Vermont Water Resources and Lake Studies Center

Annual Technical Report

FY 2000

Introduction

Attached is the Fiscal Year 2000 Annual Report for the Vermont Water Resources and Lake Studies Center. The grant, awarded under the State Water Resources Research Institute Program, is numbered 1434-HG-96-GR-02702.

Research Program

Basic Information

Title:	Identification of Candidate Parcels for Riparian Buffers: Reducing Fecal Contamination of Vermont Surface Waters
Project Number:	B-03
Start Date:	3/1/1999
End Date:	2/28/2000
Research Category:	Water Quality
Focus Category:	Non Point Pollution, Surface Water, Agriculture
Descriptors:	water quality, fecal contamination, nonpoint source pollution, GIS, remote sensing, agriculture, surface water
Lead Institute:	The University of Vermont
Principal Investigators:	Leslie A. Morrissey

Publication

1. O’Neil-Dunne, J. and B. Wemple, July, 2001, Hydrologic Modeling, Vermont Spatial Data Partnership Roundtable, Waterbury, VT.

Identification of Candidate Parcels for Riparian Buffers: Reducing Fecal Contamination of Vermont Surface Waters

Leslie A. Morrissey

Project Number: B-03

Descriptors: water quality, fecal contamination, nonpoint source pollution, GIS, remote sensing, agriculture, surface water

Problem and Research Objectives

Fecal contamination of surface waters in both agricultural and urban watersheds is a major environmental concern in the state of Vermont and across the U.S. Conservation practices are needed that will significantly reduce bacterial contamination of Vermont's surface waters. One effective approach to reduce contamination in runoff from adjacent agricultural fields to streams and rivers involves the construction of buffer zones and filter strips along streams and rivers. Identification and prioritization of land parcels for riparian buffer zone implementation constitute a critical need for state and federal water quality programs.

The goal of this research program is to develop and assess the GIS and remote sensing technologies required to identify and prioritize candidate parcels within the Mad River watershed for riparian buffer or filter strip development. In addition, Landsat Enhanced Thematic Mapper (ETM+) and high resolution IKONOS satellite data will be assessed for mapping and monitoring riparian buffers along streams and rivers. Finally, the results of this research will be disseminated to the public through scientific journal publications and the World Wide Web.

Methodology

Candidate land parcels are being prioritized based on a spatially explicit (GIS-based) suitability model. The model utilizes the Revised Universal Soil Loss Equation (RUSLE) to estimate annual soil loss and corresponding pollutant input. Candidate land parcels will be identified based on their probable fecal contribution to adjacent waters as modeled using environmental parameters that are readily available (e.g. streams, landuse, slope, ownership parcels) or directly measured through field sampling (e.g. *E. coli* counts, buffer dimensions) and remote sensing (e.g. riparian buffer width, length, and vegetative type, land use, crop type). State-of-the-art digital processing of Landsat ETM+ satellite data will be used to map land use of areas adjacent to streams. IKONOS (4m) multispectral satellite data will provide the basis for identifying and characterizing riparian zones, mapping adjacent land parcels by current land use, and determining the density of drainage channels.

This research is being conducted in collaboration with state and federal agencies and local citizen volunteer groups. On-going and collaborative efforts by Friends of the Mad River, Mad RiverWatch, Natural Resources Conservation Service, and Vermont Farm Bureau will complement the project.

Principal Findings and Significance

Efforts during the first year have focused on development of the RUSLE model, GIS database integration of data layers, derivation of data layers, and hydrologic modeling. To date, we have developed a GIS database of existing data layers (streams, land cover, soils, and DEM), generated the required derivative layers (slope, aspect, and hydrology) and mapped riparian zones and adjacent fields with digital orthophotography. Based on these efforts, we have concluded that panchromatic digital orthophotography (even with 0.5m spatial resolution) acquired during leaf off stage is inadequate for mapping vegetative characteristics and distinguishing field crops.

Landsat Enhanced Thematic Mapper (ETM+) satellite data for the study were acquired for general land use/land cover mapping. However, the coarse resolution (30m) of the ETM+ data provided only broad land cover categories (e.g. forest, non-forested, agriculture, developed) and was inadequate for detailed riparian zone mapping. Therefore, digital band-sharpening techniques that are used to merge high-resolution -.5m panchromatic data (VT DOQs) with high resolution (4m) IKONOS satellite data acquired in the visible and near infrared regions of the spectrum are being tested. Since IKONOS satellite data have not yet been acquired for this particular study area due to cloud cover and acquisition scheduling conflicts, we have begun testing pan sharpening algorithms using IKONOS multispectral 4m satellite data (a test data set) with the higher resolution 0.5m panchromatic digital orthophotography (DOQ). This technique, if successful, should provide the ideal dataset to support our detailed mapping and modeling efforts.

A Web Page incorporating data from Vermont River Watch volunteer groups throughout the state, public state beaches, and our own on-going research efforts has been constructed with more than 70 pages of information on *E. coli* and recreational water quality in Vermont. This web site has received an average of 1000 hits per month (Web Page: http://www.snr.uvm.edu/www/pc/sal/ecoli/index.htm)

Students Supported

One Masters students in Water Resources

Basic Information

Title:	Lagrangian Drifters Within Lake Champlain - A Pilot Study
Project Number:	B-02
Start Date:	3/1/1999
End Date:	2/28/2000
Research Category:	Engineering
Focus Category:	Methods, Hydrology, Water Quality
Descriptors:	hydrodynamics, lagrangian, neutrally-buoyant floats, acoustics
Lead Institute:	Middlebury College
Principal Investigators:	Thomas O. Manley, Jean Claude Gascard

Publication

1. Manley, T.O., 2001, Summary of Lake Champlain Hydrodynamics, Invited Presentation at Great Lakes Environmental Research Lab, Ann Arbor, MI, January 17-20.
2. Manley, T.O., J.C. Gascard, and P. Tillier, 2001, Acoustically Tracked Lagrangian Drifters in Lake Champlain, IAGLR Annual Meeting, Green Bay, WI, June 12-15.

Lagrangian Drifters Within Lake Champlain - A Pilot Study
Thomas O. Manley

Project Number B-02

Descriptors: hydrodynamics, lagrangian, neutrally-buoyant floats, acoustics

Problem and Research Objectives

The understanding of hydrodynamics within Lake Champlain is critical in our ability to accurately model and therefore predict the movement and eventual disposition of contaminants within the water column. Although our knowledge of lake circulation has increased dramatically over the past seven years, it is nevertheless based entirely upon Eulerian observations at a few selected sites within the lake. By their very nature, Eulerian observations made at a fixed location over time possess intrinsic limitations in their ability to map complicated flow dynamics within large regions. Specifically, for Lake Champlain, large oscillatory currents created by the internal seiche mask our ability to define average flow conditions due to low average values bounded by high standard deviations. Additionally, using this approach to describe circulation throughout the entire lake would be cost prohibitive. This project seeks is testing the practicality of using a Lagrangian mapping technique, known as RAFOS, to define complicated flow trajectories of fluid parcels at different levels within the water column (over time). While this technique has been used within the oceans over the past several decades to look at a myriad of oceanographic problems ranging over a wide spectrum of temporal and spatial scales, it has never been employed in any lake environment. What is being done is a feasibility study of using acoustically tracked neutrally buoyant, free drifting subsurface floats within Lake Champlain. If successful, both Eulerian and Lagrangian measurements could be coupled to produce the next significant level of understanding of circulation dynamics within Lake Champlain. The field program has been created in two separate phases – the *feasibility study* during the first year and *an implementation study* the current year. This report covers the progress made during the first year, the feasibility component of the experiment.

Methodology

During 27-29 May, 2000, preparation of the four 780 Hz sound sources, as well as ballasting and stability calculations of the RAFOS floats, were completed at WHOI by Pierre Tillier and Jean-Claude Gascard. During the 30th of May, the equipment was transported from WHOI to the UVM ship *Melosira* for immediate deployment and testing in Lake Champlain. The summer field program lasted until mid-June and was devoted to verifying sound propagation characteristics within the Main Lake. Appendix I contains a more detailed description of the activities that occurred each day during the field program.

Several weeks prior to the arrival of equipment on Lake Champlain, discussion among several members of the SCUBA diving community prompted us to slightly modify our research program. While not believed to be a problem from a theoretical standpoint, we were requested by several members of the diving community to verify the intensity level of the sound sources at varying distances for safety considerations. In response to this request, May 31st was spent within Shelburne Bay focusing on this specific issue. The *Melosira* and the Middlebury College *R/V Baldwin* provided range testing for SCUBA divers at various distances from one of the sound sources suspended from the *Melosira* (Figure 1). This particular sound source was set up so that it could be manually controlled to transmit its standard output signal at any given time. The conclusions from this testing phase were that at a distance of approximately 45 feet, the intensity of the emitted sound signal was very tolerable to the divers. As a matter of fact, divers could barely hear the signal when they were within approximately 200 feet of the sound source. Since all of these sound sources are deployed in regions of the Main Lake that are well distant (over two miles) from any recreational diving sites and in deep water (where diving activity is highly unlikely), it was concluded that these sound sources were not a hazard to divers.

On the following day (June 1st), the four 780 Hz sound sources were deployed from the *Melosira*. The sources were positioned within the Main Lake as shown in Figure 2. The sources were programmed to transmit their signals on a rotational sequence of 0 (Valcour Island-North), 10 (Burlington Bay-East), 20 (Corlaer Bay-West), and 30 (Thompsons Point-South) minutes past every 1.5 hours interval for six days. All signals emitted by the sound sources were identical. Each transmission was 40 seconds in duration with a 5 Hz linear modulation centered around 780 Hz (i.e., the signal would start at 777.5 Hz and then linearly ramp up to 782.5 Hz at the end of the 40 sec. pulse). For example, Valcour Island would always transmit at 0000, 0130, 0300, ...hours while Thompson's Point would transmit at 0030, 0200, 0330, ... hours. In this way, verification of which sound source created the observed signal could be made. With sufficient observations, signal strength vs. distance and position away from any given source could then be created.

During the following days, the *RV Baldwin* was utilized to observe signal strength from these various sound sources over a wide range of locations as well as collect hydrographic profiles. Acoustic testing utilized a tethered receiver containing the same acoustic equipment found in the RAFOS floats. The tethered receiver was lowered from the *RV Baldwin* at various depths throughout the lake to gain specific information on the correlated signal strength from each of the sound sources. The electronics and software within the receiving unit compared the "original" signal to that of signals observed within the water column over a five-minute period. In essence, the software will step through the five-minute recording every 0.185 seconds and compare the original 40 second signal to that of the underwater recording. If it locates the signal, it will assign a correlation strength at time 't' characterizing the time of arrival (TOA) of the original sound source signal at the receiving unit. It is this capability of the RAFOS system that permits it to transmit at relatively low power, yet have high correlation at great distances.

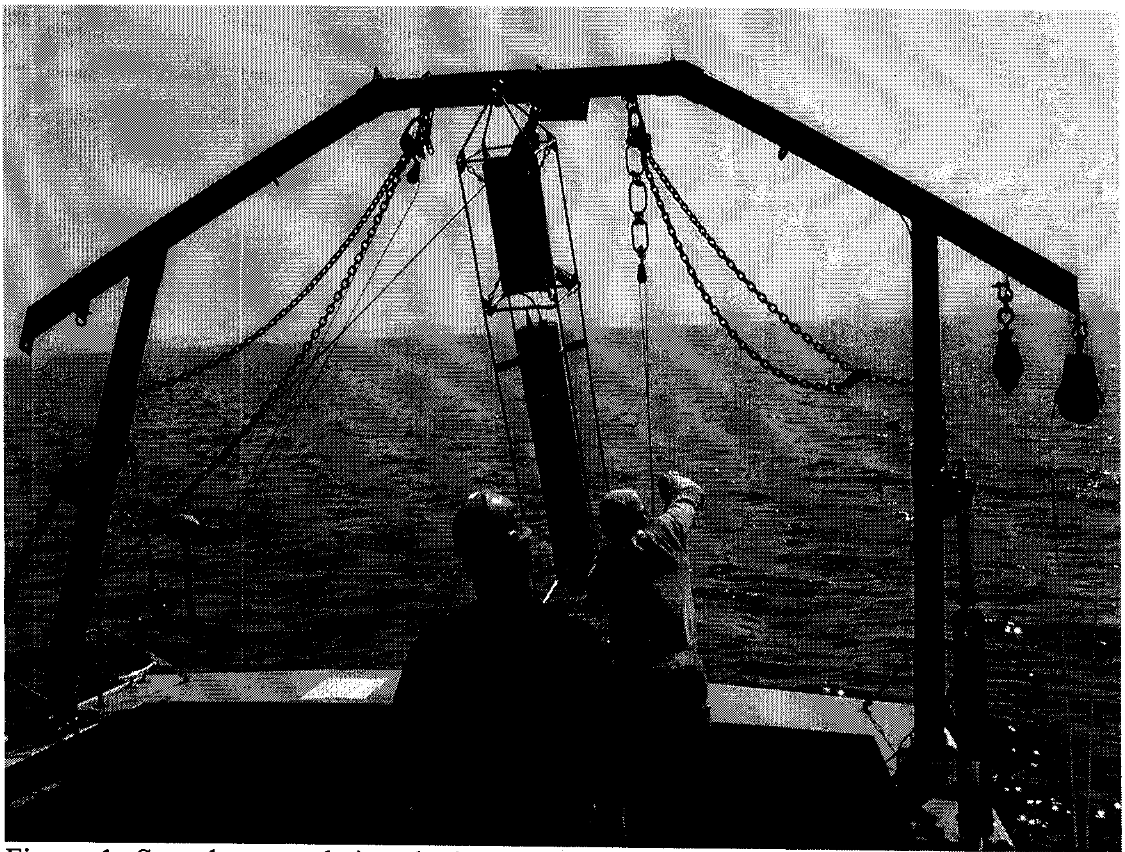

Figure 1. Sound source being deployed off of the UVM ship *Melosira* for proximity testing.

It should be noted that observations from the ship represent worst-case conditions due to the contamination of the acoustic environment by ship noise (engine, electrical, and any other movement). Therefore, in order to obtain data relating to more realistic conditions where receivers would be distant from any vessel, a simplified mooring equipped with a single RAFOS float was deployed near the western extremity of Burlington Bay. The RAFOS float was attached to the mooring line at a depth of approximately 50 feet (mid-depth of the water column), while a series of small flotation spheres were used to mark the location. Recording started at approximately 1930 UT (Universal or GMT time, June 1st) and end at 1700 UT the following day. After recovery and initial analysis of the data, it was found that the sound source at Valcour Island was not operational. As expected, though, collected data did indicate stronger correlation values (at similar distances away from the sources) compared to what had been collected from the *R/V Baldwin*.

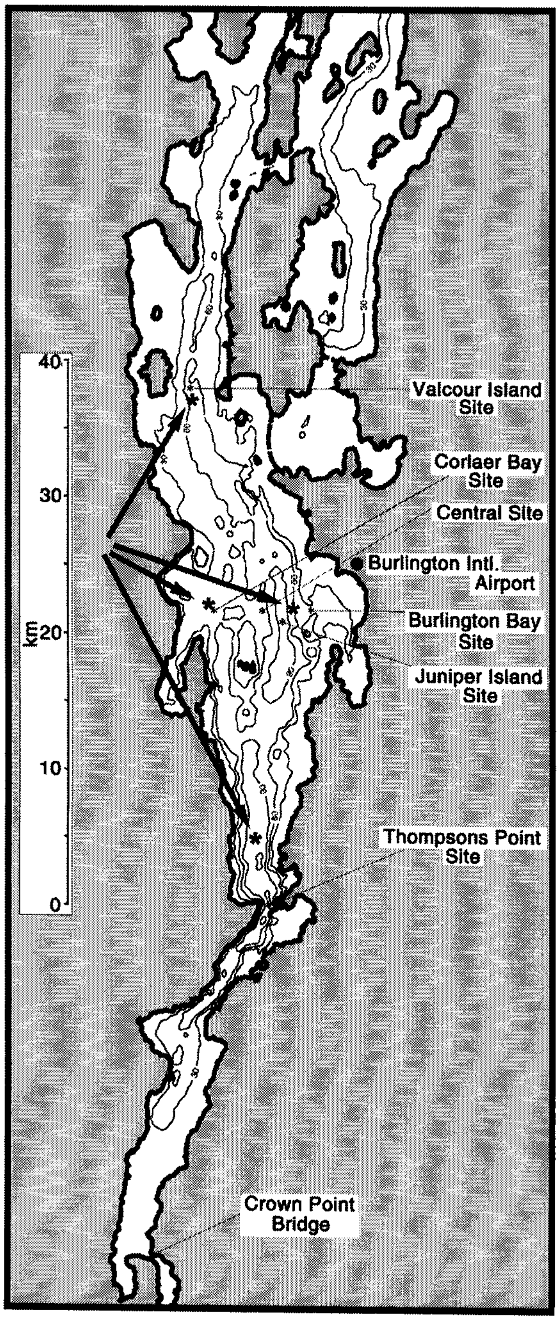

Figure 2. Positions of the four sound sources (stars) within the Main Lake during the summer 2000 field program. These are defined by the four arrows originating from the left-hand side of the diagram. Previous sites where Eulerian measurements (i.e. subsurface moorings) had been taken during the past seven years are also shown (with their names) on the right-hand side of the diagram.

On Friday (June 2nd), a free-drifting drogue equipped with three RAFOS floats was released north of the Four Brothers Islands at 1915 UT. The drogue itself was comprised of a 20-pound weight suspended beneath a crossed aluminum-plane drogue (8 ft^2 of cross-sectional drag), which was in turn connected to surface floats via 144 feet of line. In total, the length of the drogue was approximately 150 feet. Figure 3 shows the drogue assembly utilized for this phase of the experiment on the *R/V Baldwin* prior to its release. Figure 4 provides a view of the RAFOS floats and Figure 5 shows the Argos transmitter at the surface after the system was initially deployed. The surface RAFOS float was modified to transmit permanently to Argos, while the remaining two floats were positioned at 10 m and 33 m, respectively. The drift-track of the drogue was continually monitored through use of the Argos data telemetry system. Positional information could be gained with as little as a one-hour delay. While the drogue was designed to free-drift for a maximum of seven days, it grounded out north of the Four Brothers Islands at an isobath of proximally 150 feet after only a day and a half (early Sunday morning). Jean-Claude Gascard and Dick Furbush picked up the instrument string at approximately 1200 local time and re-deployed it approximately 2 km farther to the east, where it continued drifting to the south until it was picked up north of Thompsons Point on Wednesday, June 6th at 1750 UT.

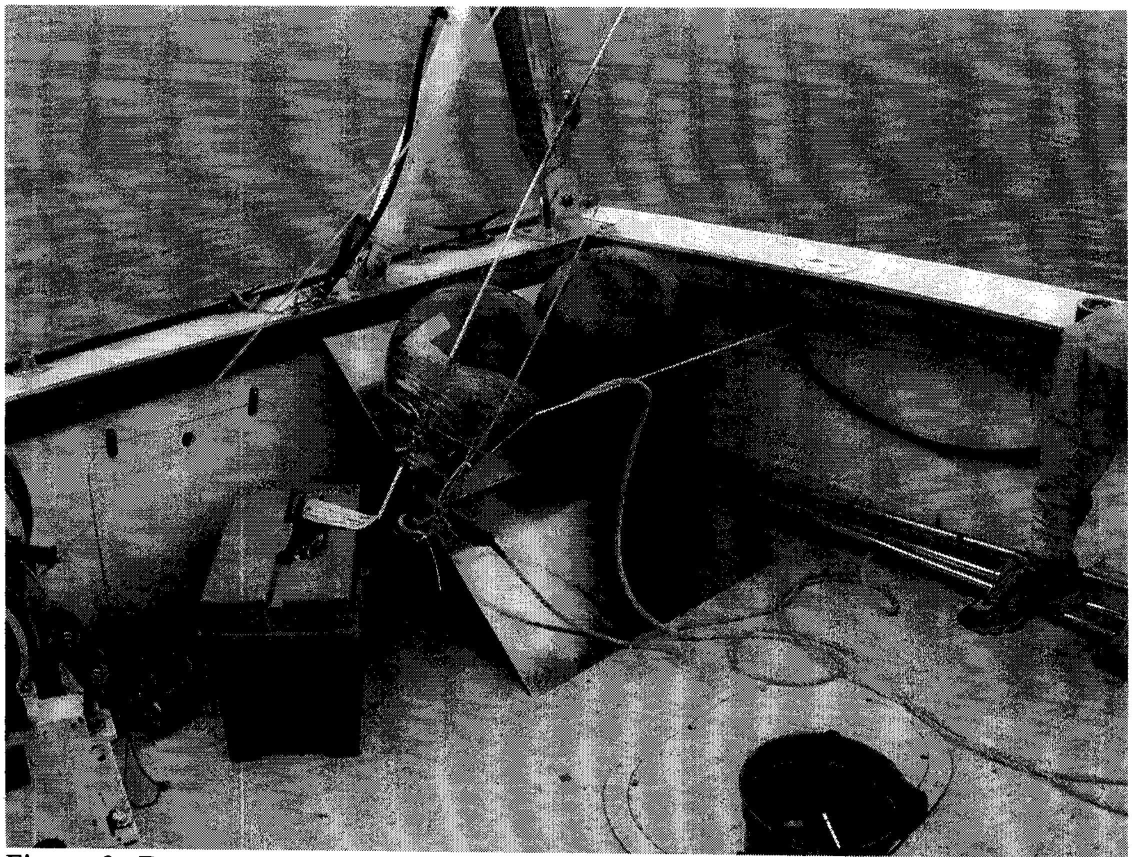

Figure 3. Drogue components on board the *R/V Baldwin* prior to release on June 2, 2000. The aluminum cross-vanes represent the component with the largest drag coefficient and was suspended at the depth of 144 ft.

Figure 4. Picture of RAFOS floats (glass enclosed) and Argos transmitter (yellow metal tube with antenna) on board the *RV Baldwin* prior to release of the drogue system on 2 June, 2000.

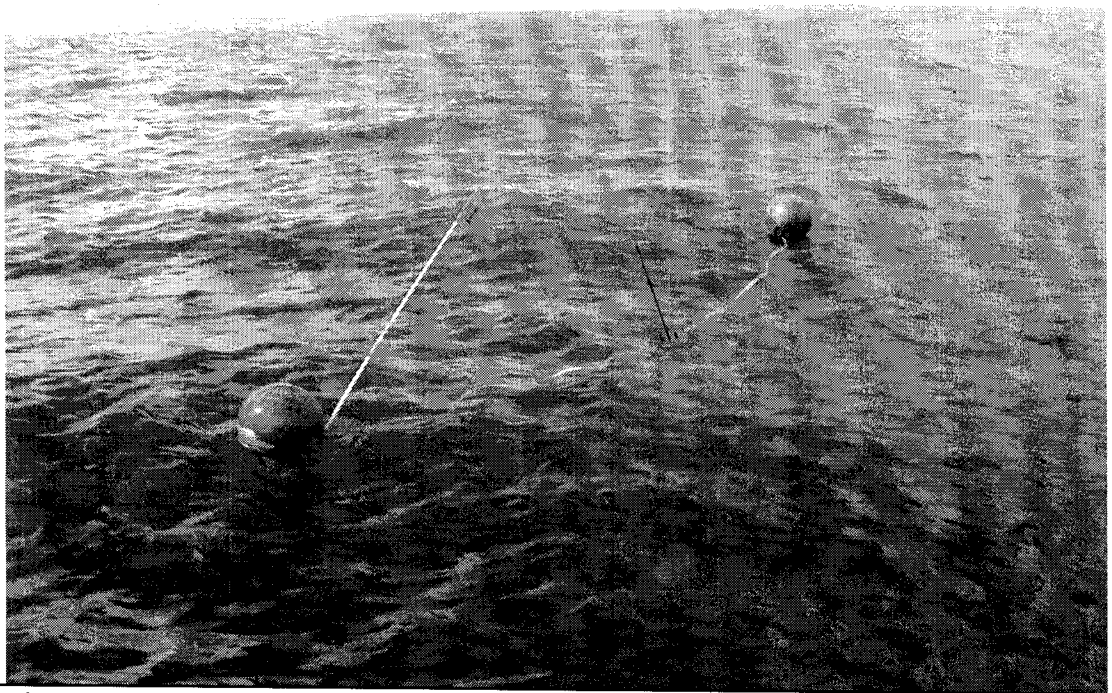

Figure 5. Surface expression of the drogue system deployed north of the Four Brothers Islands on 2 June. The Argos transmitter is located between two surface flotation spheres.

Preliminary results

CTD sections (NS and EW)

The CTD cross-sections were taken on the 5th and 6th of June, while we concurrently observed signal strength at various locations along these transect lines. The transect lines are shown in Figure 6. The resulting E-W and N-S thermal cross-sections are shown in Figures 7 and 8, respectively. What can be readily observed is that the warm epilimnion was located more to the south and western side of the lake. This corresponds well with predominantly north winds during most of the time that we were in the field. Although both figures have different vertical exaggerations, the vertical relief of the metalimnion is roughly the same over the length of each transect. When considering the vertical displacement per unit horizontal distance, the strongest gradient by far is located along the E-W transect. Combined, these cross-sections show the dominance of the uninodal internal seiche residing within the Main Lake. These data were later used for acoustic propagation modeling of sound paths within the lake.

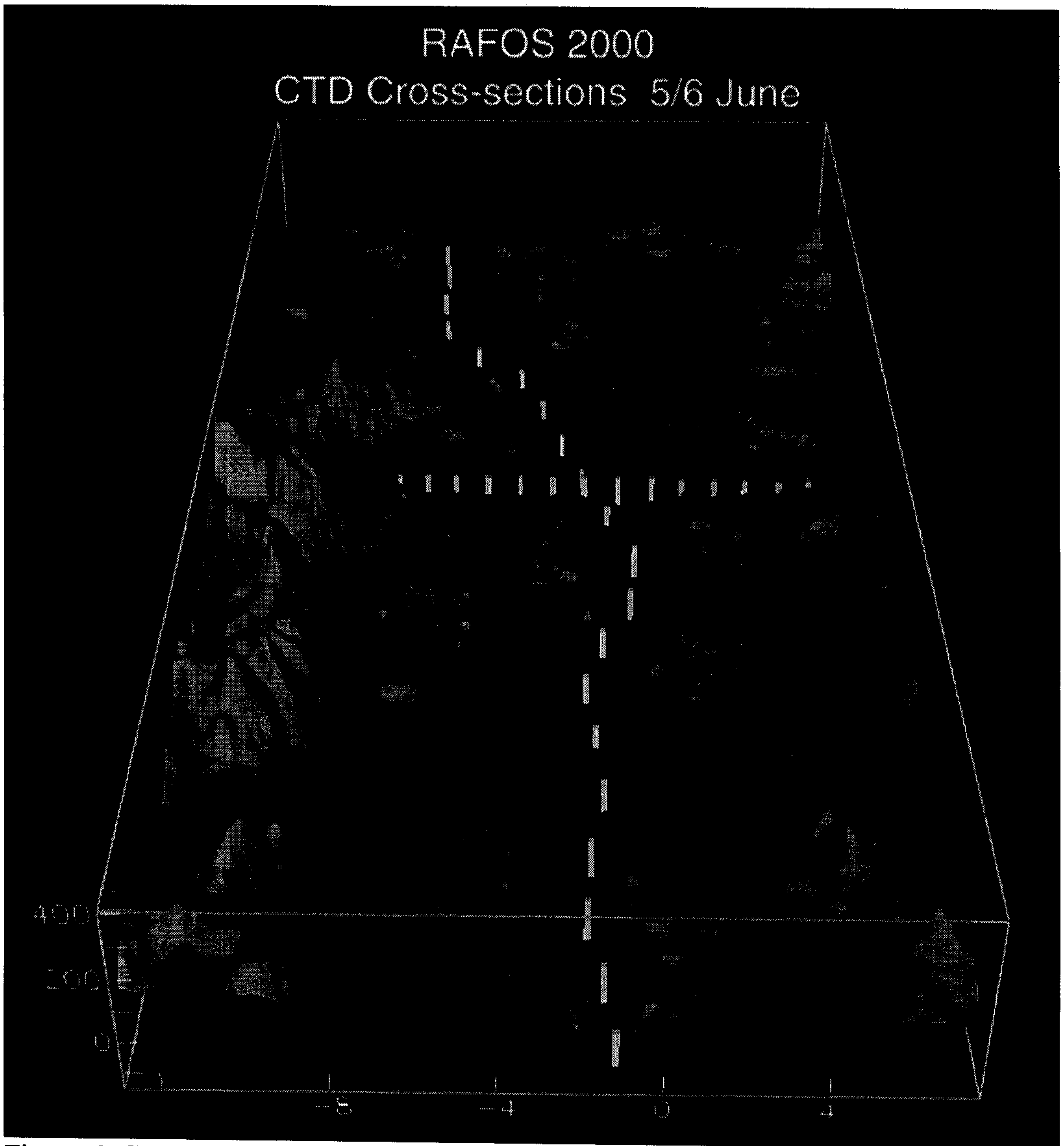

Figure 6. CTD transects obtained during the time period from 5-6 June, 2000. The E-W section was taken on the 5th while the N-S section was taken the following day.

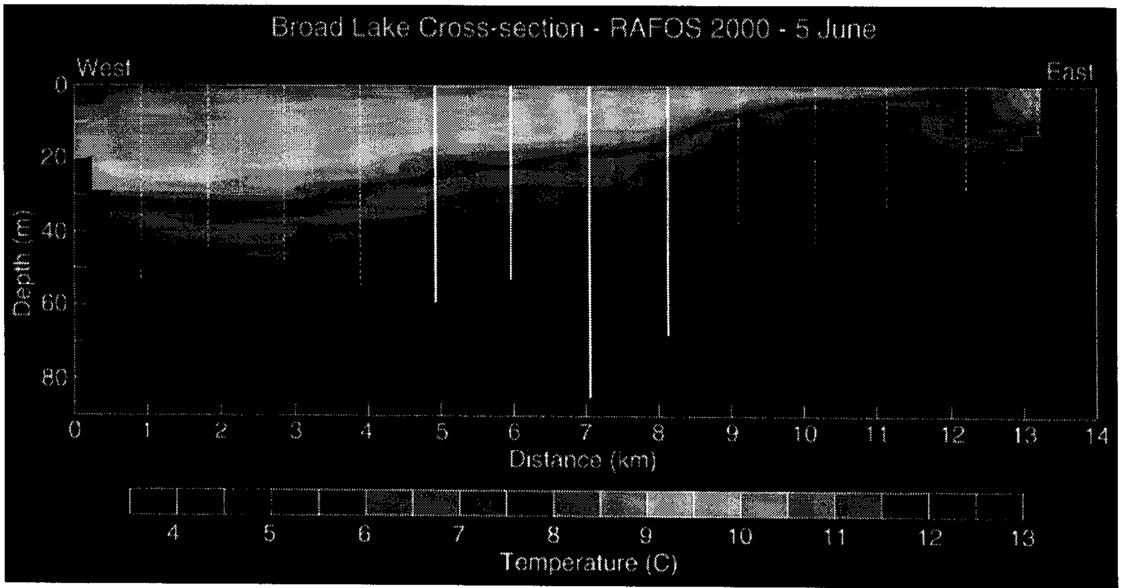

Figure 7. E-W thermal cross-section of Lake Champlain taken on 5 June, 2000. See text for details.

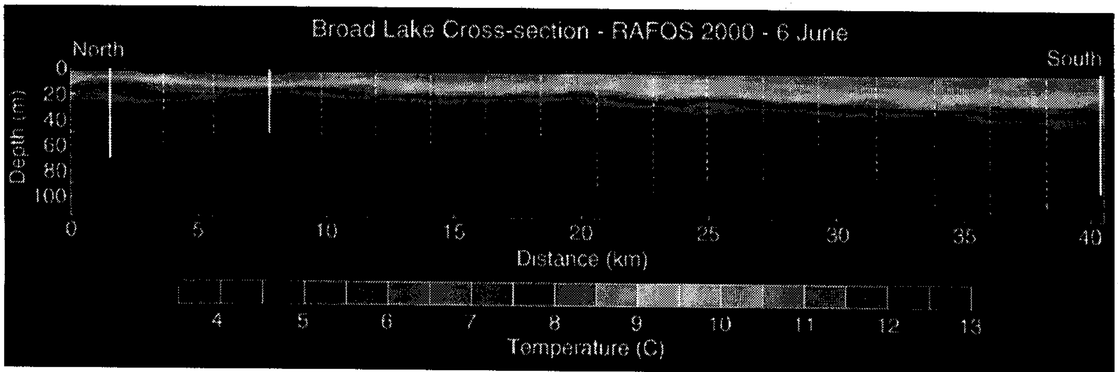

Figure 8. N-S thermal cross-section of Lake Champlain taken on 6 June, 2000. See text for details.

Acoustic Tests and Float Tracking

From shipboard operations, it was discovered that reasonably correlated listening distances varied around 10 km. Sound shadow zones were also observed behind islands (e.g., the Four Brothers) or relatively large, shallow bathymetric features (e.g., shoals). As mentioned earlier, this maximum range obtained from shipboard operations represents a worst-case scenario. Improvements on this effective range will be noted later on.

The most interesting period of the field program occurred during its final five days when the drogue system was operational. This array was deployed several km north of the Four Brothers Islands on the June 2nd and allowed to free drift until the 6th of June. Based on RAFOS #64 transmitting to satellite (Argos) during this time period, the surface trajectory of the drogue could be plotted (Figure 9). The grounding of the drogue on June 4 north of the Four Brothers Islands and the ~2 km eastward displacement are well documented on this Argos-based drift track. During these 4 days, the drogue drifted about 19 km, starting from the central basin and ending near Thompsons Point. Based on 6 and 32 meter RAFOS float (#27 and #4, respectively) observations, all acoustically calculated positions were also placed on Figure 9 as a solid line. While theoretically both should be identical, the discrepancy comes from the uncertainties in Argos positioning (+/- 500 m) and in acoustic positioning (sound speed, clock stability, etc.). For example, a clock shift of one second on the underwater RAFOS unit would result in a much closer fit to the Argos drift track (Figure 10). It should be made clear that during this phase of the experiment, absolute float positioning was not required. Rather, testing the capability of the system to be used in a lake was the highest priority, and this goal was accomplished.

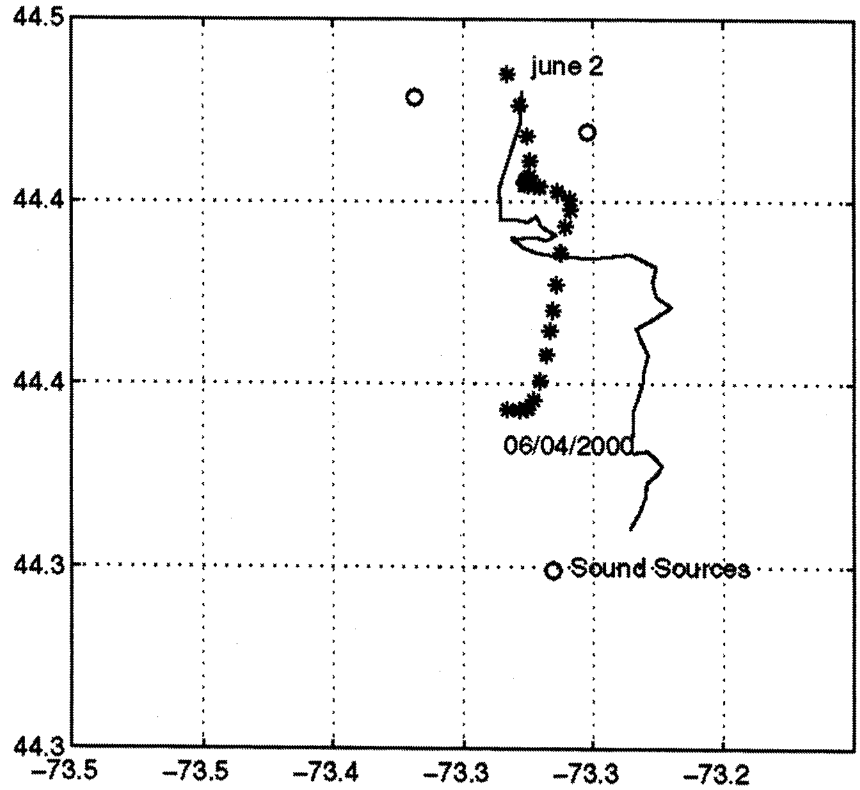

Figure 9. Surface trajectory (stars) deduced from Argos transmissions of surface RAFOS float #64 during the drift experiment starting June 2 in the central area of Lake Champlain and ending on June 6 at the southern end of the lake near Thompsons Pt. Uncorrected underwater trajectory (black line) deduced from sound sources acoustic transmission origins (circles) received by the deep RAFOS float #4 during the same period. The discrepancy between the 2 trajectories is due to several factors. Among them would be time offset between the sound sources and the underwater RAFOS float clocks, and sound speed uncertainty, which was taken as 1430 m/s.

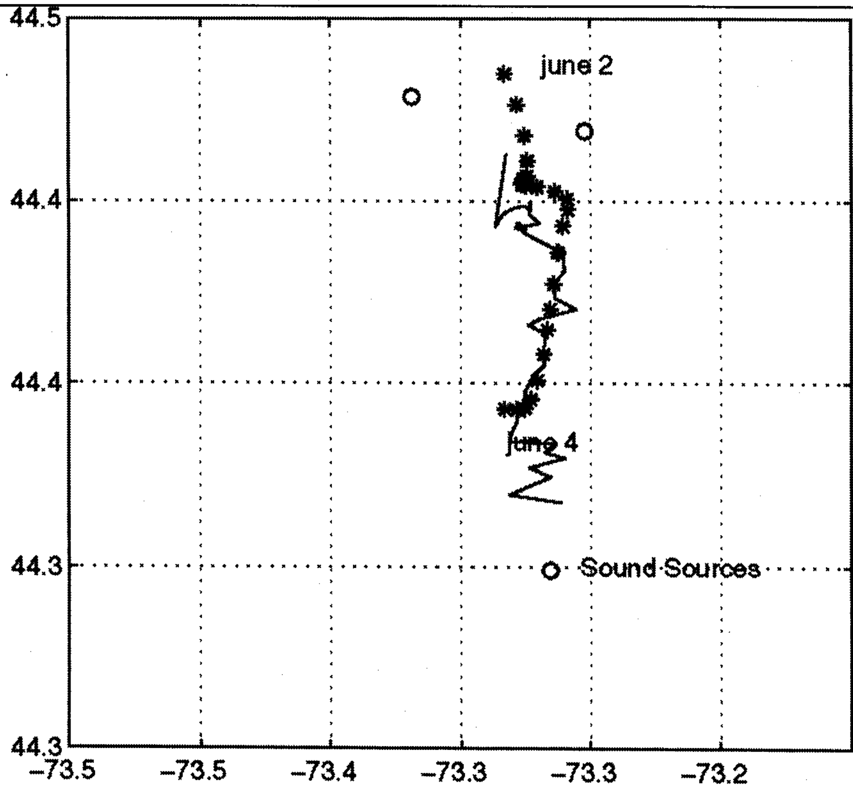

Figure 10. Same as Figure 9 but the underwater RAFOS clock has been shifted by one second.

During the time when the drogue-array was free drifting within the lake (2-6 June; Julian days 154-158, respectively), both drifters were acquiring signals from the three operational sound sources within the lake. Sound sources #2, #3, and #4 (defined in all subsequent figures as S2, S3 and S4) represent Burlington Bay, Corlaer Bay, and Thompsons Point, respectively. Acoustically calculated distances between drifter #4 (32 m depth) and the previously defined sound sources, as well as signal correlation through time, are provided in Figure 11. It can be seen from these panels that as the array moved from north to south, signals from the Thompsons Point sound source became stronger and more highly correlated, while signals from Burlington Bay remained consistently high throughout the entire drift. Signals from Corlaer Bay, on the other hand, became weaker (but still correlated) due to acoustic interference related to the Four Brothers Islands. Fifteen km represents the maximum acoustically tracked distance reached by the floats at the end of the drifting phase relative to the Corlaer and the Burlington sound sources; however, the expected maximum distance would be more when considering the slight decrease in signal strength along the lake's thalweg between Burlington and Thompsons Point (VCM04-S2). In other words, the limit of the acoustic range was far from being reached. It is our belief that even if the Valcour Island sound source had been operational, shadowing by the various shoals and islands would have weakened the signal well before refractive or reflective losses. From these results, it is presently estimated that the acoustic range limit would be on the order of 30+ km for an unobstructed channel. This extended range would suggest that floats could be tracked everywhere within the Main Lake, provided that sound sources are deployed in appropriate locations that would avoid or minimize "shadow zones" created by shallow topography.

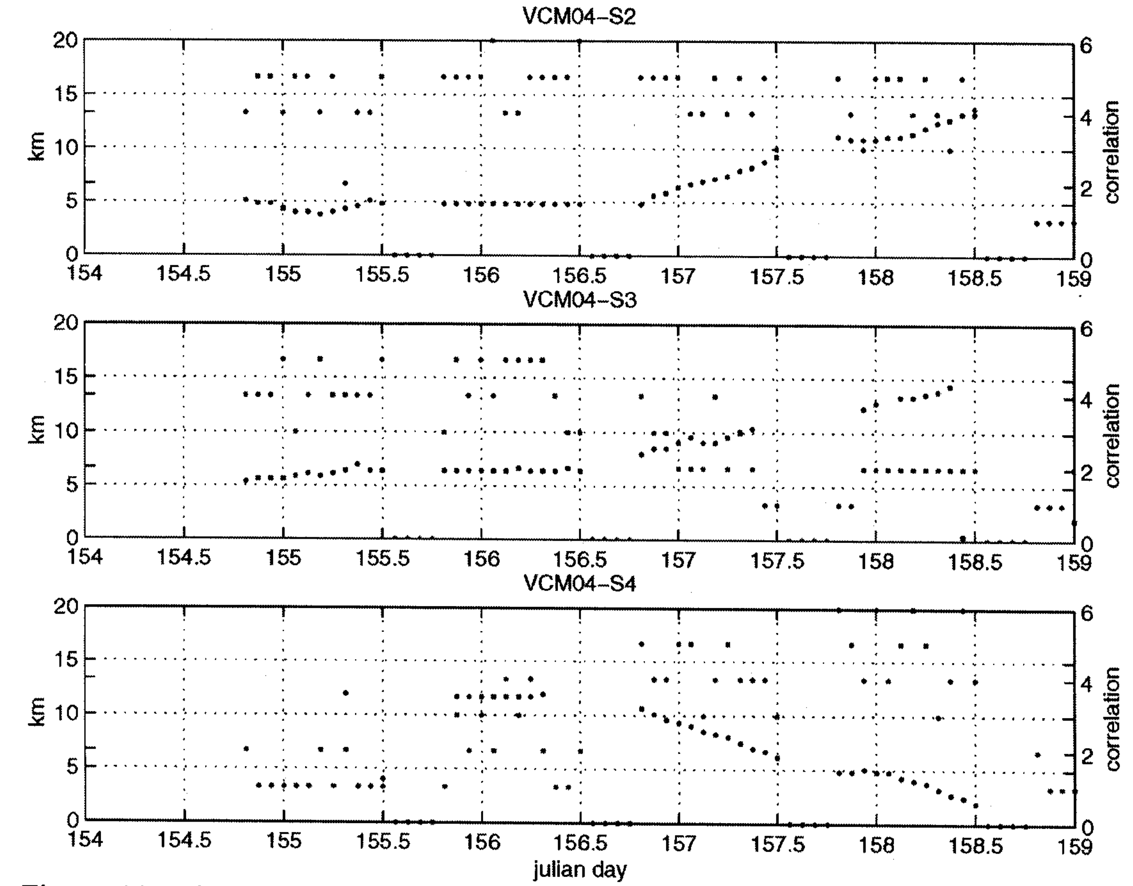

Figure 11. Distances (blue dots) between RAFOS drifter #4 (VCM04 at 32m) and sound sources S2 (Burlington Bay), S3 (Corlaer Bay), and S4 (Thompsons Point) calculated from the time of arrival of sound source signals to the float between 2 June (day 154) and 6 June (day 158). Acoustic correlation values (red dots) are associated with the right hand axis.

While drifters can be equipped with a wide variety of sensors, those used in Lake Champlain recorded only temperature and pressure. As can be seen in Figure 12, the recorded pressure for drifter #4 was fairly consistent at 33 db (~33 m) until its recovery in the early afternoon of day 158 (6 June) when pressure dropped to 0. The near surface RAFOS float is not shown in this diagram since it recorded data only once per day due to an error in programming the instrument. Observed thermal variations at a depth of 32 m ranged from approximately 5-6.5 °C in what appeared to be a 2-day period cyclic behavior. Upon closer investigation of the data, this apparent cyclic thermal variation can be directly attributed to the drogue's trajectory through the internal thermal structure of the lake. Figure 13 shows the path of the drogue over time with respect to the hydrographic cross-section (Figures 7 and 8). The drift track can also be divided into 3 distinct sections, A to B, B to C, and C to D, as also shown in Figure 13. As the drifters moved in a southerly direction from the beginning of the deployment to their eventual grounding slightly north of the Four Brothers Islands (section A-B), the expected thermal signature from the N-S transect would be a consistent increase in temperature which was, in turn, observed (Figure 14). During the transit from B to C, while the system was slowly dragged to its new position farther to the east, the E-W transect showing decreasing temperatures at a depth of 33 m agrees well with the observations again (Figure 14). As the drogue continues along its new southerly track with no further groundings (section C-D), observations of increasing temperatures again are supported by the N-S transect. As a result, the 'apparent' 2-day oscillation observed in the data was, in reality, caused by the repositioning of the drogue by the *Melosira* and not a natural phenomenon.

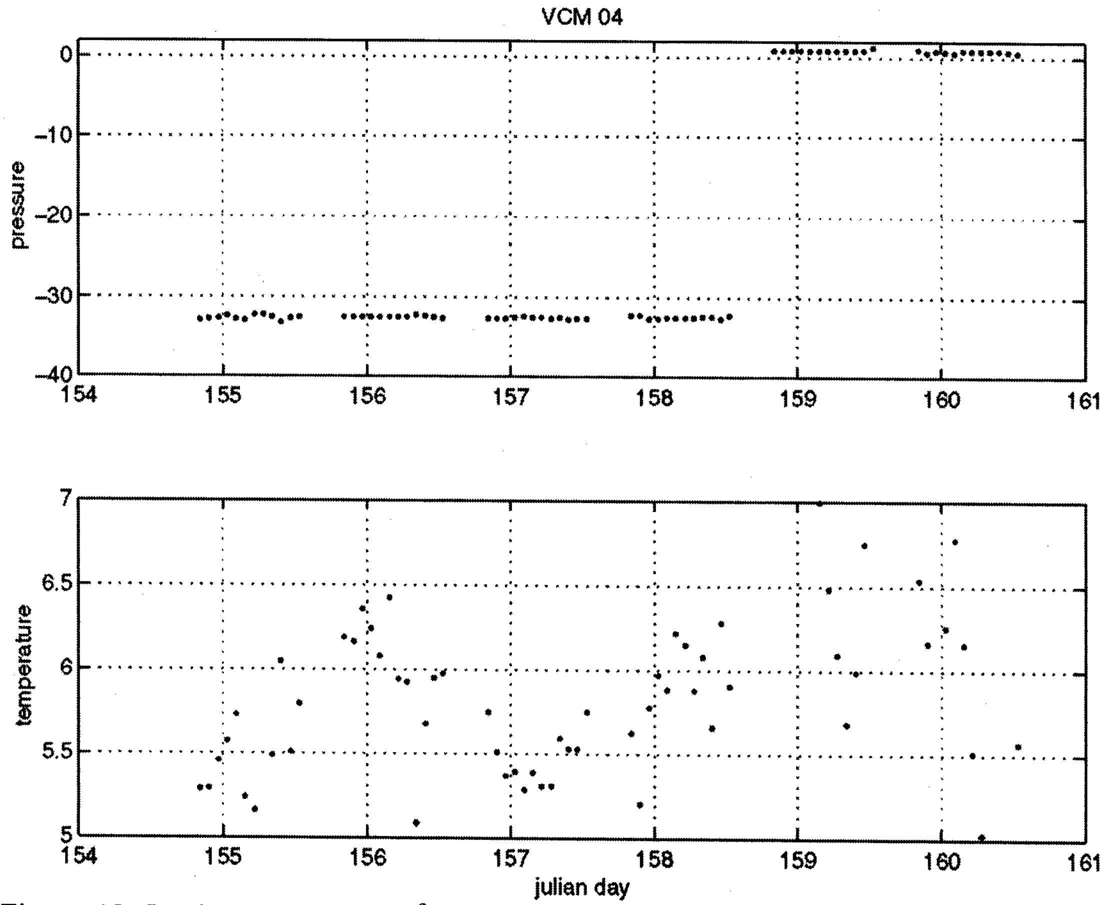

Figure 12. In situ temperature (°C) and pressure (db) recorded internally by RAFOS drifter #4 during the drift experiment from 2-6 June, 2000.

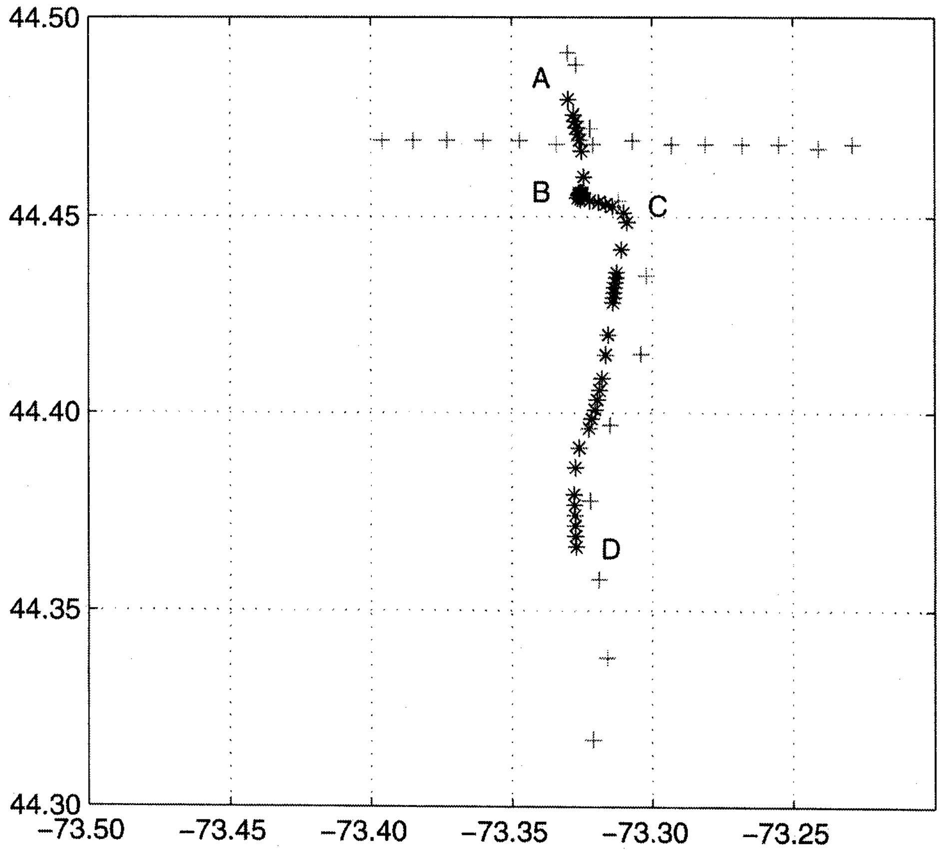

Figure 13. Drift track of drogue array (blue stars) with locations of all CTD stations taken during the program. Cross-sections from the thermal observations can be seen in Figures 7 and 8. Letters A, B, C, and D are position indicators that are also used in the Figure 14.

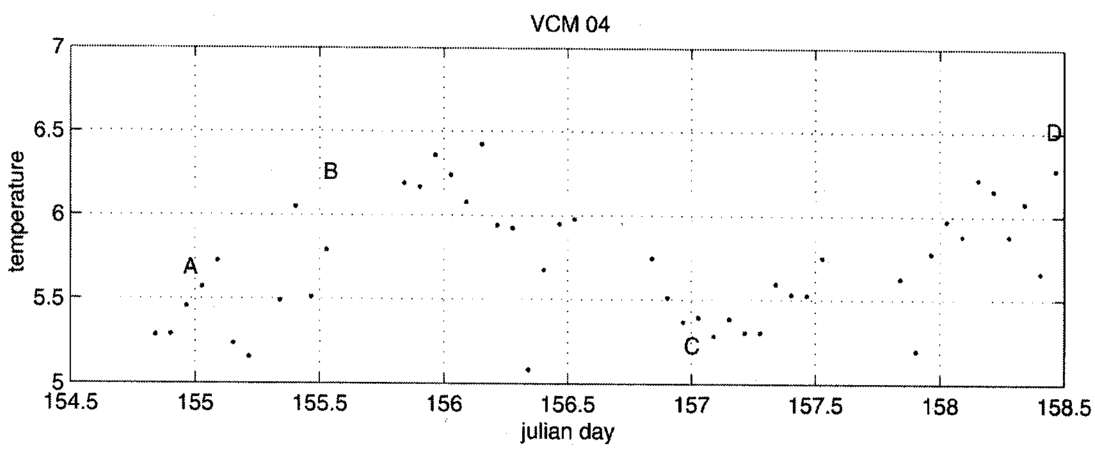

Figure 14. Temperature observations by 33 m float (VCM04) along the path of the drifting array. See text for further details.

Ray path diagrams based on the thermal cross-sections collected during the experiment, as well as the depths of both acoustic transmitters (sound sources) and receivers (RAFOS floats) as a function of distance between them, were modeled. From Figure 15, it can be seen that for a sound source and a receiver operating at a similar depth of 30 m (below the thermocline), the lake behaves like a half wave-guide. On the other hand, with a sound source at 30 m and a receiver at 10 m, the lake appears to be responding as a full wave-guide (Figure 16). In essence, a full wave-guide represents a sound channel where the bending of acoustic ray paths (due to sound speed variations in the vertical) cause sound to be refracted up and down inside the guide and, therefore, never escape from it. In cases where sound channels exist, transmission distance can be very large, since energy is not lost in surface or bottom reflections. A half wave-guide, on the other hand, is one where one-half of the acoustic wave-guide exists. In this case, there will be multiple reflections at a bounding surface (air-water or sediment-water interface) that rapidly dissipate sound energy and therefore reduce transmission distances.

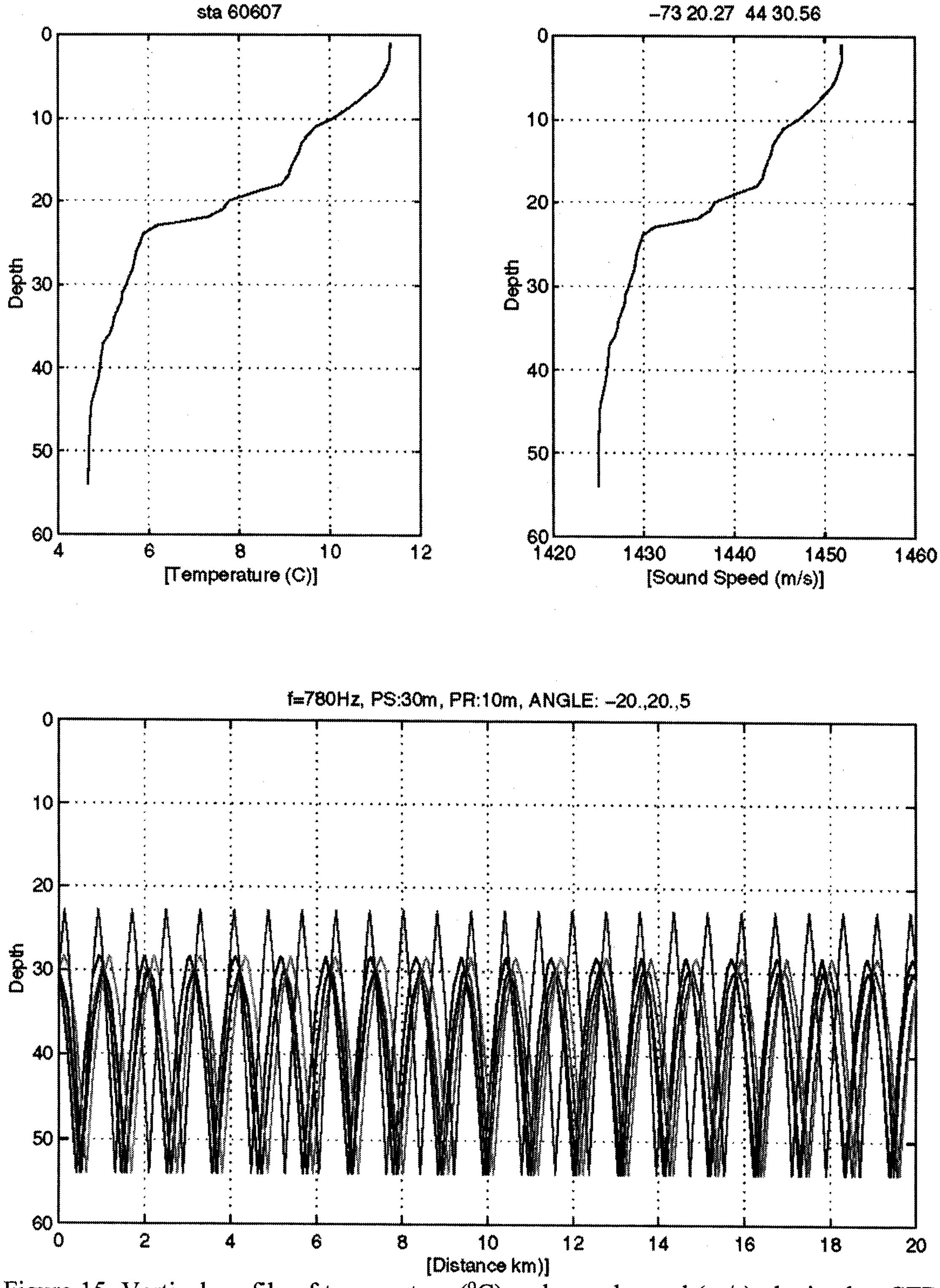

Figure 15. Vertical profile of temperature (°C) and sound speed (m/s) obtained at CTD site 60607 near the center of the lake are shown in the top panels. The bottom panel defines a computer modeled ray path diagram with a sound source and receiver at 30 m depth and separated by 20 km. Under these conditions, the lake behaves as a half wave-guide where reflection is confined to the sediment-water interface. The different intensity traces in the lower panel represent different acoustic ray paths which make their way through the fluid, depending on the conditions imposed in limiting the emission cone to +5° and -5° from the horizontal with a resolution of 0.5° angle.

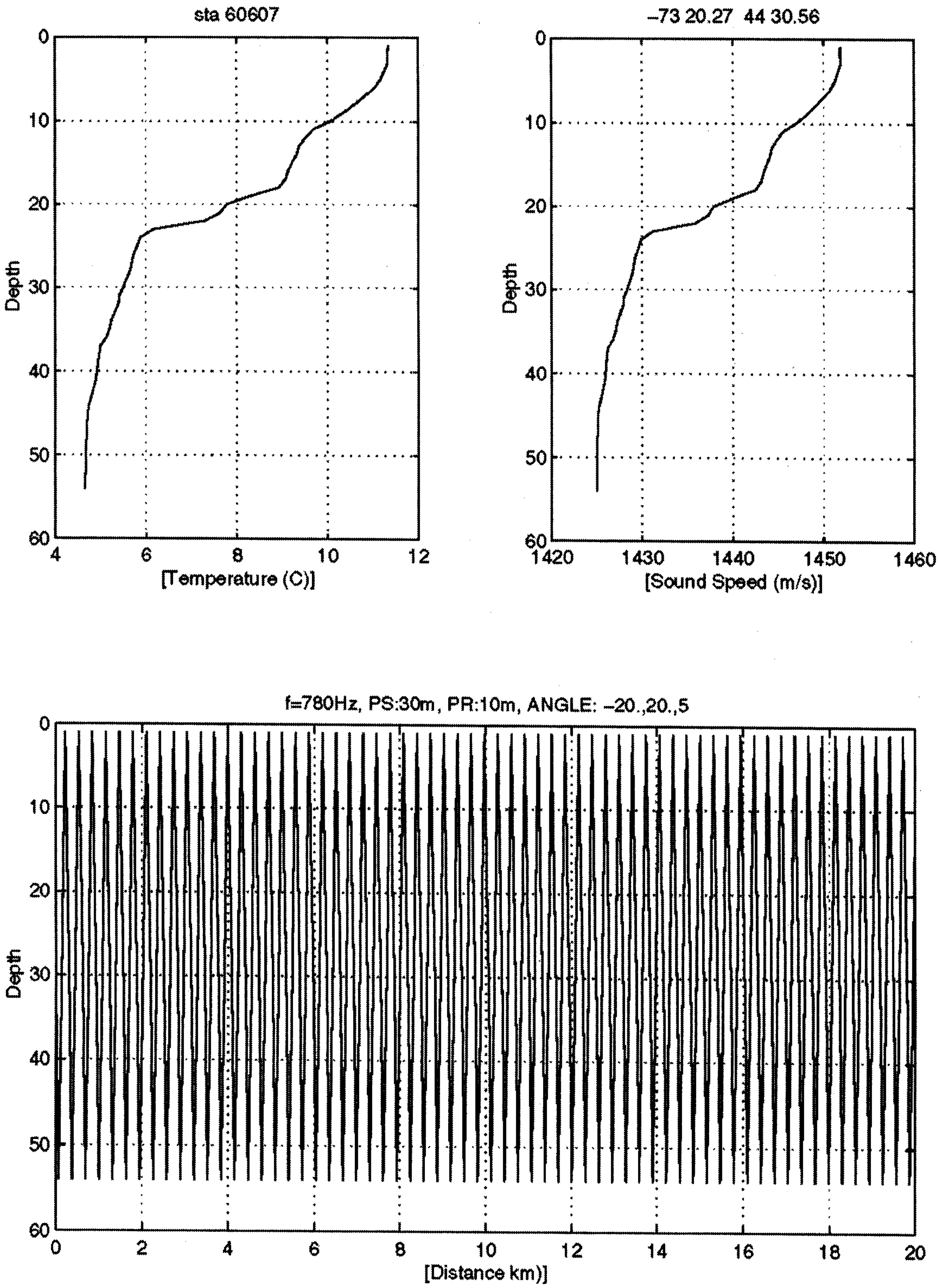

Figure 16. Same as Figure 15 but the ray path diagram now corresponds to an underwater receiver located at 10 m. In this situation, the lake behaves like a full wave-guide.

Float Ballasting

All the glass and metal RAFOS floats were tested at the Woods Hole Oceanographic Institution (WHOI) pressure tank facility to precisely measure their compressibility at low pressures. This had never been done before, since the floats are usually operated in the deep ocean at pressures usually ranging from 100-4000 m. In Lake Champlain, the observational pressure range would vary from 5-80 m, significantly outside the typical range found in the ocean. In fact, oceanographers have always been interested in shallower regions, but compressibility and stability were such a problem that they avoided it. Limnologists cannot. Results obtained from WHOI demonstrate clearly that all the RAFOS floats (no matter what kind) are unstable within the first 100 m. Apparently, the soft components of the RAFOS float (which consist of o-rings and the rubber coated transducer) displayed high compressibility within this pressure range. The glass enclosure, on the other hand, is strongly incompressible and, therefore, has very stable characteristics for ballasting at specific depths. The compressibility of the "soft" components change the volume of the instrument enough so that it cannot be ballasted at any depth less than 100 m. As a result, RAFOS floats would be stable at only two locations within Lake Champlain or any shallow body of water. These stable postions are the surface and the bottom.

While this initially appeared to be a serious problem, attention has shifted to another instrument that was recently created at WHOI and Scripps Institute of Oceanography that could be successfully utilized within Lake Champlain (i.e., the SOLO float). These specific profiling instruments are free drifters (similar to the RAFOS float); however, they are designed to profile vertically within the water column and therefore have their own computer driven ballasting mechanism (Figures 17 and 18). For the Lake Champlain pilot study, there is no need for such a large and sophisticated device as the SOLO float. Rather, a smaller, less expensive unit, which we refer to as the Lake Champlain Profiler (LCP), will be created utilizing this technology. Unfortunately, none of these specific "SOLO" floats were available for testing in Lake Champlain on such a short notice. It is expected, however, that lab testing this type of float for operation in Lake Champlain will begin at Seascan and WHOI during the summer of 2001, while an actual field test will be made in the lake from Oct-Nov this year.

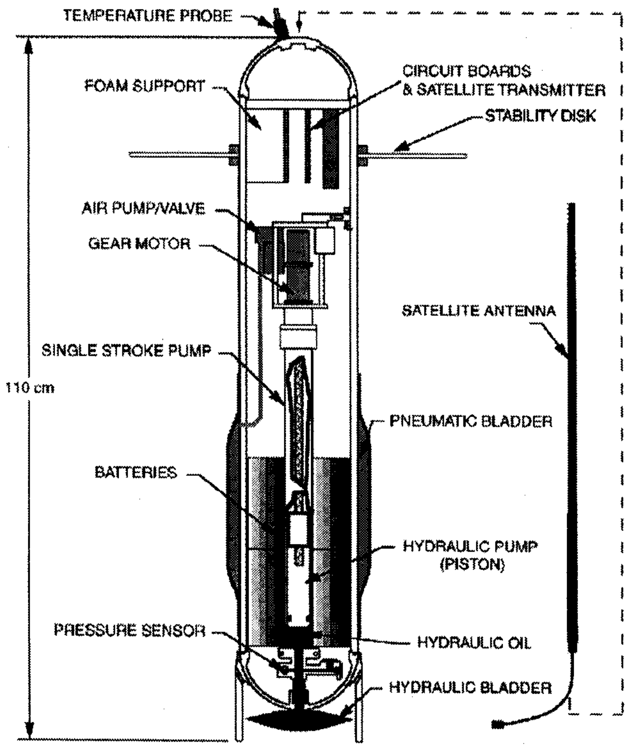

Figure 17. Cross-sectional schematic of the "SOLO" float. See text for further details. Diagram obtained from the WHOI web site.

Figure 18. Relative size of the "SOLO" float.

Results

From this field program, we are confident in stating the following conclusions:

1) The 780 Hz system was too large for Lake Champlain. In essence, this type of system should have easily transmitted well over 100 km. The reason that these distances were not observed is not due to the frequency or the power of the system or even the decorrelation of the signal due to multipath reflections off the lake surface and bottom bathymetry, but rather to limitations imposed by geometry of the lake and irregularities like shoals and islands which create shadow zones for direct acoustic paths. As a result, a smaller and cheaper 1560 Hz system could be used just as effectively.

2) With the observed bottom bathymetry and correlation distances within the Main Lake, it would take approximately 6-8 sound sources to completely "cover" the main sector of the lake from Valcour Island to Thompsons Point.

3) The "SOLO" float would offer the best solution for creating a free-drifting neutrally-buoyant float for Lake Champlain. The units that would be created are estimated to be cheaper and lighter than their oceanic counterparts.

4) A Lagrangian drifters program within Lake Champlain has an even higher probability of success than our first estimate.

5) Jean-Claude Gascard purchased the RAFOS floats from this program for utilization in some of his deep-ocean research. Only the expendables such as batteries, ballasting, and shipping were paid for by this program.

Program Direction for 2001

Our initial plan was to continue on a slow and very directed testing program of the various components needed to assure success within Lake Champlain. Specifically, this would be to create the first LCP and complete a very rigorous buoyancy (depth stability) checkout of the device in Lake Champlain. Furthermore, we would purchase only enough sound sources (1-3) to carry out the testing of this specific drifter. Unfortunately, no-cost extensions were not permitted for any contracts for the current fiscal year, since USGS was closing all of their contract accounts. As a result, we could not hold any money in reserve as the program continues to verify all components within the system.

Because all funds had to be expended prior to February 1, 2001, an acceleration of the program's timetable was required. As a result, several of the sound source components have been purchased. Funds available for this year will be utilized to purchase the remaining components for the sound sources, as well as pay for their fabrication and shipment to Middlebury College.

Presently, we are planning for an operational program during the last week of August, 2001. A total of 6 sound sources will be deployed within the Main Lake. It is important to mention that a good tracking system should avoid base lines problems between floats and sources. A base line problem occurs every time a float is located along the line joining 2 sound sources. In this case, float positioning is poor. Consequently, the best scenario is to deploy sound sources in the lake by pairs at different latitudes. One pair defines an eastward and a westward source at the same latitude. Since the lake is latitude elongated, a good starting estimate would be three pairs (6 sound sources) at 3 different latitudes (for instance, north of Thompsons Pt, Burlington-Corlear, and south of Valcour). An extra pair would increase tracking performance.

Two drogued arrays of listening devices will be allowed to free-drift within the lake. Each array will consist of three RAFOS floats: one at the surface continually transmitting positional information to Argos and 2 floats at different depths within the water column. It should be noted that these RAFOS floats will be rented, since it is well known that they cannot be used within Lake Champlain. Additionally, hydrographic and acoustic listing stations will be completed during the time period that the drogue-arrays are actively collecting data within the Main Lake. This field program will be utilized to test the operational capacity of the 1560 Hz sound system, as well as confirm that with 6-8 sound sources, the Main Lake can be properly instrumented for full acoustic coverage.

Pierre Tillier will also look into the program's ability to borrow an earlier designed SOLO float from Woods Hole so that initial testing of the device can be completed by late August at one of the large indoor tanks at this research facility. According to Tillier, the most important aspect of the SOLO float that must be dealt with for successful operation within Lake Champlain is the software control for ballasting stability. As a result, there will be no intentional release of a SOLO float with Lake Champlain until the software and operational control of the unit have been verified. Subsequent to this testing of the SOLO float, additional time and effort will be put into the final packaging, as well as the internal and external structure of the unit. It is expected that the Lake Champlain Profiler (LCP) will not be available for testing until the following summer. It is highly likely that additional funding will be sought for a third and possibly fourth year of the program. During the third year, it is expected that one or two LCPs would be released within the lake for detailed testing of their stability within the real environment. If successful, the fourth year would see a full deployment of LCPs within the Main Lake.

Appendix I – Program Chronology

May 26 (Friday)
Jean-Claude departs from Paris to Boston.

May 27-29 (Saturday-Monday)
Work at Seascan from May 27 until May 29 included preparation of the 4 sound sources at 780 Hz + 4 RAFOS glass tube floats and 2 RAFOS VCM (one glass and one metal). All these instruments belong to LODYC.

May 30 (Tuesday)
Pierre Tillier and JC Gascard depart from Falmouth (MA) to Burlington (VT) with a rented truck loaded with the equipment.

May 31 (Wednesday)
First acoustic tests with Melosira and Baldwin started in Shelburne Bay. Diver related issues proved not to be a problem after all.

June 1 (Thursday)
Initialization of the four sound sources commenced. Each sound source was initialized in order to transmit 16 times per day (every 1.5 hour). Each sound source transmission was shifted 10 minutes from the previous and from the following transmission. Note: in order to convert from universal time (UT) to eastern standard time (EST), subtract 4 hours.

The first cycle started at:
0000 UT for sound source #02 deployed at the northernmost point (Valcour)
0010 UT for sound source #07 deployed in Burlington Bay
0020 UT for sound source #03 deployed in Corlear Bay
0030 UT for sound source #65 deployed at the southernmost point (north of Thompsons point)

Then the second cycle started at
01.30 UT for sound source #02 - Valcour
01.40 UT for sound source #07 – Burlington Bay
01.50 UT for sound source #03 – Corlear Bay
02.00 UT for sound source #65 - Thompsons Point

There were 16 identical cycles scheduled every day for 6 days starting on June 1st corresponding to 96 total transmissions for each sound sources. Each transmission is a 40 seconds duration 780 hz frequency modulated signal.

Mooring deployments on board Melosira. First mooring at Thompsons Point from 1113 UT until 1253 UT. Water depth 300ft. Second mooring deployed at Corlaer Bay from 1352 UT until 1443 UT. Water depth 200 ft. Third mooring deployed at Valcour from 1500 UT until 1620 UT. Water depth 270 ft. Forth mooring deployed in Burlington

Bay from 1640 UT until 1710 UT. Water depth 330 ft. Positions for the moorings are as follows:

Burlington Bay -	44 28.1508 N	73 18.1282 W	deployed from 13:15-13:51 EST
Valcour Island -	44 35.3080 N	73 22.7789 W	deployed from 11:32-12:14 EST
Corlaer Bay -	44 28.7094 N	73 22.1284 W	deployed from 09:53-10:38 EST
Thompsons Point-	44 20.9415 N	73 18.9335 W	deployed from 07:30-08:53 EST

One RAFOS float (#4) was moored along a line anchored in about 100 ft of water. Float #4 was fixed along the line at mid depth. Mooring position was 44 28.4889 N and 73 17.0186 W. Mooring was deployed at about 1930 UT on June 1st and recovered the following day on June 2 at about 1700 UT. This preliminary operation was basically intended to verify (overnight) the good functioning of the sound sources (at least the nearest ones). As a matter of fact it was soon discovered that, unfortunately, the northernmost sound source (Valcour) was not transmitting shortly after it had been deployed in the water the previous day.

June 2 (Friday)

Following the recovery of the mooring equipped with the RAFOS float #4, a drifting line 144 ft long was released at 44 29.301 N and 73 19.967 W on June 2 at about 1915 UT from the Baldwin. This line was drogued at one end (deep part) and buoyant at the other end including a surface RAFOS float (#64) transmitting permanently to Argos (#25027). Along the line and beneath the surface, 2 RAFOS floats (#27 and #4) were installed at 20ft depth and 100 ft depth, respectively. These 2 subsurface floats remained in the listening mode until the end of the experiment.

June 4 (Sunday)

Since the drifting line equipped with the 3 RAFOS floats appeared to be grounded north of the « 4 brothers shoal » early on June 4, it was decided to drag the drifting line 1.2 mile eastward in deeper water. The second deployment occurred between 1630 and 1707 UT on June 4 at 44 27.36 N and 73 18.24 W in 325 ft of water on board the Melosira.

June 5 (Monday)

An east-west hydrological section was accomplished on board the Baldwin between Corlaer and Burlington and at the same time some listening tests were made along this section. During the transect, the sound sources deployed in the east (Burlington) and west (Corlaer) of the Lake were received loud and clear. Of course the northernmost Sound source was not giving any signal and most of the time the southernmost Sound source was received weak or not at all.

June 6 (Tuesday)

A north-south hydrological section was accomplished on board the Baldwin between Valcour and Thompsons Point together with listening stations at each stations and during sound sources transmission times. At the end of this day the drifting mooring line equipped with the 3 RAFOS floats was recovered at about 1750 UT and 44 21.625 N and 73 19.615 W.

June 7 (Wednesday)

Recovery of the four moorings equipped with the sound sources on board the Melosira. Field program completed.

Students Supported –

One BA Student in Geology

Information Transfer Program

During the grant period, the Vermont Water Resources and Lake Studies Center published two issues of its newsletter, distributing copies to more than 600 Vermonters with interests in water. Routine contacts with a number of parties, including the public, public interest groups, state and federal managers with interests in water, and staff from Vermont's Congressional delegation, were an important information transfer activity during the reporting period as well.

Basic Information

Title:	Information Transfer Program
Start Date:	3/1/1999
End Date:	2/28/2000
Descriptors:	distribution of newsletters, water resources
Lead Institute:	Vermont Water Resources and Lake Studies Center
Principal Investigators:	Linda Marek Howe, Alan W. McIntosh

Publication

1. Howe, L.M., A.W. McIntosh, 2000, Reflections on Water, January, Volume 21, Number 1, 5 pages.
2. Howe, L.M., A.W. McIntosh, 2000, Reflections on Water, June, Volume 21, Number 2, 6 pages.

USGS Summer Intern Program

Student Support

Student Support					
Category	**Section 104 Base Grant**	**Section 104 RCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	1	0	0	0	1
Masters	1	0	0	0	1
Ph.D.	0	0	0	0	0
Post-Doc.	0	0	0	0	0
Total	2	0	0	0	2

Notable Awards and Achievements

None

Publications from Prior Projects

1. Ferber, L., S. Levine, and A. Lini, 2000, Nitrogen dynamics in Shelburne Pond, VT, International Association of Great Lakes Research, 43rd Conference Program and Abstracts, p. A-44.
2. Ferber, L., S. Levine, A. Lini, and G.P. Livingston, 2000, Nitrogen dynamics in Shelburne Pond, ASLO Meeting 2000, Abstract Volume.
3. Lini, A., S. Levine, R.C. Howse, and L. Ferber, 2000, Stable isotope composition of lake biota and sediments as proxy for lake trophic state, International Association of Great Lakes Research, 43rd Conference Program and Abstracts, p. A-91.
4. Lini, A., P. Keane, J.C. Galster, and R.C. Howse, 2000, Integrated analysis of modern and sedimentary stable isotope data in lakes, ASLO Meeting 2000, Abstract Volume.
5. Lescaze, M.M., 1999, Estimation of the relative contribution of atmospheric nitrogen to lake phytoplankton nutrition: a stable isotope approach, MS Dissertation, Water Resources, School of Natural Resources, The University of Vermont, Burlington, VT, 88 pages.
6. Ferber, L.R., 2001, Nitrogen dynamics of blue green algal blooms in a eutrophic Vermont lake, MS Dissertation, Water Resources, School of Natural Resources, The University of Vermont, Burlington, VT, 135 pages.