Autonomous Year-Round Sampling and Sensing to Explore the Physical and Biological Habitability of Permanently Ice-Covered Antarctic Lakes

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PAPER

Autonomous Year-Round Sampling and Sensing to Explore the Physical and Biological Habitability of Permanently Ice-Covered Antarctic Lakes

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ABSTRACT

The lakes of the McMurdo Dry Valleys, Antarctica, are some of the only systems on our planet that are perennially ice-covered and support year-round metabolism. As such, these ecosystems can provide important information on conditions and life in polar regions on Earth and on other icy worlds in our solar system. Working in these extreme environments of the Dry Valleys poses many challenges, particularly with respect to data collection during dark winter months when logistical constraints make fieldwork difficult. In this paper, we describe the motivation, design, and challenges for this recently deployed instrumentation in Lake Bonney, a lake that has been the subject of summer research efforts for more than 40 years. The instrumentation deployed includes autonomous water, phytoplankton, and sediment samplers as well as cable-mounted profiling platforms with dissolved gas and fluorometry sensors. Data obtained from these instruments will allow us, for the first time, to define the habitability of this environment during the polar night. We include lessons learned during deployment and recommendations for effective instrument operation in these extreme conditions.

Keywords: lakes, sensors, extreme environments

Introduction

The McMurdo Dry Valleys in southern Victoria Land, Antarctica, contain a number of permanently ice-covered lakes that have been considered the closest earthly analogs to conditions that existed on Mars in the past and on other icy worlds in our solar system (Doran et al., 1998, 2003; Priscu et al., 1998; Priscu & Hand, 2012). In these lakes, we can begin to understand how life exists in what otherwise might be considered an inhospitable environment. Data collected on Lakes Bonney, Hoare, and Fryxell (all in Taylor Valley) as part of the McMurdo Dry Valleys Long-Term Ecological Research (LTER) program during the late winter, summer, and early fall have shown that most organisms in the lakes are not just "surviving the extremes" but are actively feeding, growing, and reproducing (Bielewicz et al., 2011; Priscu et al., 1987a, 1987b; Takacs & Priscu, 1998; Vick & Priscu, 2012). As such, they are ecosystems in which we can identify physiological and genomic adaptations in the context of one of the most extreme environments on our planet.

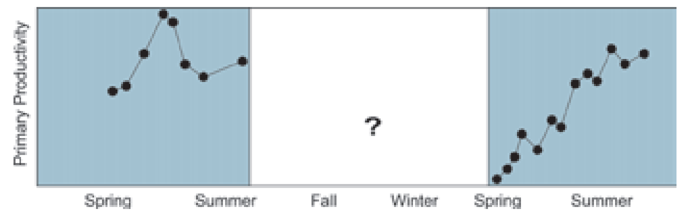
Almost all research on the Dry Valleys lakes has been restricted to the austral spring, summer, and fall (c. late August through mid-April) when access to the lakes is possible due to the dependence of helicopter support on daylight conditions. While in summer, there are 24 hours of sunlight, there are 4 months of complete darkness in winter when air temperatures can drop to −50°C. Significant logistical expenditure is necessary to sample beyond these dates, as previously evidenced by one late fall and two late winter field seasons (Kong et al., 2012; Lizotte et al., 1996; Vick & Priscu, 2012). These conditions make fieldwork difficult, if not impossible outside the core summer season.

Figure 1 demonstrates the gap where no data exist on primary productivity (PPR) and other physical, chemical, and biological properties. Predictions of late summer through winter processes in these lakes have been based on ecosystem models built on spring-summer data. Models of PPR and community respiration (R) in Lake Bonney revealed that contemporary biomass cannot be supported by the phytoplankton photosynthesis measured during the summer months only (Priscu et al., 1999; Takacs et al., 2001a). These results imply that respiratory carbon losses exceed new carbon gains via photosynthesis and the lakes should eventually run out of reduced carbon to support heterotrophic life. However, year-round data on the relevant carbon fluxes and processing cannot be collected manually, and this deficit may be explained by understanding year-round movement and processing of carbon. *In situ* sensors and samplers can collect annual observations critical to better understanding of the chemical, biological, and physical processes occurring in these extreme systems.

Existing sensors have substantially improved our ability to monitor the physical aspects of the Dry Valley lakes. On- and in-lake temperature, light, and pressure sensors have been used for over two decades to understand the year-round physical dynamics of the lakes. The Dry Valleys also have good meteorological and gaging station coverage, complementing the lake stations. However, only recently have sensors and instrumentation started to allow us to autonomously

FIGURE 1

Biological parameters such as PPR have never been measured during the polar winter.



monitor the chemical and biological aspects of the lakes through the development of submersible and long-term deployable fluorometry, dissolved CO_2 sensors, and autonomous water and sediment samplers.

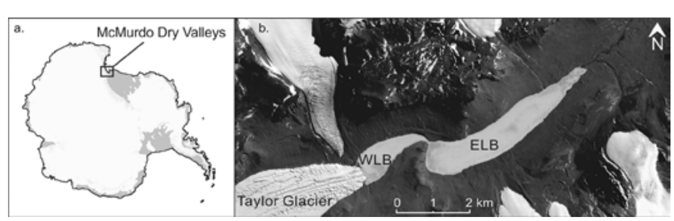
To extend the chemical and biological observation of these lakes, we deployed an instrument suite under the ice of Lake Bonney for year-round measurement and sample collection. These instruments augment existing summer field campaigns and year-round monitoring of physical and meteorological conditions of the lakes. The newly developed and deployed instrumentation includes automated water samplers, filtering samplers, and a profiling platform to record water column chemical, physical, and biological conditions. These instruments will provide us, for the first time, observations on the year-round fate of the carbon (quality and biomass) fixed during the summer season. In the remainder of this paper, we discuss details of the existing and new technologies being used in the McMurdo Dry Valley lakes and challenges of deploying instrumentation in these harsh environments.

Site Description

Lake Bonney is a meromictic lake in western Taylor Valley, a large ice-free valley in the central McMurdo Valleys in southern Victoria Land, Antarctica (Figure 2). A sill in a narrow channel separates the lake into two lobes, West Lobe Lake Bonney (WLB, 0.97 km^2) and East Lobe Lake Bonney (ELB, 3.25 km^2). The sill depth in the narrows currently has a depth of 17.7 m (January 2011), which effectively isolates the bottom waters of each lobe. Lake levels of WLB and ELB are, respectively, 43 and 41 m above sea level (January 2014). Lake Bonney is a proglacial lake that receives the majority of annual inflow from Taylor Glacier through subglacial and stream

FIGURE 2

(a) The location of the McMurdo Dry Valleys on the Antarctic continent, (b) a map of western Taylor Valley showing the west (WLB) and east (ELB) lobes of Lake Bonney, and the terminus of Taylor Glacier.



flow. Taylor Glacier, an outlet glacier from the East Antarctic Ice Sheet, abuts the western end of WLB and may contribute significant amounts of subglacial discharge high in dissolved solids to the deeper, saline waters. As opposed to the glacial sources in WLB, the water balance of ELB is dominated to a large extent by inflow from WLB across the narrows (Spigel & Priscu, 1998; unpublished data). All other surface inflow to the lake comes from small ephemeral streams that drain upstream valley glaciers or from surface melt from Taylor Glacier. Surface inflows have low dissolved solid concentrations and mix with the fresh near-surface waters of the lake. There is no surface outflow from the lake, and groundwater exchange is negligible, so all water loss is the result of evaporation and sublimation at the ice surface (Spigel & Priscu, 1998).

Lake Bonney is covered by 3–5 m of permanent ice. A small moat melts out around the edges during summer, which amounts to about 1% of the lake surface area (Priscu et al., 1996). The permanent ice cover restricts wind-induced turbulence, limits degassing of the water column (Andersen et al., 1998; Priscu, 1997; Priscu et al., 1996), and impedes the penetration of solar radiation into the water column (Fritsen & Priscu, 1999; Howard-Williams et al., 1998). Because ice cover is never lost, sediment that is blown onto the lake is entrained within the ice cover and supports an ecosystem living within the lake ice (Priscu et al., 1998). These in-ice aggregates further decrease light penetration and limit water column primary production (Howard-Williams et al., 1998; Lizotte & Priscu, 1992).

The isolation of bottom waters has led to distinct geochemistry in each lobe. In WLB, total dissolved solids (TDS) increase from 0.39 at the top to 144 g/L at the bottom, with a sharp pycnocline (rapid change in density) at 15-m depth. In ELB, TDS increases from 0.61 to 272 g/L, with a more gradual pycnocline at 18–25 m (Green & Lyons, 2009). Temperatures in WLB range from 0°C beneath the ice cover to a maximum of 3°C at 9–10 m, followed by a decrease to −5°C near the bottom. In ELB, temperature increases to 6°C at around 15 m, decreasing to −2°C near the bottom. The high-salinity gradient in both lobes results in a highly stable, stratified water column with no thermohaline convection cells (Spigel & Priscu, 1998). To our knowledge, the density gradients in this lake are among the most extreme occurring naturally on Earth.

Core Instrumentation

As part of the McMurdo LTER program in Taylor Valley, lake monitoring stations have operated in the center of each lake since 1995. Figure 3 shows the lake levels recorded by the instrumentation over the monitoring period of nearly 20 years. Over the years, the equipment has evolved in step with technology and scientific interests. The stations are essentially meteorological stations adapted to measure long-term trends in the physical parameters of the lakes, including lake level, ice ablation, ice thickness, and underwater photosynthetically active radiation (PAR) (Table 1; Figure 4).

The core instrumentation has allowed us to better observe year-round and long-term processes in the Dry Valley lakes. For instance, in 2001–2002, the Dry Valleys experienced a flood year. From the lake station data, researchers were able to quantify the extent of inflow in comparison with normal years and understand the ecosystem response to an unprecedented deluge (Barrett et al., 2008). The overwinter sensors have also provided an estimate of year-round processes, such as ice ablation (Dugan et al., 2013), and past deployments of thermistor strings enabled the ice dynamics to be modeled (Doran et al., 2003).

Samplers and Profilers

Over the past year, we have taken advantage of increased availability and performance of automated sampling and observation platforms available to the market. The sensor suite is composed of four McLane Laboratories (Falmouth, MA) devices: one each of a sediment trap, phytoplankton sampler (PPS), Remote Access Sampler (RAS), and a modified Ice Tethered Profiler (ITP; Figure 5). The overarching goal of these instruments is to better understand the chemical and biological processes occurring

FIGURE 3

Long-term measurements of lake level in Lake Bonney (LB), Lake Hoare (LH), and Lake Fryxell (LF) recorded by deployed lake monitoring stations. (Adapted from Dugan et al., 2013)

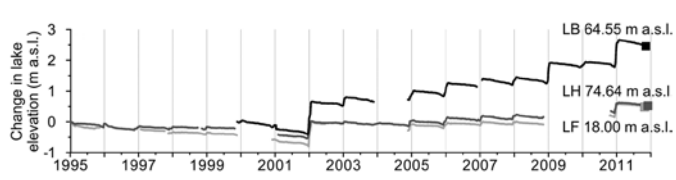


TABLE 1

Primary instrumentation at lake stations.

Parameter	Instrument	Model	Record Period	Sensor Accuracy
Data storage	Data logger	Campbell Scientific CR1000 (previously CR10X)	N/A	N/A
Ice thickness	Upward facing sonar altimeter	Benthos PSA-916	2012–Present	±1 cm
Stage	Lake bottom-mounted pressure transducers	Campbell Scientific CS-455	1994–Present	±0.1% full scale (0–30 m)
Ablation	Ice-mounted pressure transducer	Campbell Scientific CS-455	1994–Present	±0.1% full scale (0–30 m)
UW PAR	Quantum PAR sensor	Licor LI-193	1994–Present	±5%

FIGURE 4

Core monitoring stations deployed in Lake Bonney (not to scale).

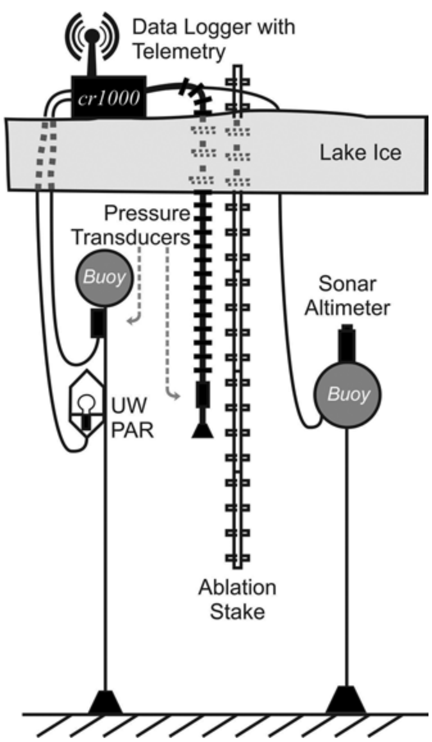
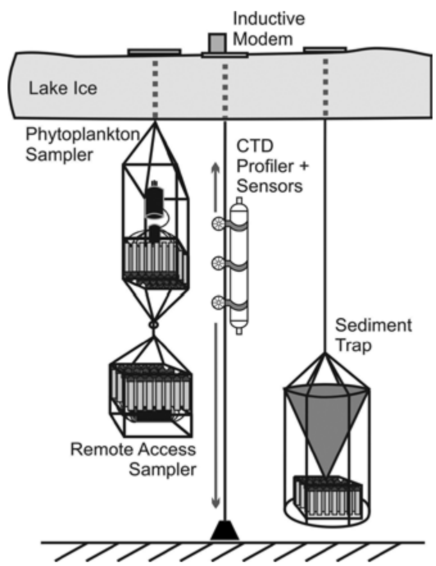


FIGURE 5

A diagram of the recent additions to automated sampling and measurement in Lake Bonney.



within the lakes year-round. We describe in detail the usage and design considerations of each in the following section.

Time-Series Sediment Traps

In November 2000, sediment traps were deployed near the monitoring stations in ELB and WLB to evaluate the magnitude and timing of sediment mass flux and C, N, and P flux in three size classes (<63, 63–250, >250 μm) to the bottom of the lakes (essentially the "lowest" point in the McMurdo Dry Valleys ecosystem). This distribution of the material collected by the sediment traps was recently reallocated to include C:N:P. These benthic flux measurements can be considered an end point to the connected Dry Valley ecosystem.

The deployed sediment traps (Figure 6a) allow for the collection and preservation of falling sediments into individual containers on a programmed interval. The time-series samplers are programmed to collect every 3 weeks (Table 2), a balance between sample capacity and the deployment length. With these observations, we can capture year-round variability in fallen organic and inorganic particulates. Previous measurements of sedimentation were passive, continuous collectors. Their data were potentially affected by falling sediment from ice-melting activities (discussed below) for deployment and retrieval (Takacs et al., 2001b). The time-series sediment traps allow us to ignore the samples affected by ice melting and observe naturally occurring sedimentation rates, improving estimates of particulate organic matter flux from the ice. Because melting the ice results in significant fallen sediment, to get a full annual cycle of naturally occurring sedimentation, it was important to reduce retrieval to every 2 years.

The original sediment traps used dry-cell batteries, which supplied a battery capacity of 5 Ah. This was enough to support a 1-year deployment, not the 2 years required here. In addition, the dry-cell batteries often failed early because of the low operating temperatures (<0°C) in the deep waters of Lake Bonney. To address this, McLane Laboratories designed a compatible

FIGURE 6

(a) A sediment trap being transported over the ice to be deployed, (b) ITP deployment in ELB, (c) deployment of PPS in ELB, and (d) filter caps with internal compartment for fixative.

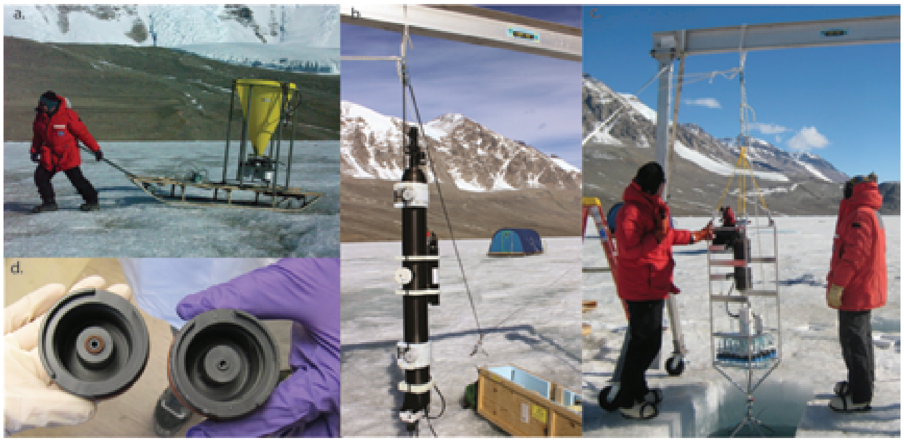


TABLE 2

Sampling or measurement schedule for all instrumentation.

Instrument/Sampler	Measurement/Sample Frequency
Core instrumentation (e.g., level, ice; Figure 4)	20 min (to 2013) 15 min (after 2013)
Sediment traps	3 weeks
ITP	Daily at solar noon
RAS	9 days (with five duplicate events)[a]
PPS	18 days (with three duplicate events)[b]

[a]Duplicate events are back-to-back samples on the same day.
[b]RAS and PPS sampling co-occurs at 18-day intervals.

lithium-ion battery pack that has a capacity of 17 Ah. This provides sufficient power for the extended deployment (24 months) at low temperature (<0°C).

Water Sampler (RAS)

The McLane RAS autonomously collects water samples into preinstalled 500-mL sample bags for later collection and analysis. The RAS can hold up to 48 sample bags, allowing it to collect up to 48 individual samples before manual retrieval and maintenance are required (Figure 7b). The schedule can be configured to sample on specified dates. For the Lake Bonney deployment, we chose a schedule that maximized the number and temporal resolution of samples collected over 1 year while still overlapping with the PPS collection schedule. This resulted in a 9-day sampling interval with five same-day sample events to be used as replicates. To preserve the samples, 5 mL of saturated mercuric chloride was added to each of the sample bags prior to deployment. The RAS was otherwise unmodified from the standard supplied configuration.

Profiler (ITP)

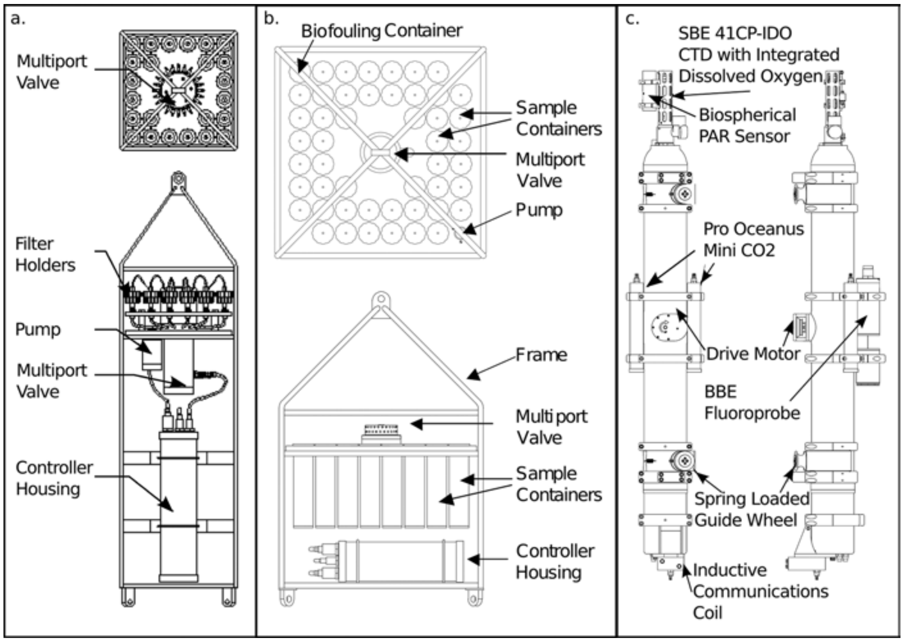
The most complex and challenging instrumentation deployed was a McLane Laboratories ITP. The ITP is a cable-crawling profiler traditionally outfitted with a Sea-Bird Electronics (Bellevue, WA) 41CP Argo-style float endcap (Figures 6b and 7c). The profiler is self-contained, with internal control, logging, and power system for autonomous deployment and sensor payloads. It has been successfully deployed in the Arctic (Toole et al., 2011) and will provide a platform for continuous monitoring of lake conditions throughout the year.

Unlike previous deployments of the ITP, in Lake Bonney, the profiler platform had to deal with an extremely corrosive environment and an extremely strong salinity gradient, and the sensors had to be capable of a wider range of parameter values including the most basic measurements of conductivity (0–14 S/m), temperature (−5 to 5°C), and saturation levels for oxygen (>200%). To accommodate some of these physical challenges, the custom sensing package had to be configured to measure water with salinity that ranged from near-fresh to hypersaline and gas concentrations many times those typically found in natural waters. Unfortunately, with such extreme density gradients and gas concentrations, thorough laboratory and field testing with the expected site conditions were not possible. Year 1 will be the full vetting of all systems on this platform, after which modifications can be implemented as necessary.

To add the additional parameters beyond those supplied by the Sea-Bird CTD endcap, several customizations were made. The CTD itself was modified by Sea-Bird to handle an extended conductivity range from 0 to 14 S/m. Additional parameters were handled

FIGURE 7

Technical drawings for the McLane Laboratories (a) PPS, (b) RAS, and (c) ITP with additional sensors.



by affixing sensors to the center of the profiler housing (Figure 7c). To measure *in situ* CO_2 concentration across the full depth range of the lake, two Pro-Oceanus (Bridgewater, Nova Scotia, Canada) Mini-Pro CO_2 sensors, each with a different configured measurement range (ELB: 0–2000 and 0–20,000 ppm; WLB: 0–2000 and 0–200,000 ppm), were added to each ITP. Finally, to directly observe vertical distribution of phytoplankton and their photosynthetic condition through time, a BBE-Moldanke (Schwentinental, Germany) Fluoroprobe was also added and wired into the ITP control system. The Fluoroprobe differentiates between pigments associated with cyanobacteria, green algae, diatoms, and cryptophytes using different excitation wavelengths. All sensors are powered and controlled by the central ITP. At the start of each profile, the ITP initiates independent logging on the CO_2 and Fluoroprobe sensors at their maximum sampling frequency (0.5 and 0.25 Hz, respectively). The sensors continuously sample at this rate until the profile is completed. The ITP data acquisition firmware then downloads the collected data from each sensor and stores it. All other parameters, including the CTD, dissolved oxygen (DO), and PAR, are sampled at 1 Hz, and data were recorded directly to the ITP's central storage.

PPS

The McLane Laboratories PPS is an autonomous sampler designed to filter and collect suspended particulates from the water column (Figures 6c and 7a). A pump and valve mechanism pushes a user-configurable volume of water across a filter, up to 10 L or until a minimum pumping rate threshold is reached. In contrast to the RAS, the PPS can collect only 24 samples. Each of the 24 filters is stored in an individually numbered filter chamber. The filtering schedule was distributed evenly through the year at 18-day intervals with the exception of three overlapping sample events for replicate sample validation (Table 2).

In order to achieve an accurate snapshot of the microbial communities filtered at each sampling, it is necessary to fix the filtered samples immediately upon collection. Therefore, custom filter chambers with reservoirs (Taylor et al., 2013) (Figure 6d) were used to hold the preservative sucrose lysis buffer (SLB) until sample collection. The filter chambers were designed to be used with preservative such as glutaraldehyde, but because some preservative escapes the filter units into the lake and environmental preservation is of primary importance in the Dry Valleys, we chose to use SLB, which is nontoxic and is a superior preservative when used to preserve DNA for sequencing (Mitchell & Takacs-Vesbach, 2008). Because the filter chambers were designed to use a preservative less dense than the surrounding water and SLB density is greater than the lake water, the PPS was deployed upside down with the preservative reservoirs above the filters (Figure 6c). The intake hose from the PPS was run downward to meet the intake from the water sampler so that both intakes were at the same depth.

Challenges of Limnological Research in the McMurdo Dry Valleys

The permanently ice-covered lakes of the McMurdo Dry Valleys allow for year-round, under-ice limnological monitoring. However, mooring instruments on a constantly changing ice surface present certain obstacles.

We have learned to contend with ice ablation, strong valley winds, sediment laden ice covers, and 4 months of total darkness.

A certain level of expertise and awareness has been built around how to operate and deploy equipment in this environment. Such experiences are rarely communicated, and researchers must often reinvent the wheel. Here, we detail the methods we employ in the field that are unique to limnological research in the McMurdo Dry Valleys. The issues we highlight below are included so that the reader may benefit from the lessons we have learned in working in these extreme systems.

Logistics

Transport of gear and personnel is a significant challenge when working in the Dry Valleys. To get to the Dry Valleys, all gear and personnel must travel from the U.S. to New Zealand by boat or plane, then to McMurdo base by plane, and finally, to the Dry Valleys via helicopter. Antarctica is known for storms, and what is planned as a quick journey can stretch out for days. For equipment, lead times are long, requiring that most gear leave the U.S. 2–3 months before fieldwork begins. For items like lithium-ion batteries, which cannot be flown on commercial aircraft, purchasing and shipping (by boat) also begins many months before deployment. In 2013, these logistics were further complicated by the U.S. federal government shutdown. While our departure was only delayed by 6 days, the impact on overall polar program logistics was substantial. We were notified that our project was *not* canceled 3 days before we were to depart, one of our team received her flight tickets less than 24 hours before her flight, and we arrived in McMurdo before the majority of our equipment.

Once on the Antarctic continent, there are additional challenges associated with working in such a remote location. While proper preplanning is a must, good communications and internet access in the field can be especially helpful when unforeseen circumstances arise. The field camps in the Dry Valleys have intermittent internet access, but unfortunately in 2013, Lake Bonney field camp could not be set up with a connection. This limited our communications with the outside world to Iridium satellite phones, severely curtailing communication with equipment manufacturers and our ability to adapt to unexpected situations and conditions.

Ice Drilling and Melting

The cold, thick ice of the dry valley lakes is difficult to drill through and is made more difficult by sediment entrained in the ice cover. Any sediment blown onto the lake melts part of the way down through the ice and is trapped in the middle of the ice where it can remain for years. To penetrate the 3- to 5-m ice cover, drilling and melting through ice represent a significant time investment. To drill, mixed-gas, Jiffy Model 30 Ice Drills (Sheboygan Falls, WI) are used for their simplicity and reliability in cold temperatures. In many of the lakes, high concentrations of sediment are present between 1- and 3-m depths in the ice cover (Fritsen & Priscu, 1999). When drilling this ice, new or freshly sharpened blades, even for drilling a single hole, are essential (Figures 8a and 8b).

Depending on the task, it is often necessary to further enlarge the drill holes, which are typically 5–10 inches (13–25 cm) in diameter. This procedure is common for melting out cables frozen into the lake ice or deploying large instruments. In the Dry Valleys, enlarging the ice holes is commonly carried out with Hotsy Model 500 diesel-fueled industrial power washers (Camas, WA). These instruments are modified to circulate heated ethylene glycol through a closed loop (Figure 8c). A custom-made stainless steel or copper coil is part of the loop and is placed in the starter hole to transfer heat into the water.

Enlarging ice holes becomes increasingly difficult when ice temperatures rise. As the ice becomes isothermal and water becomes saturated, added heat is quickly dissipated by the water. However, fuel efficiency in heating the glycol loop increases with air temperature. Therefore, melting is most efficient in late October and November, when air temperatures are slightly below 0°C.

Wind and Ice Ablation

Katabatic winds are common to the McMurdo Dry Valleys and can reach speeds of 70 km/h (Nylen et al., 2004). With no windbreaks on the surface of the lakes, instrumentation must be installed to withstand this force. Unfortunately, ice ablation creates a constantly changing rough surface, which makes permanent moorings impossible. Wood is one of the few materials that will sit on the surface of ice without melting in. The disadvantage of this excellent thermal insulator is that it can prevent ice from ablating beneath it, which can lead to instrument pallets sitting on tables of ice. When a platform is elevated or tilted due to ablation, high winds can flip the platform (Figure 8d), potentially damaging power systems and instrumentation. We continue to struggle with long-term solutions to this

FIGURE 8

Challenges and strategies of working on Dry Valley lakes. (a) Sediment laden ice debris from drilling in a Dry Valleys lake and (b) dulled auger blades after drilling part of a hole. (c) A Hotsy is used to melt out sensor cables for servicing, and (d) ablation tipped and wind flipped this sensor platform during the winter of 2013.

problem, although we are experimenting with guy lines frozen into the ice.

Corrosion

The saline lakes in the Dry Valleys are strongly corrosive environments (Green & Lyons, 2009). While the near-surface waters are close to fresh water (Spigel & Priscu, 1998) having recently come from glacial meltwater, the salinity in bottom waters creates a challenging environment. Existing instrumentation has primarily been deployed near surface and tends to suffer little from corrosion, but new instrumentation is being deployed in deeper waters, so care has to be taken to prevent unmanageable corrosion. All metal-on-metal connections were electrically isolated to minimize electrochemical oxidation. When possible, instrument housings of titanium or 316 stainless steel (over the more easily corroded 304 stainless) were selected. When not available or prohibitively expensive, galvanized steel was used.

Inductive Communications

The McLane ITP includes an inductive modem provided by Sea-Bird to provide active communication and data retrieval after deployment. Unfortunately, the bandwidth available through our Iridium-based telemetry system is not sufficient for year-round communication with the ITP. The data will be manually downloaded from the internal ITP logs each year. Despite this, we intended to use the inductive modem while physically in the field to verify the operation of the ITP after deployment. Unfortunately, after our initial tests, we were unable to reliably communicate with the ITP via inductive communications. Despite a great deal of testing and experimentation, we were unable to find a definitive cause. The most popular theory revolves around the extremely strong potential gradient from the surface to bottom of the lake caused by the strong salinity and dissolved gas gradient (described above). The top water ground was located in the near-fresh surface waters, while the other end made contact in the highly reducing and saline bottom waters. This gradient set up a potential of almost 0.5 V between the surface and bottom-water contacts of the inductive loop, preventing inductive communication. To use this method in the future, alternative connections to the lake water should be employed.

Density Gradients

Beyond corrosion issues, working in an environment with such a strong gradient in ionic concentration poses buoyancy challenges for profiling floats despite tethering. The density of water near the surface, which is freshwater at about 0°C, is c. 1,000 kg/m^3, while the saline bottom waters are 1,200 and 1,141 kg/m^3 in the west and east lobes, respectively (calculated from 2012 data using equations in Spigel & Priscu, 1998). For devices that displace a significant volume, their weight in water can change drastically across the depth profile.

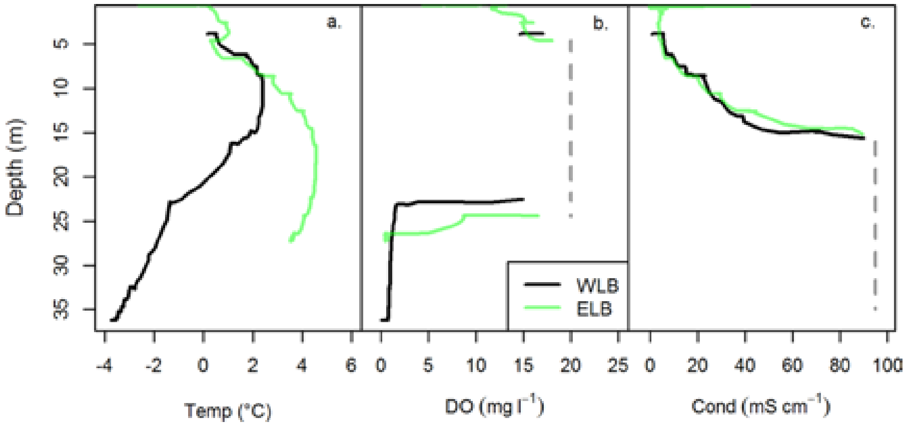
For instrumentation that must operate within a certain buoyancy range, this environment can be particularly challenging. Because the ITPs work best when they are neutrally buoyant across the full-depth range, the density gradient in Lake Bonney restricted the effective profiling range. We are currently collaborating with the engineers at McLane Laboratories to retrofit our deployed ITP systems to improve their ability to overcome density gradients.

Extreme Values

Water temperature is the most moderate of environmental conditions in the Dry Valley lakes, hovering around 0°C most of the year (Figure 9a), although it varies from approximately −5°C to 5°C throughout the water

FIGURE 9

Preliminary profiles from manual ITP runs. Dashed gray line indicates out-of-range data.



column. Dissolved gas levels and salinities, on the other hand, are quite extreme for inland waters. For example, most lakes have DO concentrations near or below 100% saturation (Hanson et al., 2007), and inland waters tend to be fresh, with a few notable exceptions in endorheic basins (Hammer, 1986). Observed values fall far beyond even typical marine values (average of c. 35 mS/cm; Kaye & Laby, 1995), causing issues with sensors tuned for such environments. In our deployment, both DO and conductivity proved problematic. Observations of DO using chemical techniques can reach as high as 47 mg/L. The standard ITP sensor range is 120% of air-equilibrated saturation, which, for 0°C freshwater, is around 18 mg/L. This out-of-range cutoff can be seen in Figure 9b. Conductivity measurements were also challenged by extreme values (Figure 9c), although the root cause is less clear as the sensor was configured for an extended range. We are working with manufacturers to address these issues for the 2014–2015 field season.

Conclusions

Conducting research in the McMurdo Dry Valleys is challenging. Rapidly improving instrumentation is providing new techniques to understand these extreme systems. The deployment of such equipment is nontrivial, and continued work is needed to realize its full potential. We have presented our experiences and recommendations for using instrumentation in Dry Valley lakes and encourage others to do the same. Only with open collaboration and discussion between scientists and engineers working and specializing in polar research will rapid progress be made toward easily deployable systems that will aid researchers in understanding the extreme environments of our planet.

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