0.55	0.00	0.00	0.44	0.53	0.58	0.53	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7/1/2010 4:00	0.58	0.45	0.00	0.46	0.53	0.54	0.47	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7/1/2010 5:00	0.54	0.48	0.00	0.40	0.45	0.41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7/1/2010 6:00	0.64	0.56	0.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7/1/2010 7:00	0.59	0.55	0.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7/1/2010 8:00	0.51	0.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7/1/2010 9:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.49	0.00
7/1/2010 10:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.54	0.00
7/1/2010 11:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.47	-0.48	0.00
7/1/2010 12:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.40	0.00	-0.44	0.00	0.00
7/1/2010 13:00	-0.44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.48	-0.48	0.00	0.00	0.00
7/1/2010 14:00	-0.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.46	-0.47	-0.50	0.00	0.00	0.00
7/1/2010 15:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.43	0.00	-0.42	0.00	0.00	0.00
7/1/2010 16:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7/1/2010 17:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Figure 3.20: "Medium Warm" and "Medium Cold" events at Spring C on 6/30 and 7/1 throughout the whole water column

Date/Time	13	12.2	11.15	10.1	9.1	8.05	7	6	4.95	3.9	2.9	2	0.85	0.1
7/6/2010 6:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7/6/2010 7:00	0.00	0.00	0.00	0.00	0.41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7/6/2010 8:00	0.00	0.00	0.00	0.00	0.53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7/6/2010 9:00	0.00	0.00	0.00	0.00	0.52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7/6/2010 10:00	0.00	0.00	0.00	0.00	0.53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7/6/2010 11:00	0.00	0.00	0.00	0.00	0.52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7/6/2010 12:00	0.00	0.00	0.00	0.00	0.44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7/6/2010 13:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7/6/2010 14:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7/6/2010 15:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7/6/2010 16:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7/6/2010 17:00	0.00	0.00	0.00	0.00	-0.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7/6/2010 18:00	0.00	0.00	0.00	-0.43	-0.56	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7/6/2010 19:00	0.00	0.00	0.00	-0.54	-0.65	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7/6/2010 20:00	0.00	0.00	0.00	-0.64	-0.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7/6/2010 21:00	0.00	0.00	0.00	-0.58	-0.43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7/6/2010 22:00	0.00	0.00	0.00	-0.41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7/6/2010 23:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7/7/2010 0:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7/7/2010 1:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7/7/2010 2:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.44	0.45	0.00	0.00
7/7/2010 3:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.41	0.52	0.59	0.48	0.00
7/7/2010 4:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.46	0.59	0.68	0.58	0.00
7/7/2010 5:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.48	0.63	0.73	0.64	0.00
7/7/2010 6:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.45	0.50	0.49	0.00
7/7/2010 7:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7/7/2010 8:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Figure 3.21: "Medium Warm" and "Medium Cold" events at Spring C on 7/6-7 on the bottom 5 m and 9-10 m

Date/Time	13	12.2	11.15	10.1	9.1	8.05	7	6	4.95	3.9	2.9	2	0.85	0.1
7/7/2010 9:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7/7/2010 10:00	0.00	0.00	-0.43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7/7/2010 11:00	0.00	0.00	-0.44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7/7/2010 12:00	0.00	-0.47	-0.49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7/7/2010 13:00	0.00	-0.59	-0.52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7/7/2010 14:00	0.00	-0.73	-0.43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7/7/2010 15:00	-0.49	-0.65	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7/7/2010 16:00	-0.53	-0.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7/7/2010 17:00	-0.45	-0.41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7/7/2010 18:00	-0.43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7/7/2010 19:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7/7/2010 20:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7/7/2010 21:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7/7/2010 22:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7/7/2010 23:00	0.47	0.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7/8/2010 0:00	0.70	0.58	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7/8/2010 1:00	1.02	0.86	0.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7/8/2010 2:00	1.35	1.15	0.81	0.49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7/8/2010 3:00	1.55	1.33	0.96	0.64	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7/8/2010 4:00	1.27	1.28	1.01	0.77	0.50	0.41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7/8/2010 5:00	1.06	1.23	1.05	0.88	0.63	0.53	0.44	0.41	0.00	0.00	0.00	0.00	0.00	0.00
7/8/2010 6:00	0.95	1.14	1.08	0.98	0.73	0.62	0.52	0.47	0.00	0.00	0.00	0.00	0.00	0.00
7/8/2010 7:00	0.55	0.77	0.76	0.84	0.67	0.60	0.57	0.51	0.00	0.00	0.00	0.00	0.00	0.00
7/8/2010 8:00	0.00	0.00	0.48	0.58	0.65	0.60	0.55	0.50	0.00	0.00	0.00	0.00	0.00	0.00
7/8/2010 9:00	0.00	0.00	0.00	0.00	0.47	0.44	0.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7/8/2010 10:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7/8/2010 11:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Figure 3.22: "Medium Warm", "Medium Cold" and "Warm" events at Spring C on 7/7-8 at the surface and intermediate depths

Date/Time	13	12.2	11.15	10.1	9.1	8.05	7	6	4.95	3.9	2.9	2	0.85	0.1
7/10/2010 21:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7/10/2010 22:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7/10/2010 23:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.49
7/11/2010 0:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.57
7/11/2010 1:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.66
7/11/2010 2:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.74
7/11/2010 3:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.65
7/11/2010 4:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.53
7/11/2010 5:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7/11/2010 6:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7/11/2010 7:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Figure 3.23: "Medium Warm" events at Spring C on 7/11 in the bottom meter

Date/Time	13	12.2	11.15	10.1	9.1	8.05	7	6	4.95	3.9	2.9	2	0.85	0.1
7/13/2010 8:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7/13/2010 9:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7/13/2010 10:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.42	-0.47	-0.49	-0.49
7/13/2010 11:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.44	-0.48	-0.51	-0.52
7/13/2010 12:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.42	-0.44	-0.46
7/13/2010 13:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7/13/2010 14:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7/13/2010 15:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Figure 3.24: "Medium Cold" events at Spring C on 7/13 in the bottom 3 m

Date/Time	13	12.2	11.15	10.1	9.1	8.05	7	6	4.95	3.9	2.9	2	0.85	0.1
7/14/2010 14:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7/14/2010 15:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7/14/2010 16:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7/14/2010 17:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7/14/2010 18:00	0.53	0.47	0.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7/14/2010 19:00	0.59	0.54	0.48	0.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7/14/2010 20:00	0.65	0.62	0.57	0.52	0.50	0.48	0.45	0.43	0.42	0.41	0.00	0.00	0.00	0.00
7/14/2010 21:00	0.64	0.63	0.58	0.56	0.56	0.55	0.53	0.50	0.51	0.51	0.49	0.49	0.47	0.46
7/14/2010 22:00	0.66	0.64	0.58	0.55	0.55	0.56	0.55	0.53	0.55	0.57	0.57	0.57	0.56	0.56
7/14/2010 23:00	0.70	0.69	0.62	0.60	0.61	0.61	0.60	0.58	0.60	0.61	0.62	0.62	0.61	0.62
7/15/2010 0:00	0.66	0.67	0.61	0.59	0.60	0.60	0.58	0.57	0.58	0.58	0.58	0.56	0.54	0.55
7/15/2010 1:00	0.63	0.63	0.57	0.55	0.54	0.53	0.52	0.52	0.52	0.49	0.46	0.43	0.00	0.40
7/15/2010 2:00	0.57	0.55	0.51	0.48	0.41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7/15/2010 3:00	0.51	0.51	0.50	0.43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7/15/2010 4:00	0.43	0.45	0.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7/15/2010 5:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7/15/2010 6:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Figure 3.25: "Medium Warm" events at Spring C on 7/14-15 through the whole water column

Date/Time	13	12.2	11.15	10.1	9.1	8.05	7	6	4.95	3.9	2.9	2	0.85	0.1
7/15/2010 23:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7/16/2010 0:00	0.00	0.00	-0.46	-0.49	-0.47	-0.45	-0.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7/16/2010 1:00	-0.45	-0.52	-0.57	-0.55	-0.52	-0.51	-0.47	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7/16/2010 2:00	-0.69	-0.60	-0.61	-0.55	-0.52	-0.49	-0.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7/16/2010 3:00	-0.91	-0.71	-0.60	-0.53	-0.50	-0.47	-0.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7/16/2010 4:00	-1.00	-0.76	-0.59	-0.49	-0.43	-0.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7/16/2010 5:00	-0.93	-0.68	-0.51	-0.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7/16/2010 6:00	-0.77	-0.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7/16/2010 7:00	-0.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7/16/2010 8:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7/16/2010 9:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7/16/2010 10:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Figure 3.26: "Medium Cold" and "Cold" events at Spring C on 7/16 in the surface and intermediate depths

Site C: Year-Long

The first series of "Medium Cold" events seen in May 19 in Spring Line C (Figure 3.27); they were located a distance of 0.1 m from bottom.

Date	12.2M	9.2M	5.1M	1M	0.2M	0M
5/19/2010 16:00	0.00	0.00	0.00	0.00	0.00	0.00
5/19/2010 17:00	0.00	0.00	0.00	0.00	0.00	0.00
5/19/2010 18:00	0.00	0.00	0.00	0.00	0.00	0.00
5/19/2010 19:00	0.00	0.00	0.00	0.00	-0.45	0.00
5/19/2010 20:00	0.00	0.00	0.00	0.00	-0.56	0.00
5/19/2010 21:00	0.00	0.00	0.00	0.00	-0.67	0.00
5/19/2010 22:00	0.00	0.00	0.00	0.00	-0.68	-0.43
5/19/2010 23:00	0.00	0.00	0.00	0.00	-0.57	-0.49
5/20/2010 0:00	0.00	0.00	0.00	0.00	-0.48	-0.49
5/20/2010 1:00	0.00	0.00	0.00	0.00	0.00	-0.48
5/20/2010 2:00	0.00	0.00	0.00	0.00	0.00	-0.44
5/20/2010 3:00	0.00	0.00	0.00	0.00	0.00	0.00
5/20/2010 4:00	0.00	0.00	0.00	0.00	0.00	0.00
5/20/2010 5:00	0.00	0.00	0.00	0.00	0.00	0.00
5/20/2010 6:00	0.00	0.00	0.00	0.00	0.00	0.00

Figure 3.27: "Medium Cold" events at YL C on 5/19-20in the bottom meter

The second series of events were seen until the end of June through the first days of July. The first events happened around June 27 and 28 and most of the events happened in the bottom 5 meters of the lake at YL C; the "Medium Warm" events happened in 5 m from bottom while the "Warm" events happened at the bottom 1 m (Figure 3.28). The second events occurred on June 28 to 29 and were "Medium Warm" and "Warm" events; they happened in the bottom 5 meters (Figure 3.29). June 29 and 30, these were "Medium Warm" events, which happened in the bottom 5 meters (Figure 3.30). The third events were "Medium Warm" and "Medium Cold" and occurred on July 1 in the surface and intermediate depths and in the bottom 5 meters respectively (Figure 3.31).

The third series of events were seen on July 6-7 and they were "Medium Warm" and "Medium Cold"; most of them happened at the bottom 10 m (Figure 3.32). More "Medium Warm", "Medium Cold" and "Warm" events were seen on late July 7-8 (Figure 3.33). These events were mostly seen at the surface and intermediate depths.

The fourth series of events were seen starting on July 13, and were "Medium Cold" at the bottom meter (Figure 3.34). The next events were "Medium Warm" and were seen in through the whole water column from July 14-15 (Figure 3.35). Finally, "Medium Cold" events were seen in the surface and intermediate depths on July 16 (Figure 3.36).

Date	12.2M	9.2M	5.1M	1M	0.2M	0M
6/27/2010 15:00	0.00	0.00	0.00	0.00	0.00	0.00
6/27/2010 16:00	0.00	0.00	0.00	0.00	0.00	0.00
6/27/2010 17:00	0.00	0.00	0.00	0.46	0.00	0.00
6/27/2010 18:00	0.00	0.00	0.00	0.69	0.00	0.00
6/27/2010 19:00	0.00	0.00	0.00	0.92	0.00	0.00
6/27/2010 20:00	0.00	0.00	0.42	1.09	0.40	0.00
6/27/2010 21:00	0.00	0.00	0.45	1.14	0.65	0.00
6/27/2010 22:00	0.00	0.00	0.42	1.03	0.84	0.00
6/27/2010 23:00	0.00	0.00	0.00	0.77	1.03	0.47
6/28/2010 0:00	0.00	0.00	0.00	0.48	1.18	0.61
6/28/2010 1:00	0.00	0.00	0.00	0.00	1.07	0.74
6/28/2010 2:00	0.00	0.00	0.00	0.00	0.79	0.76
6/28/2010 3:00	0.00	0.00	0.00	0.00	0.45	0.68
6/28/2010 4:00	0.00	0.00	0.00	0.00	0.00	0.53
6/28/2010 5:00	0.00	0.00	0.00	0.00	0.00	0.00
6/28/2010 6:00	0.00	0.00	0.00	0.00	0.00	0.00

Figure 3.28: "Medium Warm" and "Warm" events seen in the bottom 5 meters at YL C on 6/27-28

Date	12.2M	9.2M	5.1M	1M	0.2M	0M
6/28/2010 15:00	0.00	0.00	0.00	0.00	0.00	0.00
6/28/2010 16:00	0.00	0.00	0.00	0.00	0.00	0.00
6/28/2010 17:00	0.00	0.00	0.00	0.00	0.00	0.00
6/28/2010 18:00	0.00	0.00	0.00	0.00	0.00	0.00
6/28/2010 19:00	0.00	0.00	0.00	0.41	0.00	0.00
6/28/2010 20:00	0.00	0.00	0.00	0.46	0.00	0.00
6/28/2010 21:00	0.00	0.00	0.00	0.48	0.53	0.00
6/28/2010 22:00	0.00	0.00	0.00	0.47	0.67	0.00
6/28/2010 23:00	0.00	0.00	0.00	0.41	0.70	0.00
6/29/2010 0:00	0.00	0.00	0.41	0.00	0.76	0.40
6/29/2010 1:00	0.00	0.00	0.45	0.00	0.81	0.49
6/29/2010 2:00	0.00	0.00	0.00	0.00	0.64	0.56
6/29/2010 3:00	0.00	0.00	0.00	0.00	0.00	0.56
6/29/2010 4:00	0.00	0.00	0.00	0.00	0.00	0.47
6/29/2010 5:00	0.00	0.00	0.00	0.00	0.00	0.00
6/29/2010 6:00	0.00	0.00	0.00	0.00	0.00	0.00

Figure 3.29: "Medium Warm" and "Warm" events seen in the bottom 5 meters at YL C on 6/28-29

Date	12.2M	9.2M	5.1M	1M	0.2M	0M
6/29/2010 21:00	0.00	0.00	0.00	0.00	0.00	0.00
6/29/2010 22:00	0.00	0.00	0.00	0.00	0.00	0.00
6/29/2010 23:00	0.00	0.00	0.00	0.00	0.00	0.00
6/30/2010 0:00	0.00	0.00	0.00	0.00	0.48	0.00
6/30/2010 1:00	0.00	0.00	0.00	0.00	0.47	0.00
6/30/2010 2:00	0.00	0.00	0.00	0.00	0.41	0.00
6/30/2010 3:00	0.00	0.00	0.00	0.00	0.00	0.00
6/30/2010 4:00	0.00	0.00	0.00	0.00	0.00	0.00
6/30/2010 5:00	0.00	0.00	0.41	0.00	0.00	0.00
6/30/2010 6:00	0.00	0.00	0.40	0.00	0.00	0.00
6/30/2010 7:00	0.00	0.00	0.00	0.00	0.00	0.00
6/30/2010 8:00	0.00	0.00	0.00	0.00	0.00	0.00

Figure 3.30: "Medium Warm" events seen in the bottom 5 meters at YL C on 6/29-30

Date	12.2M	9.2M	5.1M	1M	0.2M	0M
7/1/2010 0:00	0.00	0.00	0.00	0.00	0.00	0.00
7/1/2010 1:00	0.00	0.00	0.00	0.00	0.00	0.00
7/1/2010 2:00	0.00	0.45	0.00	0.00	0.00	0.00
7/1/2010 3:00	0.00	0.52	0.00	0.00	0.00	0.00
7/1/2010 4:00	0.43	0.51	0.00	0.00	0.00	0.00
7/1/2010 5:00	0.41	0.45	0.00	0.00	0.00	0.00
7/1/2010 6:00	0.45	0.00	0.00	0.00	0.00	0.00
7/1/2010 7:00	0.00	0.00	0.00	0.00	0.00	0.00
7/1/2010 8:00	0.00	0.00	0.00	0.00	0.00	0.00
7/1/2010 9:00	0.00	0.00	0.00	-0.48	0.00	0.00
7/1/2010 10:00	0.00	0.00	0.00	-0.50	0.00	0.00
7/1/2010 11:00	0.00	0.00	0.00	-0.45	0.00	0.00
7/1/2010 12:00	0.00	0.00	0.00	0.00	0.00	0.00
7/1/2010 13:00	0.00	0.00	-0.41	0.00	0.00	0.00
7/1/2010 14:00	0.00	0.00	-0.46	0.00	0.00	0.00
7/1/2010 15:00	0.00	0.00	0.00	0.00	0.00	0.00
7/1/2010 16:00	0.00	0.00	0.00	0.00	0.00	0.00

Figure 3.31: "Medium Warm" and "Medium Cold" events seen through the whole water column at YL C on 7/1

Date	12.2M	9.2M	5.1M	1M	0.2M	0M
7/6/2010 6:00	0.00	0.00	0.00	0.00	0.00	0.00
7/6/2010 7:00	0.00	0.00	0.00	0.00	0.00	0.00
7/6/2010 8:00	0.00	0.44	0.00	0.00	0.00	0.00
7/6/2010 9:00	0.00	0.45	0.00	0.00	0.00	0.00
7/6/2010 10:00	0.00	0.47	0.00	0.00	0.00	0.00
7/6/2010 11:00	0.00	0.50	0.00	0.00	0.00	0.00
7/6/2010 12:00	0.00	0.50	0.00	0.00	0.00	0.00
7/6/2010 13:00	0.00	0.00	0.00	0.00	0.00	0.00
7/6/2010 14:00	0.00	0.00	0.00	0.00	0.00	0.00
7/6/2010 15:00	0.00	0.00	0.00	0.00	0.00	0.00
7/6/2010 16:00	0.00	0.00	0.00	0.00	0.00	0.00
7/6/2010 17:00	0.00	0.00	0.00	0.00	0.00	0.00
7/6/2010 18:00	0.00	-0.51	0.00	0.00	0.00	0.00
7/6/2010 19:00	0.00	-0.61	0.00	0.00	0.00	0.00
7/6/2010 20:00	0.00	-0.50	0.00	0.00	0.00	0.00
7/6/2010 21:00	0.00	0.00	0.00	0.00	0.00	0.00
7/6/2010 22:00	0.00	0.00	0.00	0.00	0.00	0.00
7/6/2010 23:00	0.00	0.00	0.00	0.00	0.00	0.00
7/7/2010 0:00	0.00	0.00	0.00	0.00	0.00	0.00
7/7/2010 1:00	0.00	0.00	0.00	0.00	0.00	0.00
7/7/2010 2:00	0.00	0.00	0.00	0.00	0.00	0.00
7/7/2010 3:00	0.00	0.00	0.00	0.49	0.00	0.00
7/7/2010 4:00	0.00	0.00	0.00	0.57	0.00	0.00
7/7/2010 5:00	0.00	0.00	0.00	0.63	0.00	0.00
7/7/2010 6:00	0.00	0.00	0.00	0.54	0.00	0.00
7/7/2010 7:00	0.00	0.00	0.00	0.00	0.00	0.00

Figure 3.32: "Medium Warm" and "Medium Cold" events seen at intermediate depths and in bottom meter at YL C on 7/6-7

Date	12.2M	9.2M	5.1M	1M	0.2M	0M
7/7/2010 10:00	0.00	0.00	0.00	0.00	0.00	0.00
7/7/2010 11:00	0.00	0.00	0.00	0.00	0.00	0.00
7/7/2010 12:00	-0.47	0.00	0.00	0.00	0.00	0.00
7/7/2010 13:00	-0.58	0.00	0.00	0.00	0.00	0.00
7/7/2010 14:00	-0.71	0.00	0.00	0.00	0.00	0.00
7/7/2010 15:00	-0.64	0.00	0.00	0.00	0.00	0.00
7/7/2010 16:00	-0.52	0.00	0.00	0.00	0.00	0.00
7/7/2010 17:00	-0.40	0.00	0.00	0.00	0.00	0.00
7/7/2010 18:00	0.00	0.00	0.00	0.00	0.00	0.00
7/7/2010 19:00	0.00	0.00	0.00	0.00	0.00	0.00
7/7/2010 20:00	0.00	0.00	0.00	0.00	0.00	0.00
7/7/2010 21:00	0.00	0.00	0.00	0.00	0.00	0.00
7/7/2010 22:00	0.00	0.00	0.00	0.00	0.00	0.00
7/7/2010 23:00	0.45	0.00	0.00	0.00	0.00	0.00
7/8/2010 0:00	0.54	0.00	0.00	0.00	0.00	0.00
7/8/2010 1:00	0.81	0.00	0.00	0.00	0.00	0.00
7/8/2010 2:00	1.06	0.00	0.00	0.00	0.00	0.00
7/8/2010 3:00	1.19	0.00	0.00	0.00	0.00	0.00
7/8/2010 4:00	1.06	0.42	0.00	0.00	0.00	0.00
7/8/2010 5:00	1.03	0.56	0.00	0.00	0.00	0.00
7/8/2010 6:00	1.05	0.68	0.00	0.00	0.00	0.00
7/8/2010 7:00	0.77	0.72	0.00	0.00	0.00	0.00
7/8/2010 8:00	0.42	0.71	0.00	0.00	0.00	0.00
7/8/2010 9:00	0.00	0.57	0.00	0.00	0.00	0.00
7/8/2010 10:00	0.00	0.40	0.00	0.00	0.00	0.00
7/8/2010 11:00	0.00	0.00	0.00	0.00	0.00	0.00

Figure 3.33: "Medium Warm", "Medium Cold" and "Warm" events seen in the surface and intermediate depths at YL C on 7/7-8

Date	12.2M	9.2M	5.1M	1M	0.2M	0M
7/13/2010 8:00	0.00	0.00	0.00	0.00	0.00	0.00
7/13/2010 9:00	0.00	0.00	0.00	0.00	0.00	0.00
7/13/2010 10:00	0.00	0.00	0.00	-0.47	-0.46	0.00
7/13/2010 11:00	0.00	0.00	0.00	-0.49	-0.49	0.00
7/13/2010 12:00	0.00	0.00	0.00	-0.43	-0.43	0.00
7/13/2010 13:00	0.00	0.00	0.00	0.00	0.00	0.00
7/13/2010 14:00	0.00	0.00	0.00	0.00	0.00	0.00

Figure 3.34: "Medium Cold" events seen in the bottom meter at YL C on 7/13

Date	12.2M	9.2M	5.1M	1M	0.2M	0M
7/14/2010 17:00	0.00	0.00	0.00	0.00	0.00	0.00
7/14/2010 18:00	0.47	0.00	0.00	0.00	0.00	0.00
7/14/2010 19:00	0.52	0.00	0.00	0.00	0.00	0.00
7/14/2010 20:00	0.60	0.51	0.00	0.00	0.00	0.00
7/14/2010 21:00	0.59	0.55	0.48	0.44	0.43	0.00
7/14/2010 22:00	0.60	0.57	0.53	0.54	0.53	0.00
7/14/2010 23:00	0.65	0.58	0.58	0.59	0.58	0.00
7/15/2010 0:00	0.61	0.57	0.55	0.53	0.53	0.00
7/15/2010 1:00	0.60	0.51	0.49	0.00	0.40	0.00
7/15/2010 2:00	0.53	0.00	0.00	0.00	0.00	0.00
7/15/2010 3:00	0.52	0.00	0.00	0.00	0.00	0.00
7/15/2010 4:00	0.48	0.00	0.00	0.00	0.00	0.00
7/15/2010 5:00	0.00	0.00	0.00	0.00	0.00	0.00

Figure 3.35: "Medium Warm" events seen through the whole water column at YL C on 7/14-15

Date	12.2M	9.2M	5.1M	1M	0.2M	0M
7/15/2010 23:00	0.00	0.00	0.00	0.00	0.00	0.00
7/16/2010 0:00	-0.42	-0.44	0.00	0.00	0.00	0.00
7/16/2010 1:00	-0.56	-0.51	0.00	0.00	0.00	0.00
7/16/2010 2:00	-0.62	-0.50	0.00	0.00	0.00	0.00
7/16/2010 3:00	-0.66	-0.49	0.00	0.00	0.00	0.00
7/16/2010 4:00	-0.70	-0.43	0.00	0.00	0.00	0.00
7/16/2010 5:00	-0.62	0.00	0.00	0.00	0.00	0.00
7/16/2010 6:00	-0.49	0.00	0.00	0.00	0.00	0.00
7/16/2010 7:00	0.00	0.00	0.00	0.00	0.00	0.00

Figure 3.36: "Medium Cold" events seen surface and intermediate depths at YL C on 7/16

Site D: Spring

The first series of events were seen until the end of June through the first days of July. The first events happened June 28 and most of the events happened in the bottom 2 meters of the lake at Spring D; these events were "Warm" and "Medium Cold" (Figure 3.37). The second events happened on June 30 to July 1; these were "Medium Warm" events, which happened in the bottom 5 meters in June 30 (Figure 3.38) and "Medium Cold" and "Cold" events were seen in July 1 in the bottom 3 meters.

The second series of events were seen on July 9 and they were "Medium Warm" and were seen at the bottom 5 m (Figure 3.39).

The third series of events were seen starting on July 12 and were "Medium Warm" events in the bottom meter (Figure 3.40). In July 13, "Medium Cold" events were seen throughout the whole water column (Figure 3.41). The next events were "Medium Warm" and "Warm" and were seen in through the whole water column (except for the bottom 3 meters) on July 14 (Figure 3.42). Finally, "Medium Cold" events were seen in the surface and intermediate depths on July 15 (Figure 3.43).

Date/Time	11.6	10.55	9.51	8.48	7.44	6.38	5.3	4.22	3.15	2.08	1	0.2
6/27/2010 23:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6/28/2010 0:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6/28/2010 1:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6/28/2010 2:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6/28/2010 3:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6/28/2010 4:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6/28/2010 5:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.42	0.00	0.00
6/28/2010 6:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.57	0.00	0.00
6/28/2010 7:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.68	0.00	0.00
6/28/2010 8:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.77	0.00	0.00
6/28/2010 9:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.64	0.00	0.00
6/28/2010 10:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.43	0.00	0.00
6/28/2010 11:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6/28/2010 12:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6/28/2010 13:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6/28/2010 14:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.46	0.00	0.00
6/28/2010 15:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.45	0.00	0.00
6/28/2010 16:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6/28/2010 17:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Figure 3.37: "Warm" and "Medium Cold" events seen in the bottom 2 meters at Spring D on 6/28

Date/Time	11.6	10.55	9.51	8.48	7.44	6.38	5.3	4.22	3.15	2.08	1	0.2
6/30/2010 8:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.00	0.00	0.00
6/30/2010 9:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.45	0.60	0.00	0.00	0.00
6/30/2010 10:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.52	0.62	0.00	0.00	0.00
6/30/2010 11:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.52	0.55	0.00	0.00	0.00
6/30/2010 12:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.45	0.00	0.00	0.00
6/30/2010 13:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.43	0.00
6/30/2010 14:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.44	0.00
6/30/2010 15:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6/30/2010 16:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6/30/2010 17:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.41	0.00	0.00	0.00	0.00
6/30/2010 18:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6/30/2010 19:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6/30/2010 20:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6/30/2010 21:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6/30/2010 22:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6/30/2010 23:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7/1/2010 0:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.43	-0.58	0.00	0.00
7/1/2010 1:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.57	-0.78	0.00	0.00
7/1/2010 2:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.70	-0.98	0.00	0.00
7/1/2010 3:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.60	-1.06	0.00	0.00
7/1/2010 4:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.53	-0.98	0.00	0.00
7/1/2010 5:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.40	-0.81	0.00	0.00
7/1/2010 6:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.62	0.00	0.00
7/1/2010 7:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.42	0.00	0.00

Figure 3.38: "Medium Warm", "Medium Cold" and "Cold" events seen in the bottom 5 meters at Spring D on 6/30-7/1

Date/Time	11.6	10.55	9.51	8.48	7.44	6.38	5.3	4.22	3.15	2.08	1	0.2
7/9/2010 17:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7/9/2010 18:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.43	0.47	0.00	0.00
7/9/2010 19:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.44	0.00	0.00
7/9/2010 20:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7/9/2010 21:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Figure 3.39: "Medium Warm" events seen in the bottom 3 meters at Spring D on 7/9

Date/Time	11.6	10.55	9.51	8.48	7.44	6.38	5.3	4.22	3.15	2.08	1	0.2
7/12/2010 5:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7/12/2010 6:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7/12/2010 7:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7/12/2010 8:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.46
7/12/2010 9:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.51
7/12/2010 10:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.53
7/12/2010 11:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.50
7/12/2010 12:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.49
7/12/2010 13:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.40
7/12/2010 14:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7/12/2010 15:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Figure 3.40: "Medium Warm" events seen in the bottom meter at Spring D on 7/12

Date/Time	11.6	10.55	9.51	8.48	7.44	6.38	5.3	4.22	3.15	2.08	1	0.2
7/13/2010 5:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7/13/2010 6:00	0.00	0.00	0.00	-0.41	-0.43	-0.43	-0.42	-0.44	-0.44	-0.43	-0.40	0.00
7/13/2010 7:00	-0.48	-0.51	-0.51	-0.50	-0.51	-0.50	-0.48	-0.48	-0.48	-0.46	-0.42	0.00
7/13/2010 8:00	-0.49	-0.51	-0.51	-0.48	-0.48	-0.47	-0.45	-0.44	-0.43	-0.40	0.00	0.00
7/13/2010 9:00	-0.49	-0.49	-0.49	-0.43	-0.41	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7/13/2010 10:00	-0.46	-0.43	-0.43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7/13/2010 11:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7/13/2010 12:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Figure 3.41: "Medium Cold" events seen through the whole water column at Spring D on 7/13

Date/Time	11.6	10.55	9.51	8.48	7.44	6.38	5.3	4.22	3.15	2.08	1	0.2
7/14/2010 8:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7/14/2010 9:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7/14/2010 10:00	0.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7/14/2010 11:00	0.72	0.50	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7/14/2010 12:00	0.90	0.65	0.65	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7/14/2010 13:00	1.01	0.74	0.74	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7/14/2010 14:00	0.93	0.73	0.73	0.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7/14/2010 15:00	0.81	0.71	0.71	0.47	0.43	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7/14/2010 16:00	0.61	0.64	0.64	0.50	0.48	0.43	0.00	0.00	0.00	0.00	0.00	0.00
7/14/2010 17:00	0.00	0.51	0.51	0.54	0.53	0.49	0.45	0.00	0.00	0.00	0.00	0.00
7/14/2010 18:00	0.00	0.00	0.00	0.53	0.55	0.54	0.51	0.46	0.00	0.00	0.00	0.00
7/14/2010 19:00	0.00	0.00	0.00	0.47	0.49	0.50	0.48	0.44	0.00	0.00	0.00	0.00
7/14/2010 20:00	0.00	0.00	0.00	0.00	0.41	0.43	0.43	0.40	0.00	0.00	0.00	0.00
7/14/2010 21:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Figure 3.42: "Medium Warm" and "Warm" events seen through the whole water column (except in the bottom 3 meters) at Spring D on 7/14

Date/Time	11.6	10.55	9.51	8.48	7.44	6.38	5.3	4.22	3.15	2.08	1	0.2
7/15/2010 5:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7/15/2010 6:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7/15/2010 7:00	-0.44	-0.43	-0.43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7/15/2010 8:00	-0.50	-0.49	-0.49	-0.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7/15/2010 9:00	-0.53	-0.53	-0.53	-0.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7/15/2010 10:00	-0.52	-0.52	-0.52	-0.46	-0.41	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7/15/2010 11:00	-0.41	-0.42	-0.42	-0.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7/15/2010 12:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Figure 3.43: "Medium Cold" events seen in the surface and intermediate depths at Spring D on 7/15

Site D: Year-Long

The first series of events were seen until the end of June. The first events happened June 30 and most of the events happened in the bottom 4 meters of the lake at Spring D; these events were "Medium Warm" (Figure 3.44).

The second series of events were seen starting on July 13 and were "Medium Cold" and were seen throughout the whole water column (Figure 3.45). The next events were "Medium Warm", "Medium Cold" and "Warm" and were seen in through the whole water column (except for the bottom meter) on July 14-15 (Figure 3.46).

Date	11M	8.18M	4M	1.1M	0.22M	0M
6/30/2010 7:00	0.00	0.00	0.00	0.00	0.00	0.00
6/30/2010 8:00	0.00	0.00	0.41	0.00	0.00	0.00
6/30/2010 9:00	0.00	0.00	0.48	0.00	0.00	0.00
6/30/2010 10:00	0.00	0.00	0.52	0.00	0.00	0.00
6/30/2010 11:00	0.00	0.00	0.41	0.00	0.00	0.00
6/30/2010 12:00	0.00	0.00	0.00	0.00	0.00	0.00
6/30/2010 13:00	0.00	0.00	0.00	0.00	0.00	0.00

Figure 3.44: "Medium Warm" events seen in the bottom 4 meters at Spring D on 6/30

Date	11M	8.18M	4M	1.1M	0.22M	0M
7/13/2010 4:00	0.00	0.00	0.00	0.00	0.00	0.00
7/13/2010 5:00	0.00	0.00	0.00	0.00	0.41	0.00
7/13/2010 6:00	0.00	-0.42	-0.42	0.00	0.00	0.00
7/13/2010 7:00	-0.50	-0.51	-0.46	0.00	0.00	0.00
7/13/2010 8:00	-0.51	-0.49	-0.41	0.00	0.00	0.00
7/13/2010 9:00	-0.49	-0.42	0.00	0.00	0.00	0.00
7/13/2010 10:00	-0.44	0.00	0.00	0.00	0.00	0.00
7/13/2010 11:00	0.00	0.00	0.00	0.00	0.00	0.00
7/13/2010 12:00	0.00	0.00	0.00	0.00	0.00	0.00

Figure 3.45: "Medium Cold" events seen through the whole water column (except in the bottom meter) at Spring D on 7/13

Date	11M	8.18M	4M	1.1M	0.22M	0M
7/14/2010 9:00	0.00	0.00	0.00	0.00	0.00	0.00
7/14/2010 10:00	0.44	0.00	0.00	0.00	0.00	0.00
7/14/2010 11:00	0.59	0.00	0.00	0.00	0.00	0.00
7/14/2010 12:00	0.75	0.00	0.00	0.00	0.00	0.00
7/14/2010 13:00	0.79	0.00	0.00	0.00	0.00	0.00
7/14/2010 14:00	0.72	0.00	0.00	0.00	0.00	0.00
7/14/2010 15:00	0.67	0.00	0.00	0.00	0.00	0.00
7/14/2010 16:00	0.58	0.45	0.00	0.00	0.00	0.00
7/14/2010 17:00	0.42	0.49	0.00	0.00	0.00	0.00
7/14/2010 18:00	0.00	0.52	0.41	0.00	0.00	0.00
7/14/2010 19:00	0.00	0.50	0.40	0.00	0.00	0.00
7/14/2010 20:00	0.00	0.46	0.00	0.00	0.00	0.00
7/14/2010 21:00	0.00	0.00	0.00	0.00	0.00	0.00
7/14/2010 22:00	0.00	0.00	0.00	0.00	0.00	0.00
7/14/2010 23:00	0.00	0.00	0.00	0.00	0.00	0.00
7/15/2010 0:00	0.00	0.00	0.00	0.00	0.00	0.00
7/15/2010 1:00	0.00	0.00	0.00	0.00	0.00	0.00
7/15/2010 2:00	0.00	0.00	0.00	0.00	0.00	0.00
7/15/2010 3:00	0.00	0.00	0.00	0.00	0.00	0.00
7/15/2010 4:00	0.00	0.00	0.00	0.00	0.00	0.00
7/15/2010 5:00	0.00	0.00	0.00	0.00	0.00	0.00
7/15/2010 6:00	0.00	0.00	0.00	0.00	0.00	0.00
7/15/2010 7:00	-0.41	0.00	0.00	0.00	0.00	0.00
7/15/2010 8:00	-0.47	0.00	0.00	0.00	0.00	0.00
7/15/2010 9:00	-0.50	-0.41	0.00	0.00	0.00	0.00
7/15/2010 10:00	-0.49	-0.44	0.00	0.00	0.00	0.00
7/15/2010 11:00	-0.42	0.00	0.00	0.00	0.00	0.00

Figure 3.46: "Medium Cold", "Medium Warm" and "Warm" events seen in the surface and intermediate depths at Spring D on 7/14-15

Method #2 Results

Using the first method as a guide to look for underflows using the second method was a very efficient way. The events were only useful to identify when overflows, interflows, underflows and homopycnal flow where going to start and when they seemed to end.

Site C: Spring

The first series, first event happened in early May as predicted in the first method. Site C was still experiencing winter stratification (i.e. warmer water in the bottom, colder at top), when colder water entered the bottom of the lake on the 12th and on the 13th as seen in Figure 3.47. The second event happened in the middle of May and as in the first event the lake was still in winter stratification; three cold events were seen at the bottom two meters on the 19th and on the 20th (Figure 3.48).

The second series of events were seen until the end of June through the first days of July. The first underflow event happened around June 27-28, and was relatively small. The next underflow happened late June 28 and lasted into June 29. After those two events, the warmer water coming into the bottom of the lake seems to start warming higher into the column from June 30th-July 1st (figure 3.49).

In the third series, the first event was seen early on July 7th and other smaller ones later during that day in the bottom two meters. After those small underflows, most of the water column is one temperature (except for the bottom half meter, which is colder and the top two meters which is warmer) as seen in Figure 3.50. The second event was seen on late July 9th into the 10th; this underflow/interflow is 3 m to 7 m from the bottom (Figure 3.51).

In the fourth series, homopycnal events are seen through the whole vertical water column on early July 12th and early July 13th. Then on late July 14th, a homopycnal flow warms up the whole water column, which seems to warm up the top 7 meters through July 15th as seen in Figure 3.52.

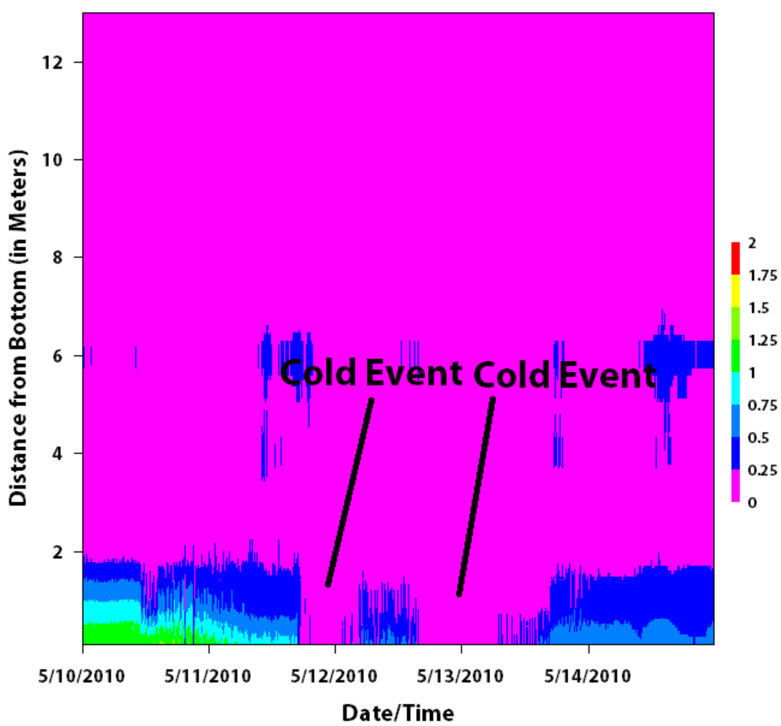


Figure 3.47: First Series; First Event on Spring C from 5/10-14

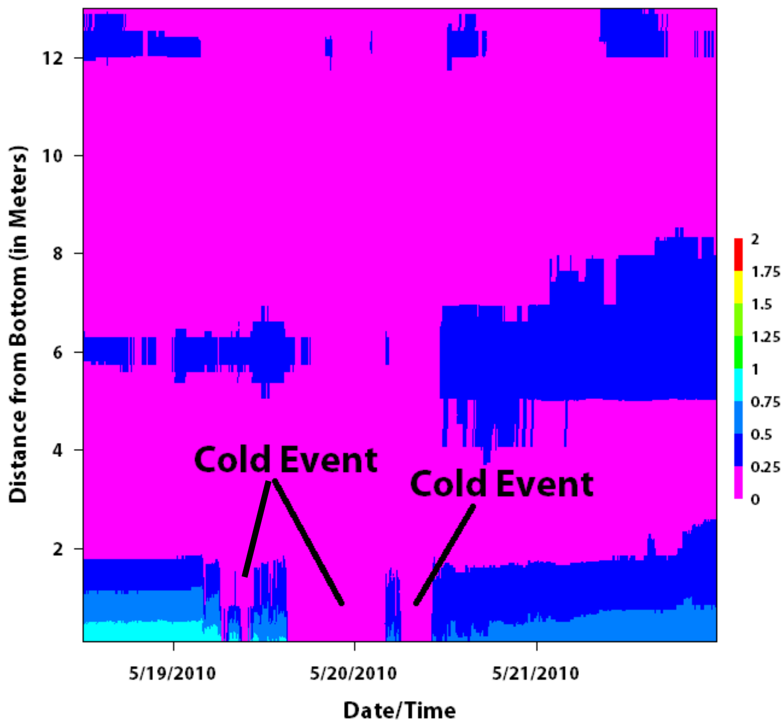


Figure 3.48: First Series; Second Event on Spring C from 5/19 to 5/21

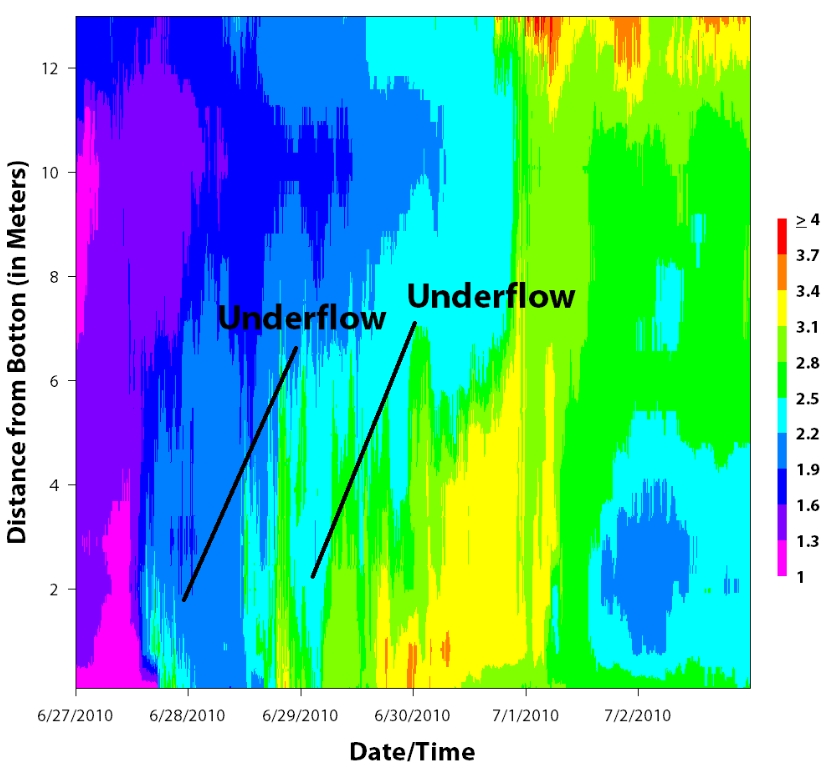


Figure 3.49: Second Series on Spring C from 6/27 to 7/2

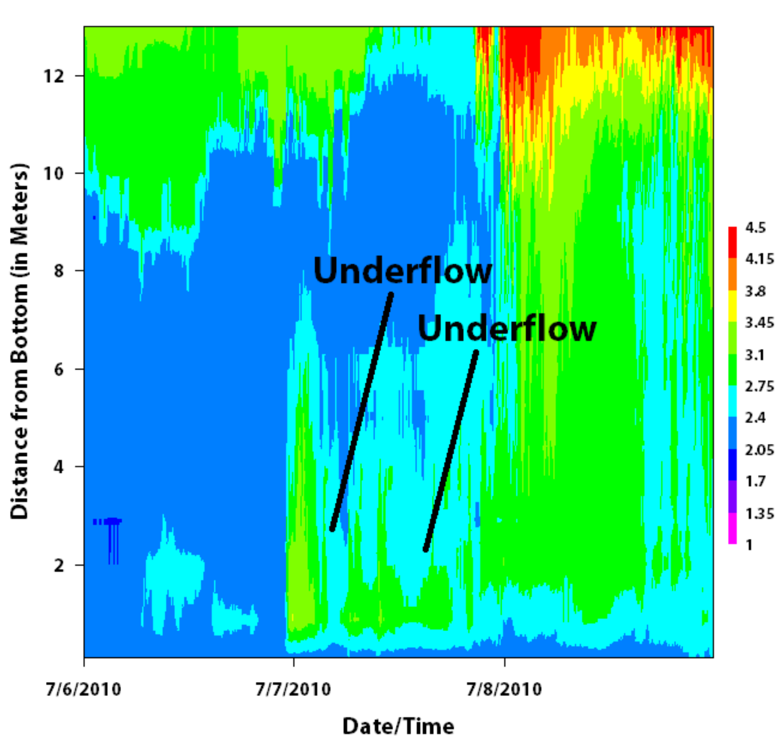


Figure 3.50: Third Series; First Event on Spring C from 7/6 to 7/8

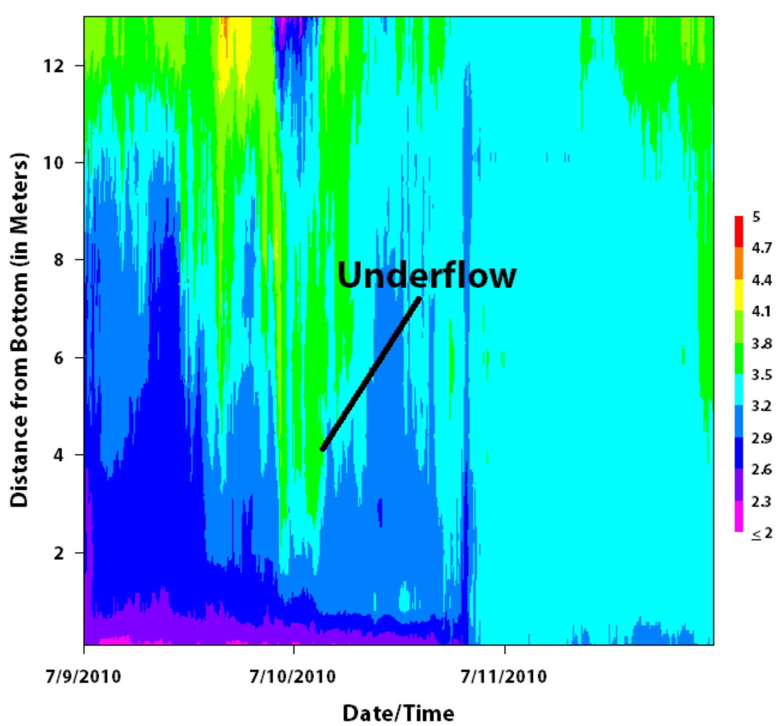


Figure 3.51: Third Series; Second Event on Spring C from 7/9 to 7/11

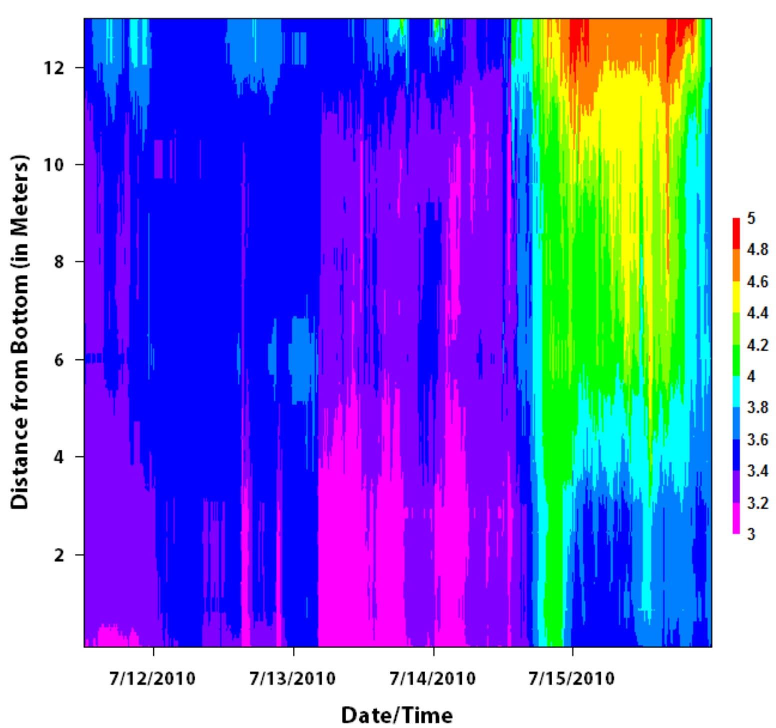


Figure 3.52: Fourth Series on Spring C from 7/12 to 7/15

Site C: Year-Long

The first series happened in the middle of May and the lake was still in winter stratification; two cold events were seen at the bottom four meters on the 19th and on the 20th (Figure 3.53).

The second series of events were seen until the end of June through the first days of July. The first underflow event happened around June 27th, and was relatively small. The next underflow happened late June 28. After those two events, the warmer water coming into the bottom of the lake seems to start warming higher into the column from June 30th-July 1st (figure 3.54).

In the third series, the first event was seen early on July 7th and a smaller one later during that day in the bottom two meters as seen in Figure 3.55. The second event was seen on late July 9th; this underflow/interflow is 4 m to 10 m from the bottom (Figure 3.56).

In the fourth series, a small underflow is seen on July 12th and a homopycnal event is seen through the whole vertical water column on late July 14th as seen in Figure 3.57.

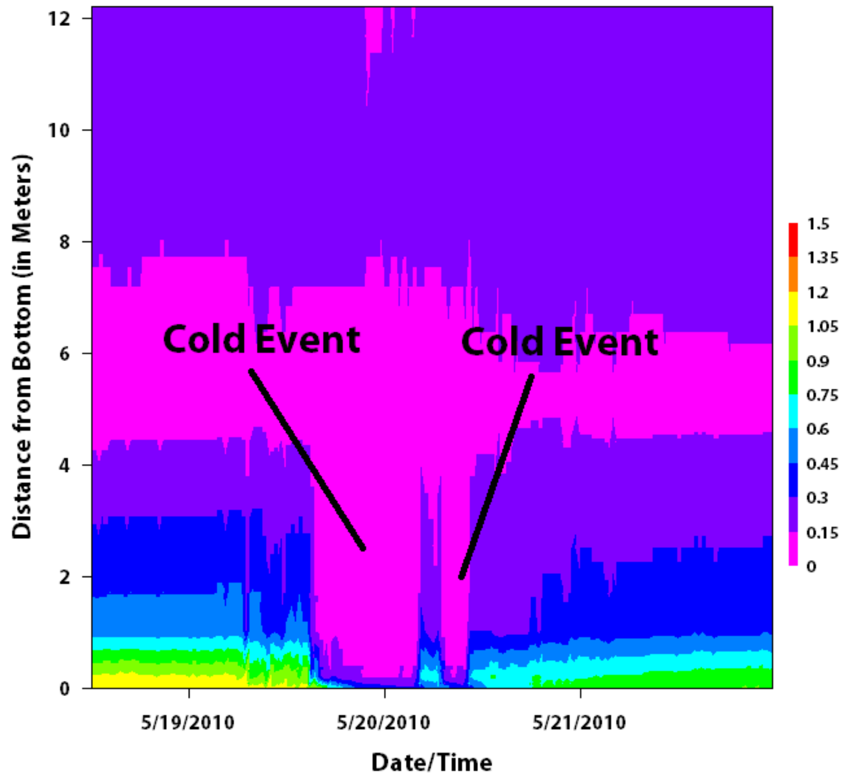


Figure 3.53: First Series on Year-Long C from 5/19 to 5/21

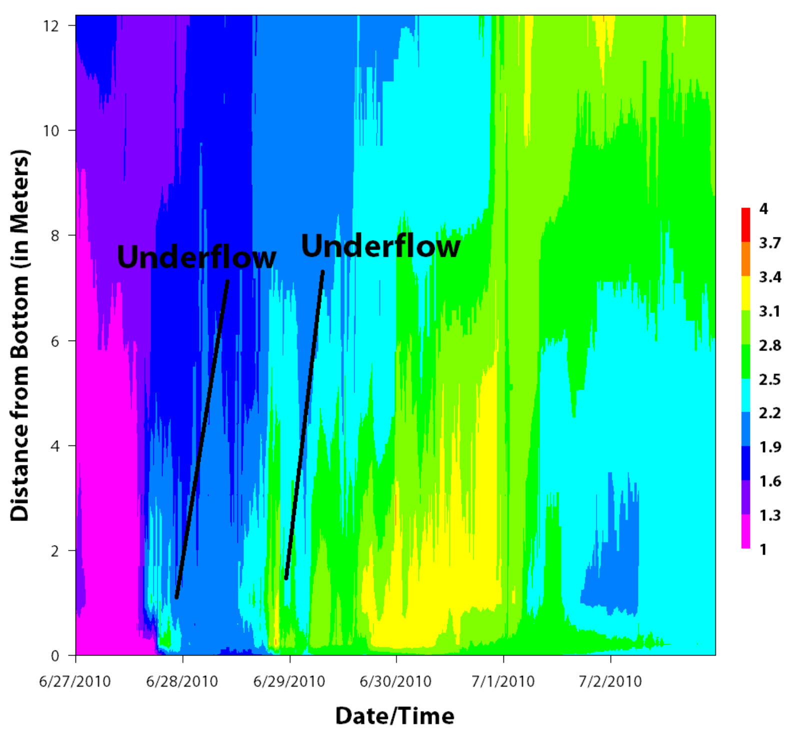


Figure 3.54: Second Series on Year-Long C from 6/27 to 7/2

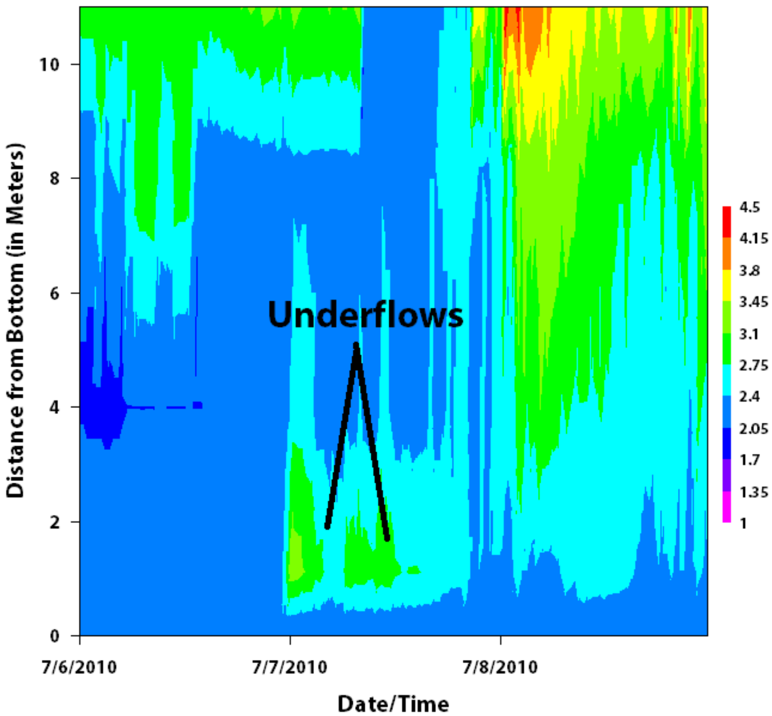


Figure 3.55: Third Series; First Event on Year-Long C from 7/6 to 7/8

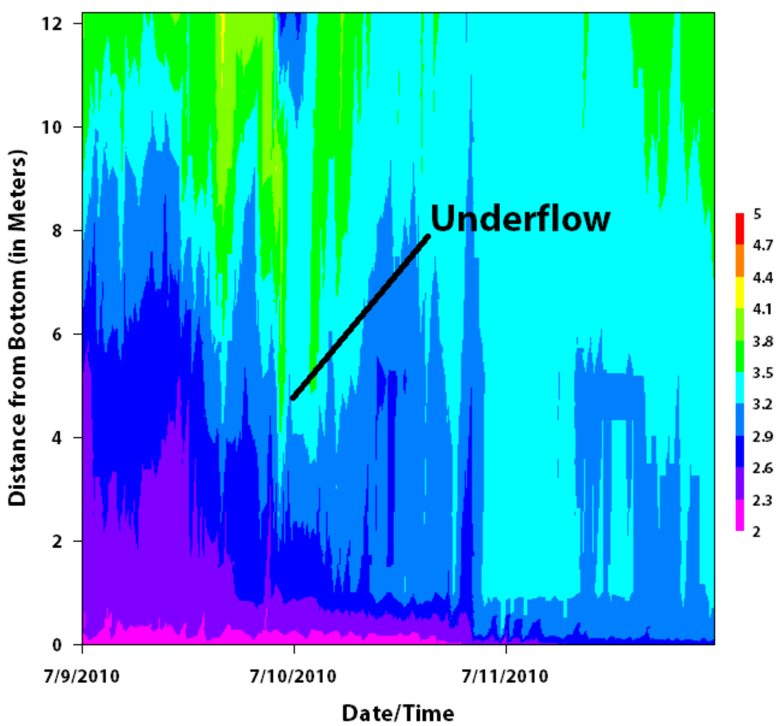


Figure 3.56: Third Series; Second Event on Year-Long C from 7/9 to 7/11

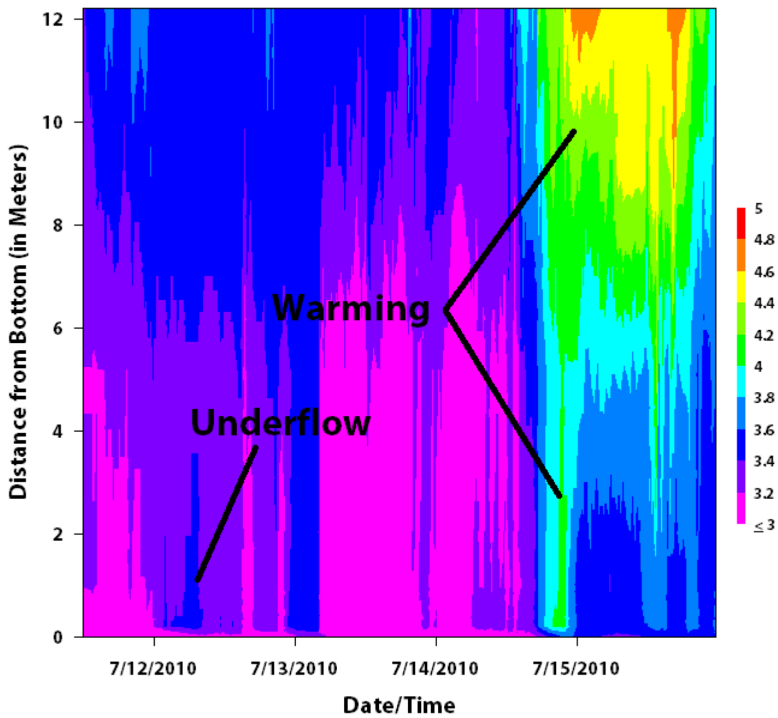


Figure 3.57: Fourth Series on Year-Long C from 7/12 to 7/15

Site D: Spring

The first series of events were seen until the end of June. The first underflow event happened around June 28th, and was relatively small. The next underflow happened early June 29th and lasted into early July 1st (Figure 3.58).

In the second series, the first events were seen mid-July 7th in the intermediate depths. After those small events, most of the water column is one temperature (except for the bottom two meters) as seen in Figure 3.59. The second event was seen on late July 9th into the 10th; this homopycnal flow is seen though all the water column except in the bottom meter while another homopycnal flow is seen late July 10th (Figure 3.60).

In the third series, homopycnal events are seen through the whole vertical water column on early July 13th and early July 14th. Then on late July 14th, a homopycnal flow warms up the whole water column, which seems to further warm up the top 6 meters through July 15th as seen in Figure 3.61.

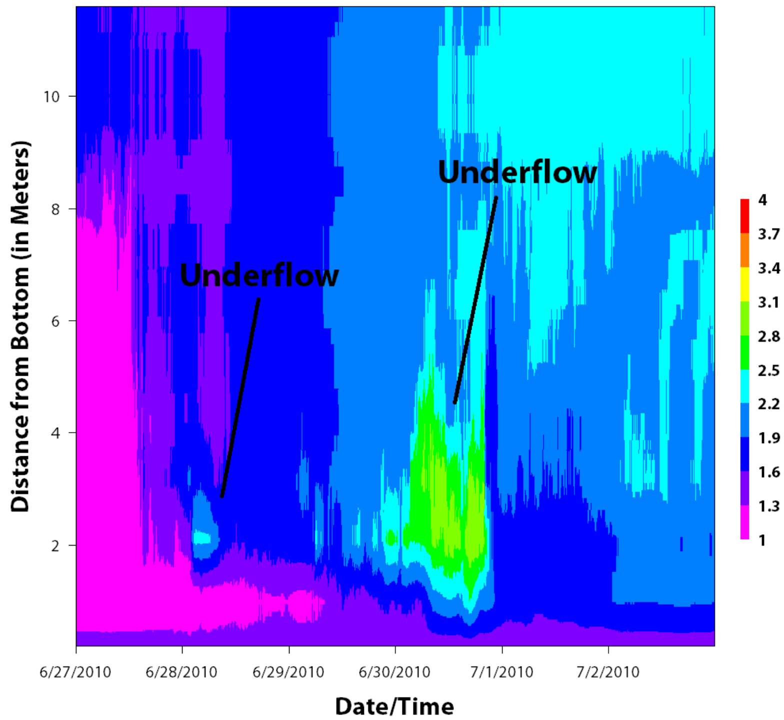


Figure 3.58: First Series on Spring D from 6/27 to 7/2

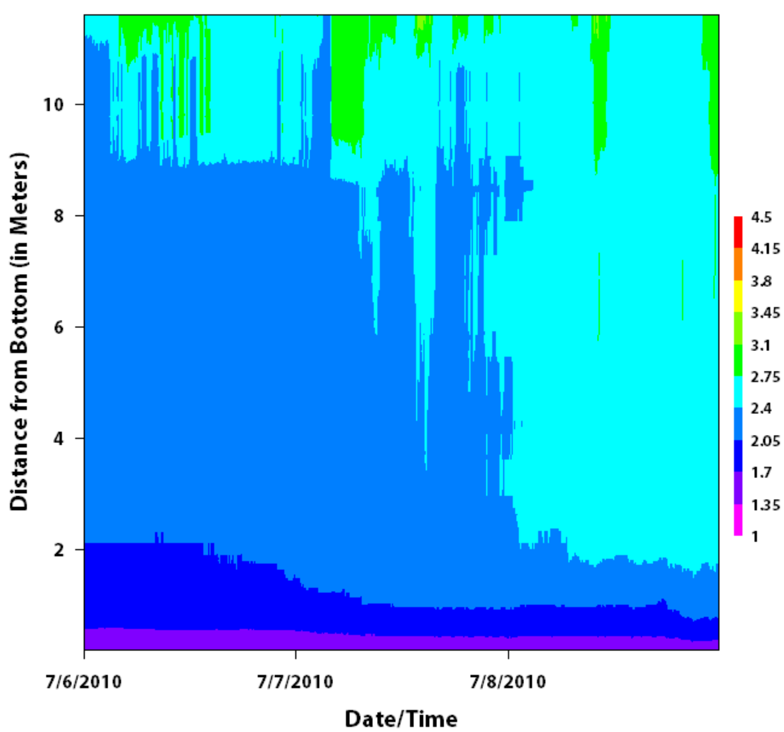


Figure 3.59: Second Series; First Event on Spring D from 7/6 to 7/8

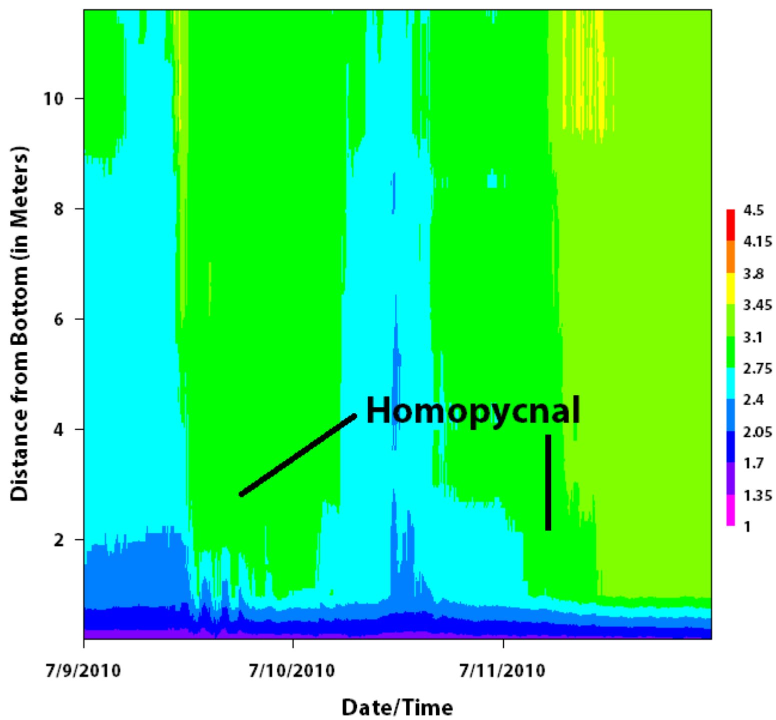


Figure 3.60: Second Series; Second Event on Spring D from 7/9 to 7/11

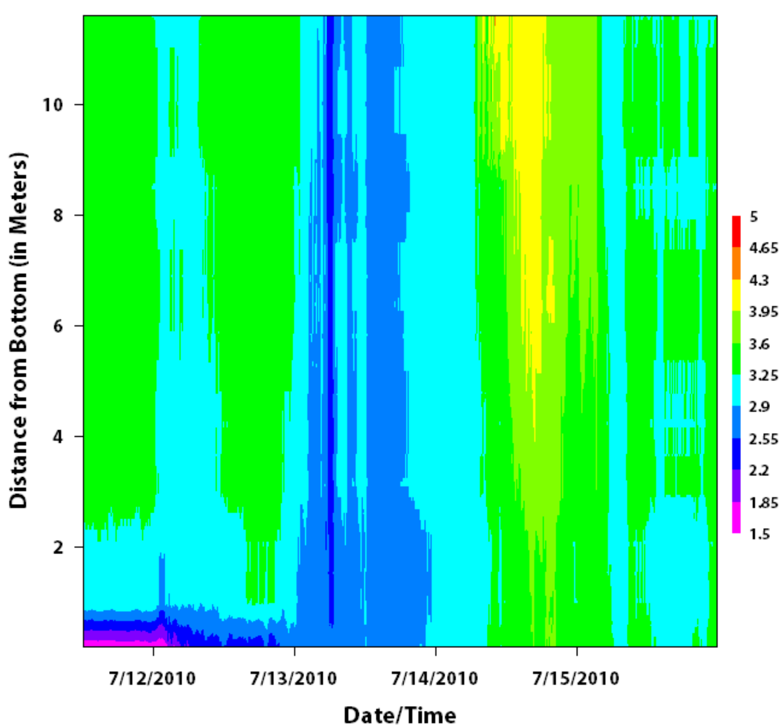


Figure 3.61: Third Series on Spring D from 7/12 to 7/15

Site D: Year-Long

The first series of events were seen until the end of June. The first underflow event happened around June 30th, and was seen mostly in the 6 m to 1 m from bottom (Figure 3.62).

In the second series, the first event was seen on late July 7th into the 8th; this homopycnal flow is seen though the entire water column except in the bottom three meter (Figure 3.63). The second events are seen in mid-late July 9th and in mid-late July 11th as a homopycnal flow as seen in Figure 3.64.

In the third series, homopycnal events are seen through the whole vertical water column on early July 13th and early July 14th. Then on late July 14th-early 15th a homopycnal flow warms up the whole water column, which seems to further warm up the top 6 meters through July 15th as seen in Figure 3.65.

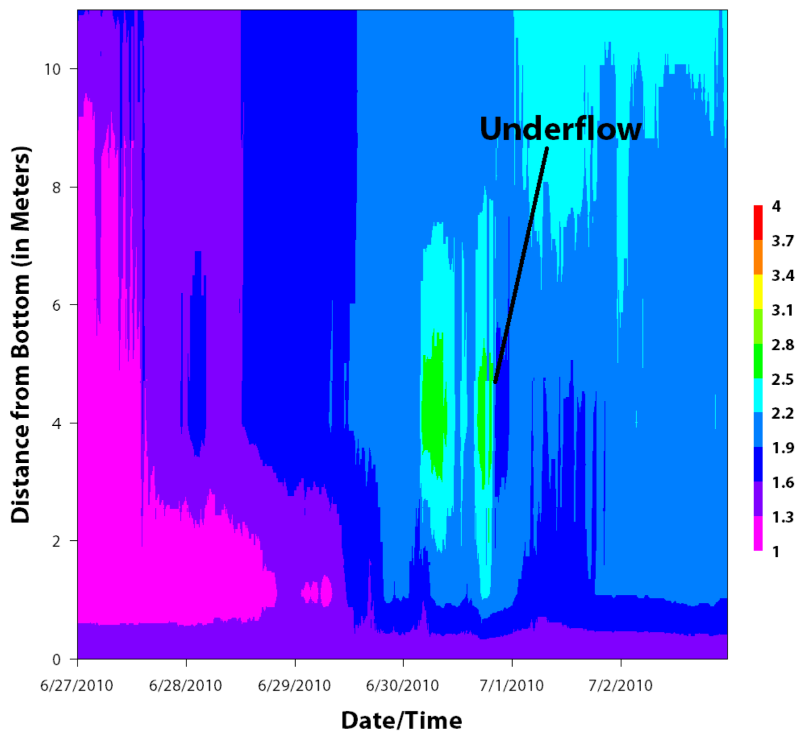


Figure 3.62: First Series on Year-Long D from 6/27 to 7/2

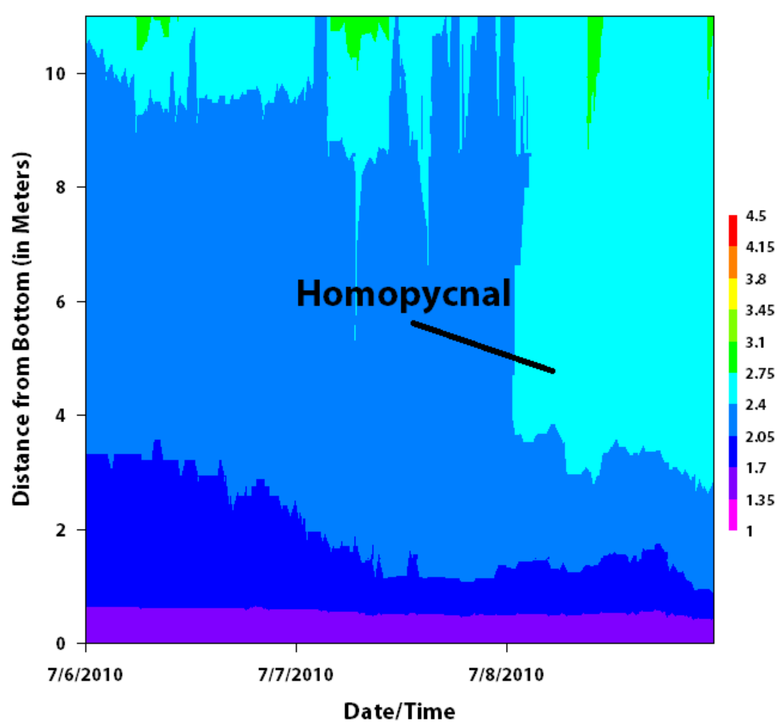


Figure 3.63: Second Series; First Event on Year-Long D from 7/6 to 7/8

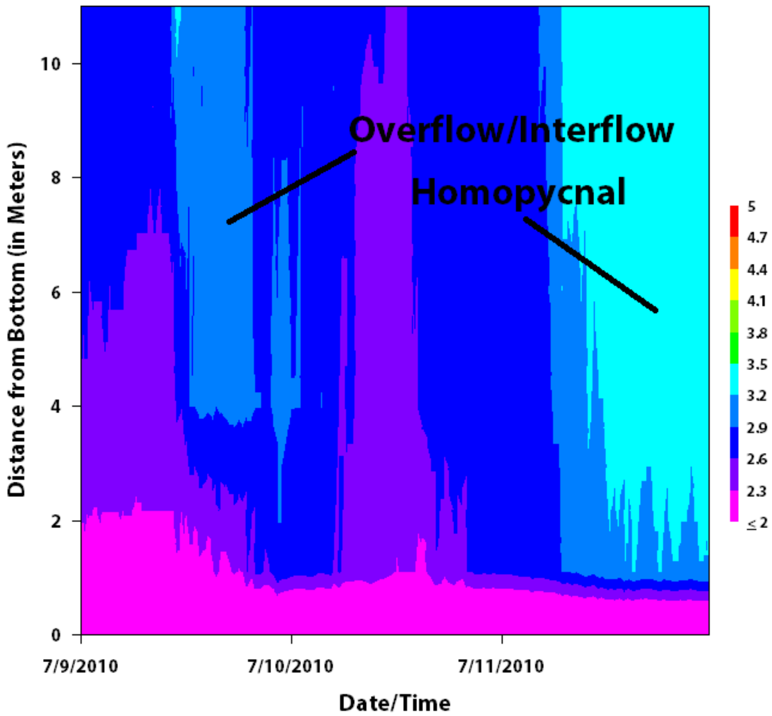


Figure 3.64: Second Series; Second Event on Year-Long D from 7/9 to 7/11

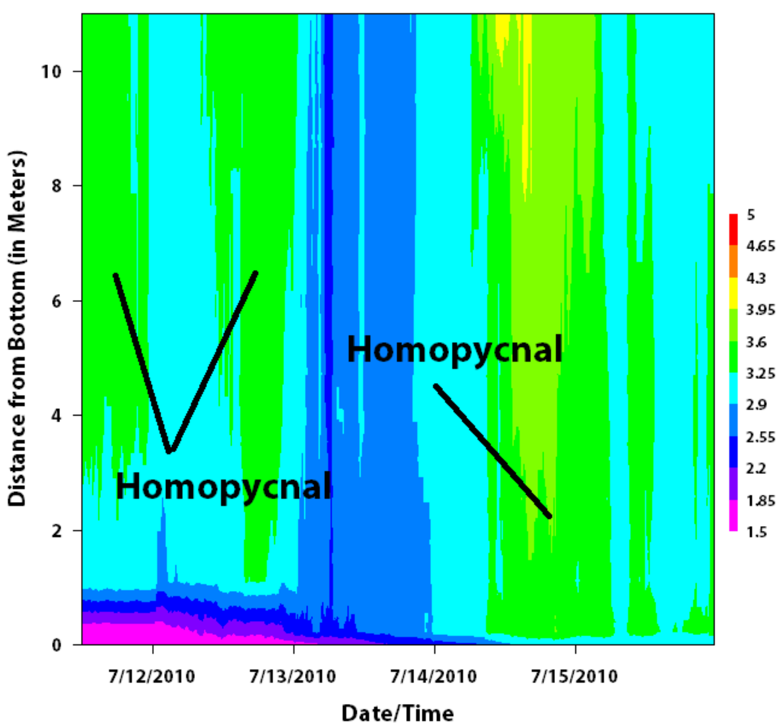


Figure 3.65: Third Series on Year-Long D from 7/12 to 7/15

Method #3 Results

Site C

The tilt meters in C logged a small change in May 11th and larger change in19th; the other days didn't log anything. At site D, the tilt meters did not log anything at all.

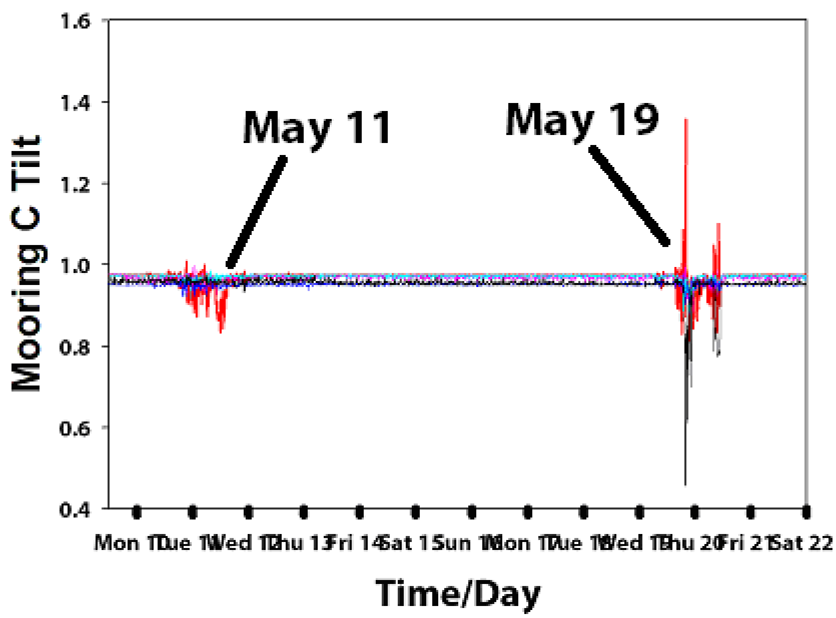
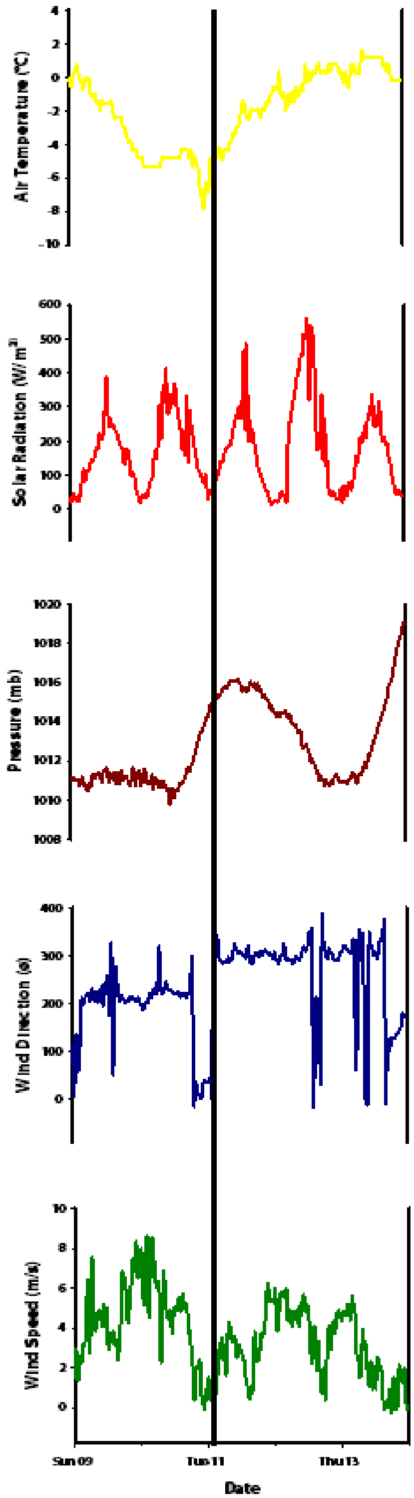


Figure 3.66: Mooring C Tilt in May 11 and 19

Weather

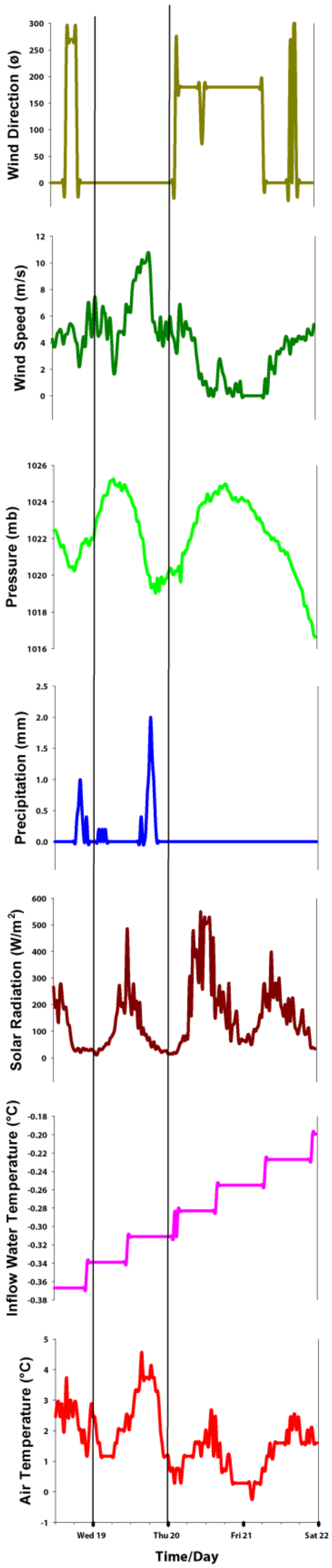
5/11



On the first series, first events, which happened in early May, the only parameters that are ±2 standard deviations are air temperature on the 10^{th} and 11^{th} with -3.71°C and -2.35°C below average respectively. On the 12^{th} solar radiation is 38.98 W/m^2 above normal. The second events, which happened mid-May, had more parameters ±2 standard deviations than in the first events (Figure 3.67).

Figure 3.67: Weather for First Series; First Event in Site C; black vertical line signals 5/11

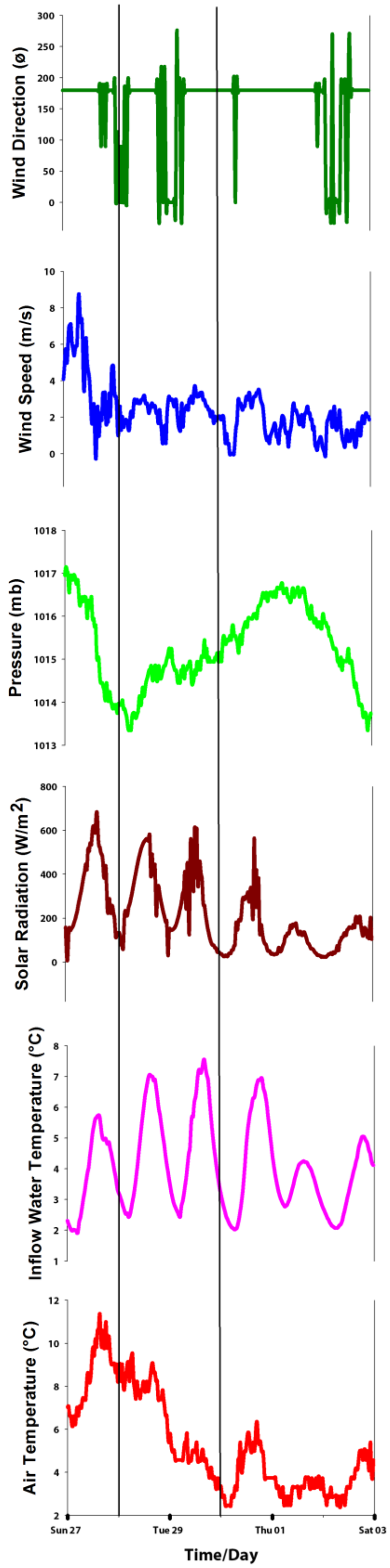
5/19



On May 19th precipitation, wind speed, pressure and air temperature, 0.16 mm, 2.77 m/s, 7.64 mb and 3.63°C above normal respectively while solar radiation was 77.06 W/m^2 below normal. On May 20th the pressure and air temperature were 7.89 mb and 2.34°C above normal. And finally, on the 21st, air temperature was 2.56°C above normal while solar radiation was 37.73 W/m^2 below normal (Figure 3.68).

Figure 3.68: Weather for First Series; Second Event in Site C; black vertical lines signal 5/19 and 5/20

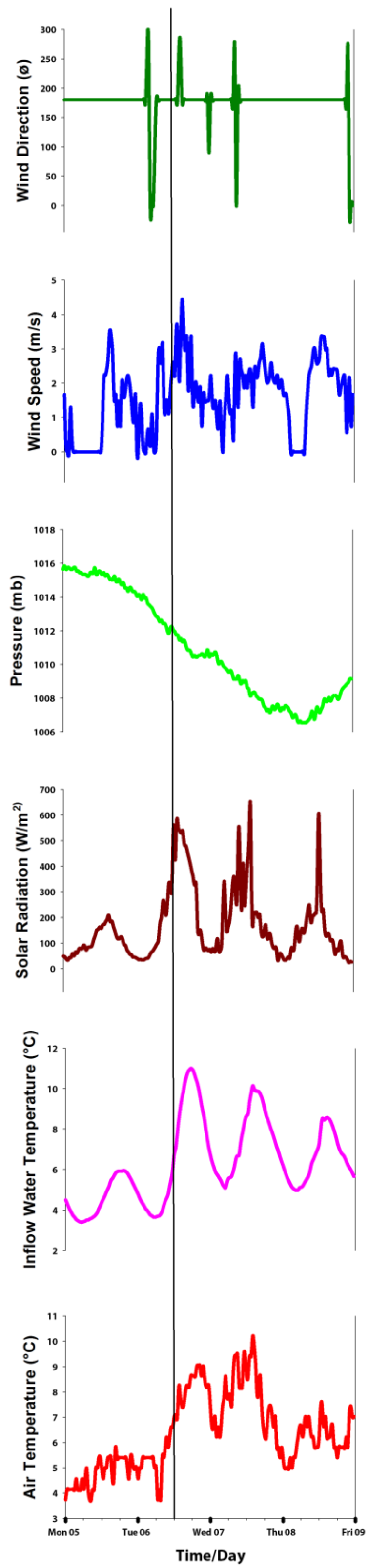
6/28-7/1



In the second series, which happened in late June and early July, the two parameters which were ±2 standard deviations above normal were solar radiation and air temperature on June 27th, 28th and 29th (156.1, 140.51 and 62.84 W/m^2 and5.68, 5.15 and 1.67°C respectively); wind speed was 1.53 m/s above normal on June 27th as well. On the 30th wind speed was -0.67 m/s below normal. On July 1st and 2nd wind speed and air temperature were 1.69 and 1.9 m/s and 3.1 and 2.77°C below normal as well; July 1st had 51.76 W/m^2 below normal (Figure 3.69).

Figure 3.69: Weather for Second Series; black vertical lines signal 6/28 and 6/30

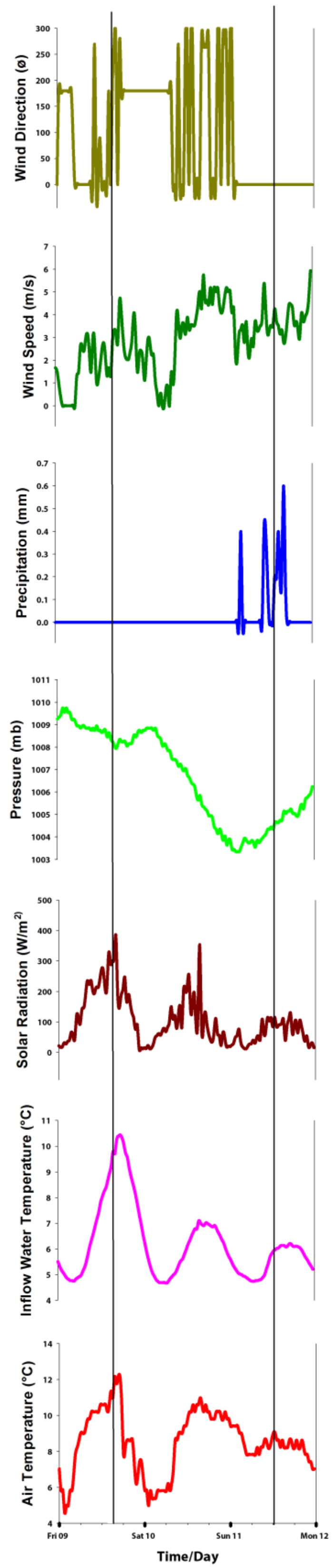
7/6



In the third series, first event which happened in and early July, the parameter which was ±2 standard deviations below normal on July 5th, 6th, 7th and 8th was wind speed (2.25, 1.5, 1.34, and 1.52 m/s, respectively). Air temperature was 1.62°C below normal on the 5th and 1.34°C above normal on the 7th. Finally, solar radiation was above normal on the 6th and 7th (95.76 and 63.73 W/m^2 respectively) (Figure 3.70).

Figure 3.70: Weather for Third Series; black vertical line signals 7/6

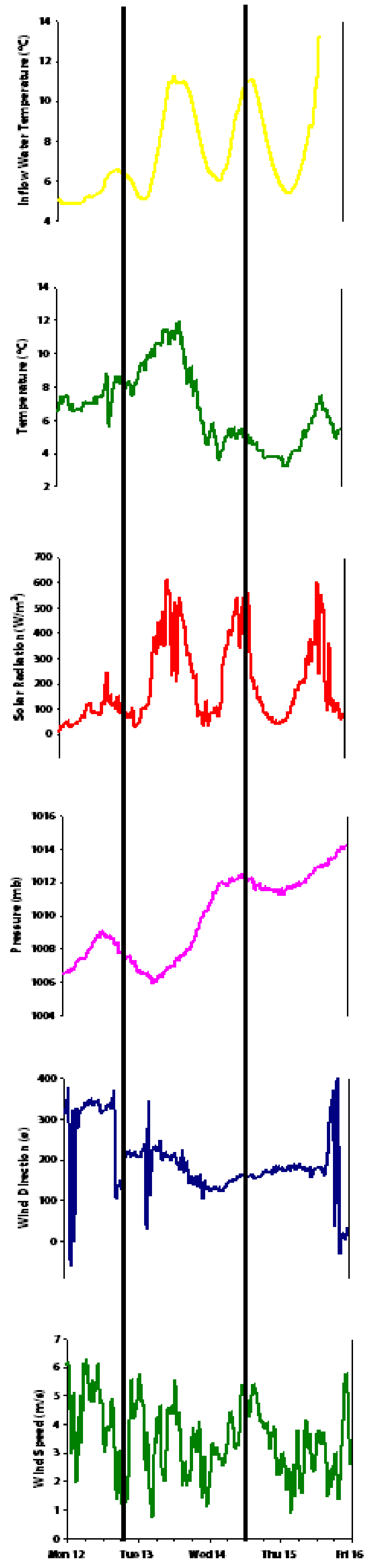
7/10



In the third series, second event which happened in early July, the parameter which was ±2 standard deviations above normal on July 9th, 10th and 11th was air temperature (2.37, 2.09 and 1.98°C, respectively); precipitation was above normal on the 11th as well (0.04mm). Solar radiation was 48.72 and 79.52 W/m^2 below normal on the 10th and 11th. Finally, wind speed was 1.29 m/s below normal on the 9th and pressure was 6.15 mb below normal on the 11th (Figure 3.71).

Figure 3.71: Weather for Third Series; Second Event black vertical lines signal 7/10 and 7/12

7/13-15



In the fourth series, which happened in mid-July, the parameter which was ±2 standard deviations below normal on July14th and 15th was air temperature (1.53 and 1.39°C, respectively); it was 3.34°C above normal on the 13th. Solar radiation was 133.37, 95.34 and 48.41 W/m^2 above normal on the 13th, 14th and 15th respectively. Finally, wind speed was 0.86 m/s above normal on the 12th and solar radiation was 54.76 W/m^2 below normal on the 12th (Figure 3.72).

Figure 3.72: Weather for Fourth Series black vertical lines signal 7/13 and 7/15

Intervalometer

Figure 3.73 shows data from the intervalometer, where the black rectangle shows the time from June 21 to July 3. Each "step" signifies two millimeters of sedimentation at site C and during that time-frame there are six "steps", which is about 12 millimeters of sedimentation.

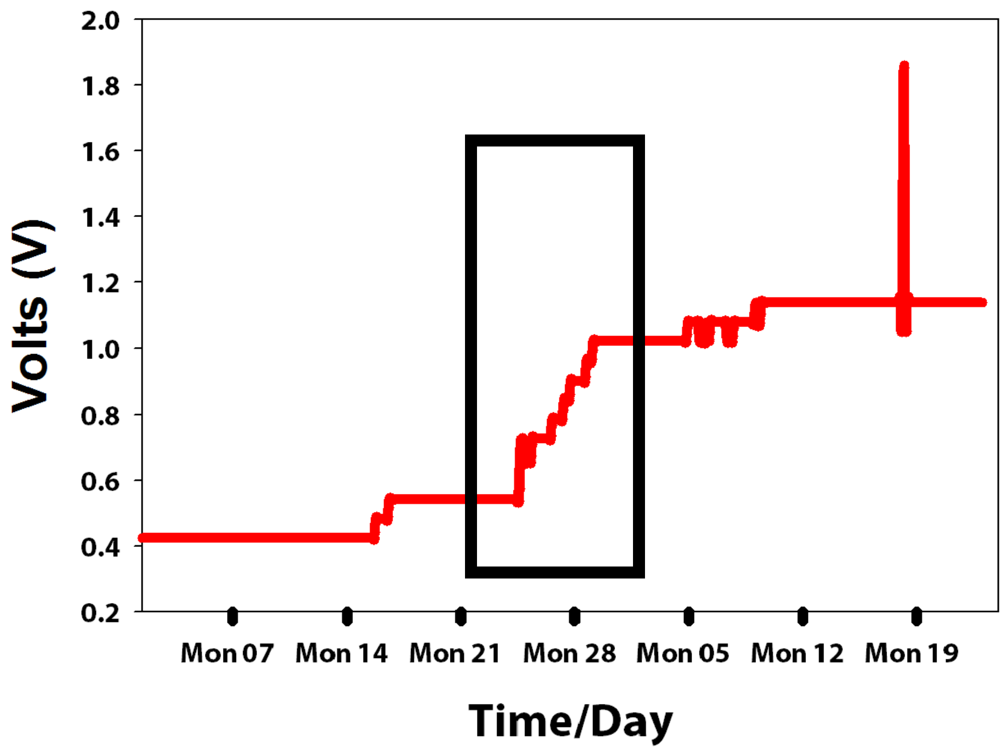


Figure 3.73: Intervalometer data from Site C, 6/1 to 7/26

Chapter 4: Discussion

4.1 Climatology

Climatological results from the data gathered in 2003 to 2010 do coincide with the results from Ingólfsson. On the other hand, the monthly air temperature averages from this study are higher than those from Bøyum and Kjensmo, which might be due to the age difference between the studies (1978 and 2010) and the on going Arctic warming. Also, the mean precipitation in the Bøyum and Kjensmo study had its highest average in August and September, while the highest averages were in January and December. The lowest averages in the 1978 study were in March and April and these do coincide with this study.

Wind Rose

During the period of the spring melt into the summer, low winds (0-4 m/s) are predominant. Although moderate to high winds (>8 m/s) have a very low frequency during these months, when they do happen they might have a large impact on the inflowing water or the lake.

4.2 Linnévatnet Events

The three methods for finding events in Linnévatnet were very useful, especially the first two methods. The first method's results were a very good guide to start looking for events in the second method (as described in the bottom section). The third method was only useful to confirm the first series (early May) and is therefore not such a good method to find/confirm events.

Underflows

The first event in the first series was only seen in the Spring mooring line. It consisted of two cold events in the bottom two meters and this event was seen in the tilt meters as shown in Figure 3.66. This event might have been influenced by the low air temperature, solar radiation and wind speed before and during the event as seen in Figure 3.67.

The second event in the first series was a much larger event which was seen in both Spring and Year-Long mooring lines and was also seen in the tilt meters as a much larger event (Figure 3.66). This event is linked to the lowering of Kongressvatnet around that same time as seen in Figure 4.1; a time-lapse picture also shows that this event was affected by Kongressvatnet as seen in a flood covering the southeast part of the lake (Figures 4.2-4.4). Finally, precipitation, wind speed, air temperature and solar radiation were above normal during this event.

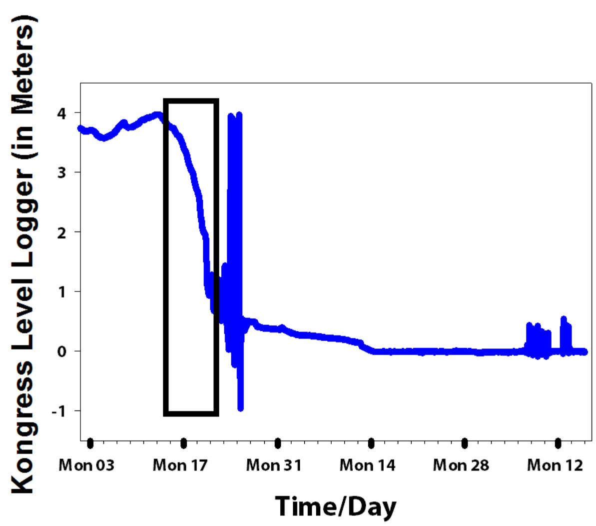


Figure 4.1: Kongressvatnet Level Logger with black rectangle showing May15-23

Figure 4.2: Picture looking into the south basin of Linnévatnet; no flood May 18th

Figure 4.3: Linnévatnet, small flood; 11 a.m. May 19th

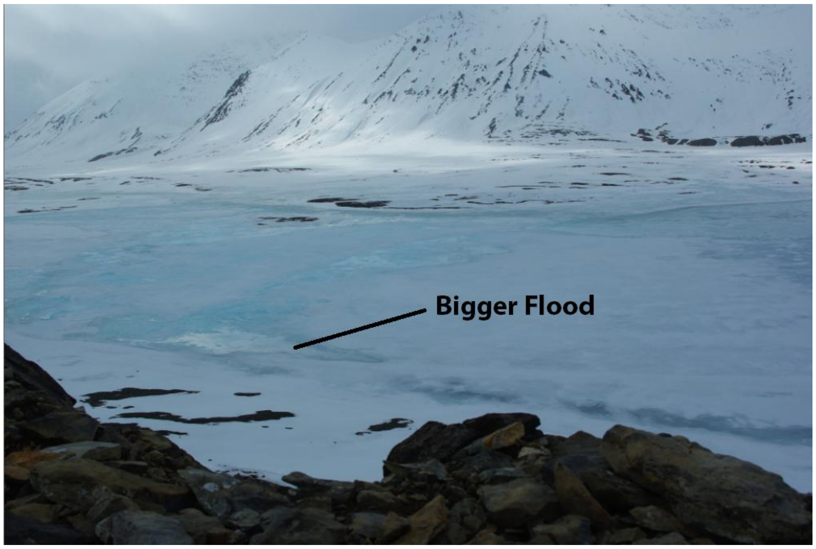


Figure 4.4: Linnévatnet, larger flood; 4 p.m. May 19th

The second series of events were seen until the end of June through the first days of July in both Spring and Year-Long C and D mooring lines. The first underflow event happened around June 27, and was relatively small. The next underflow happened late June 28 and lasted into June 29. This underflow seemed to influence the whole vertical column since it heated the bottom and at the same time the surface was also heating up, which lead to overturning around July 1. The lake then seemed to stratify for the summer (cooler water on bottom) after July 2nd as seen in Figure 4.5. Before and during the underflows, wind speed peaked on June 27 at about 8.5 m/s and inflow water temperature reached 4°C (highest water density) at about the same time. Solar radiation and air temperature were above average as well. Finally, winds before and during the underflows are coming from the south. The intervalometer data pointed that during this period about 12 mm of sediment were deposited and sediment plumes are seen in Figures 4.6 and 4.7.

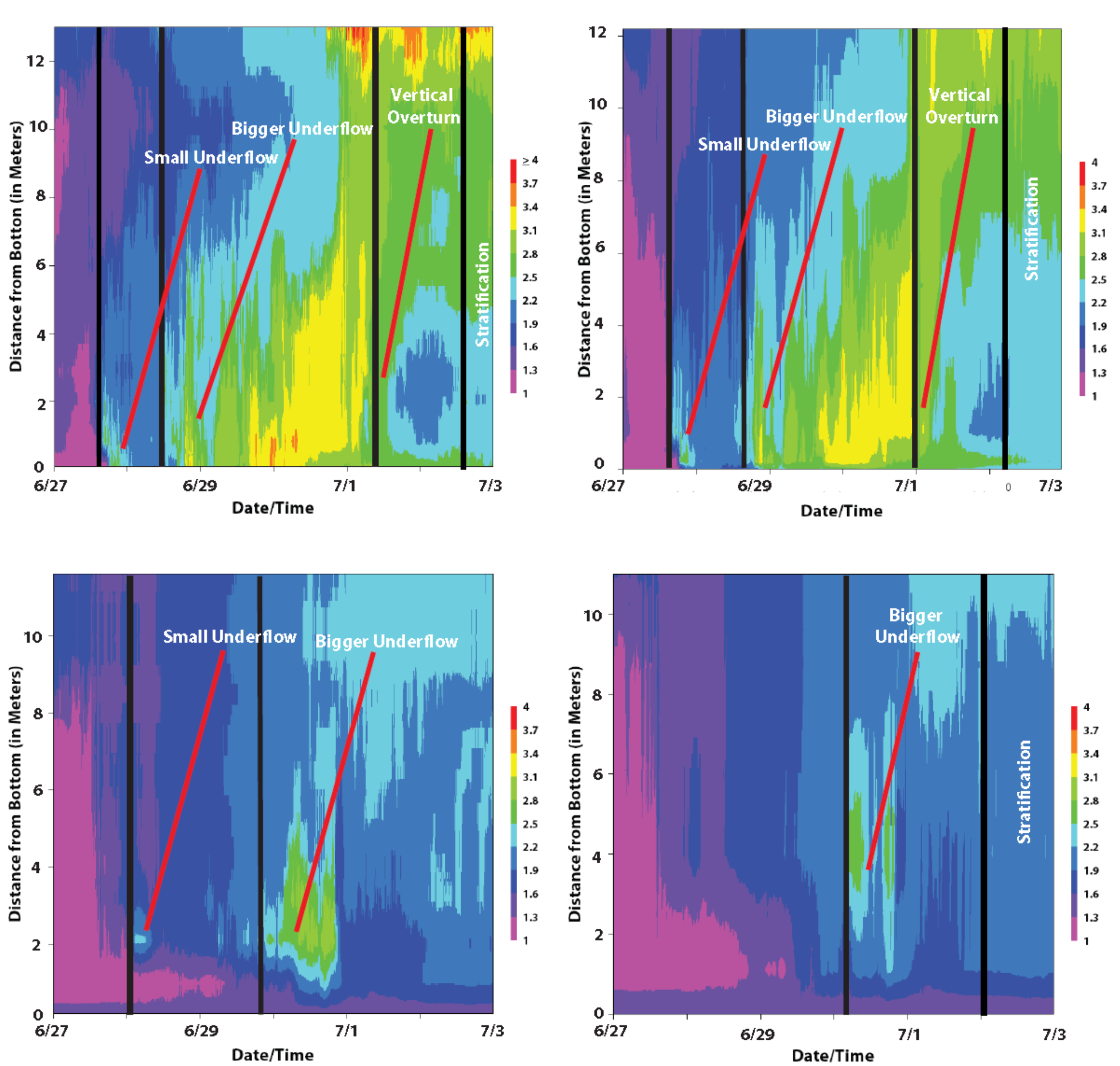


Figure 4.5: Second series of events at Spring C (top left) and Year-Long C (top right) mooring lines; Spring D (lower left) and Year-Long D (lower right)

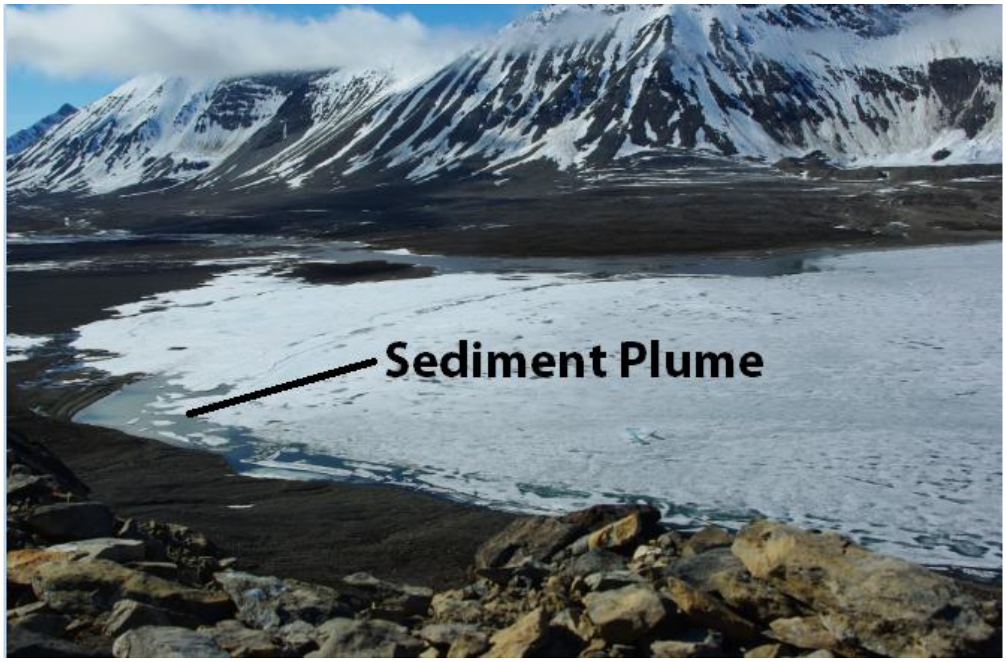


Figure 4.6: Small sediment plume seen at 11 a.m. on 6/29

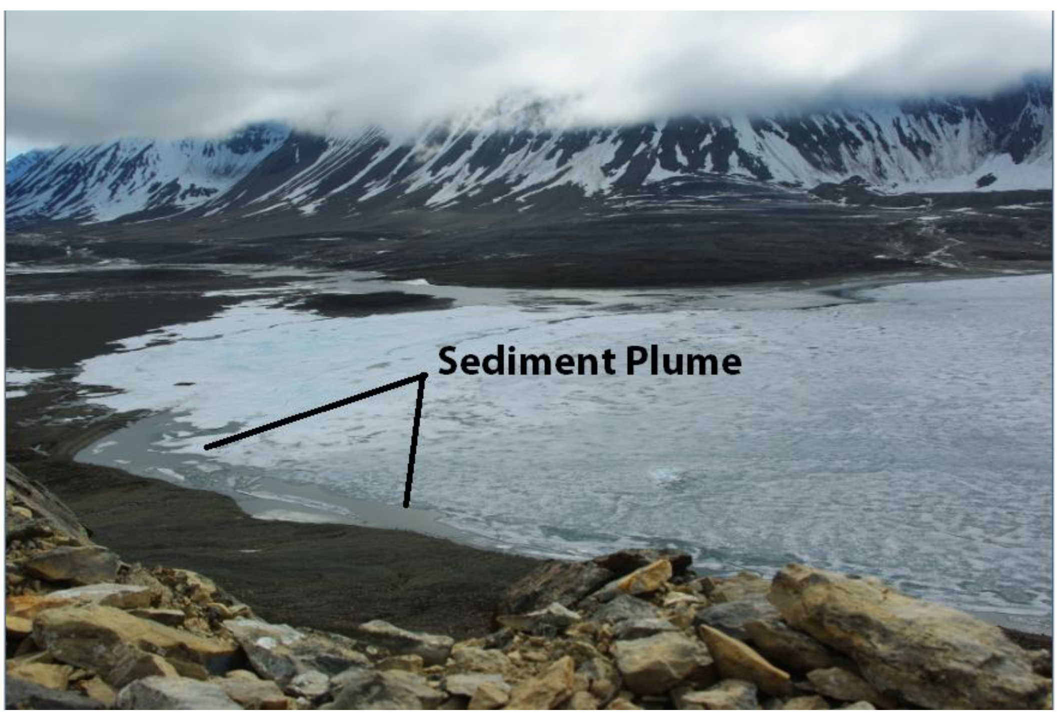


Figure 4.7: Small sediment plume seen at 4 p.m. on 6/29

The third series, first event were seen until the first week of July in both Spring and Year-Long C and D mooring lines. The first underflow event happened around July 7, and was a series of small underflows in site C. After these small underflows, on July 8, the water column thermally stratifies as seem in both C and D. Before and during the underflows, air temperature was high along with solar radiation and wind speed; these parameters peaked on July 7th. Inflow water temperature also peaked around July 7th at about 11°C. Finally, winds before and during the underflows are coming from the south. The intervalometer data pointed that during this period about 2 mm of sediment were deposited.

The third series, second event were seen until mid-July in both Spring and Year-Long mooring lines. A very small underflow event happened late July 9 in C, while in D the entire water column is around 3°C. After this the water column thermally stratifies in both sites. Before and during the underflow, air temperature was high along with solar radiation. Inflow water temperature also peaked around late July 9th at about 11°C. Finally, winds before and during the underflows are coming from the north. The intervalometer data pointed that during this period about 2 mm of sediment were deposited. When the lake thermally stratifies, all the parameters are very low, except for a rainfall event on July 11th.

Finally, the fourth series of events happen mid-July in both Spring and Year-Long C and D. On July 13-14, the lake seems to be cold, and it suddenly warms up on late July 14th. During the July 13-14, the lake has low solar radiation, air temperature and wind speed which might have led into a low inflow temperature. The intervalometer doesn't seem to record any sediment deposition, but Figure 4.8 shows a sediment plume going travelling to site C.

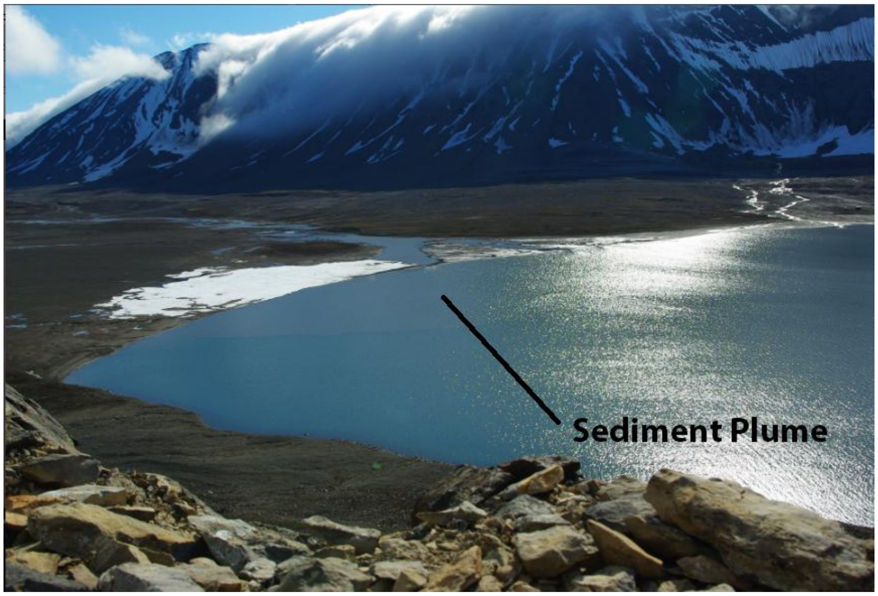


Figure 4.8: Sediment Plume seen in 7/15

4.3 Other studies

In general weather patterns, especially solar radiation, air temperature and wind speed, seen in this study seem to point out that they have an important effect on inflowing water, which in turn has a very large effect on underflows and sediment distribution and deposition. Studies in High-Arctic Canada such as Francus et al. (2008) mention that during the early-spring, a silt layer was deposited due to overflows caused by early snow melt. In Bear Lake (75°N), studies show that the inflow increases in discharge after June 29 due to increased nival melt; this melt-water enters the lake and sinks as an underflow (Lamoureux et al., 2002; Lewis et al., 2002). This study also implies that the underflows will weaken as they travel towards other locations and that melt-water is more important than rainfall events. Studies in West Lake (74°N) by Cockburn also show that discharge and sediment concentration peaks on late-June and that 90% of the total sediment deposition was during the spring melt, with most of it depositing in the proximal basin as underflows; 50% of that sediment was deposited from June 28 to June 30, just as seen in this study. Finally, it pointed out that underflows were related to peaks in inflow water temperature. Lastly, a study in Meziadin Lake (Gilbert and Church, 2004) in the lower latitude of 56°N, underflows started mid-June when the snow melt and sediment concentration were at their peak. They suggest that the highest period of deposition is during these days and that as underflows travel farther they become weaker and deposit less sediment.

Chapter 5: Conclusions

Weather seems to influence the inflow water temperature more than the lake. A high air temperature, solar radiation and wind speed might increase the rate of snow melt and temperature of the inflow, which will influence the lake. The first underflows happened after the inflow water coming into the lake reached 4°C. Water will have the highest density around this temperature and when it's coming into the lake will sink and travel as an underflow. The first underflows might have not lasted that long due to a lower concentration of sediment in the water while later underflows last longer due to a higher concentration of sediment and higher inflowing water temperature. After the bottom and surface waters have warmed enough, they will overturn and will have the same temperature for a while until the lake stratifies for the summer. Finally, as seen in the contour graphs for mooring D, underflows slow down and become weaker as they travel away from the source, so it's possible that less than 14 mm of sediment might have deposited in D during this period. Finally, site C might not be an appropriate place to study long-term deposition since very small events deposit sediment, while at site D only big, long-lasting events will reach it.

Future Work

The next step in the project would be to analyze logger temperature data after the spring melt confirm the hypothesis that inflow water will not have a big effect on the lake since it's already above 4°C; weather might have a more important role (Braun et. al., 2000).

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