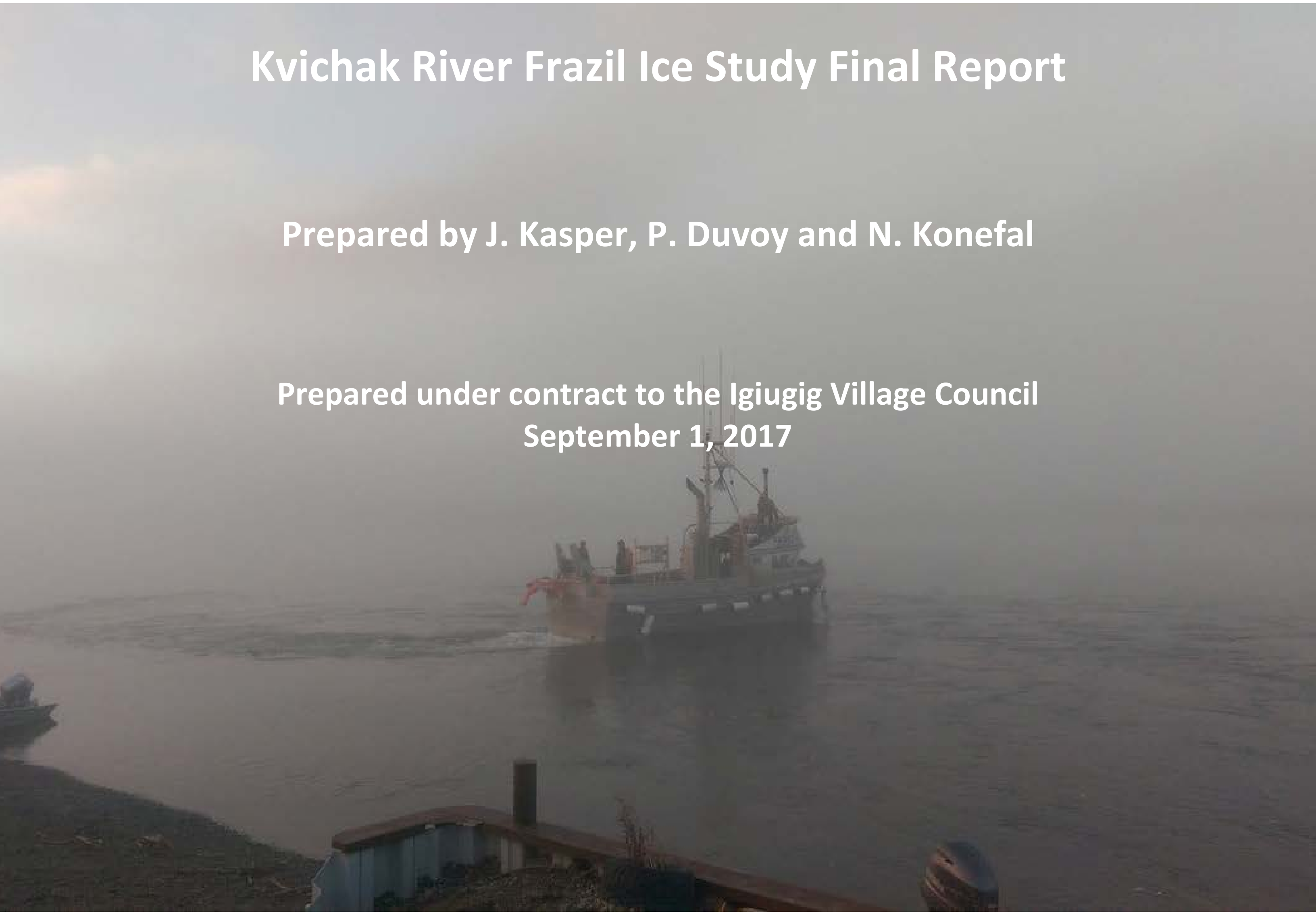
Kvichak River Frazil Ice Study Final Report

Prepared by J. Kasper, P. Duvoy and N. Konefal

Prepared under contract to the Igiugig Village Council
September 1, 2017



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1 Table of Contents

2 List of Figures

3 List of Tables

4 Summary

The University of Alaska Fairbanks (UAF) Alaska Hydrokinetic Energy Research Center was tasked with developing a real-time data telemetry / remote power generation system to monitor frazil ice conditions in the Kvichak River in support of the U.S. Department of Energy funded “Next Generation MHK River Power System Optimized for Performance, Durability and Survivability” project. A real-time telemetry system was requested because of the short time span between the end of the frazil ice season when the instruments would be recovered, limited vessel availability and the project end-date.

To meet the project objectives, UAF designed and assembled a remote power/real-time data telemetry system that included an auto start propane generator, a small PV array, a small battery bank and line-of-sight radios as well as two sonar systems to monitor river velocity and water column acoustic backscatter strength. Both sonars included internal batteries for powering the instruments in case of failure of the shore based power system. The sonars, deployed in ~5 m of water on the bed of the Kvichak River, adjacent to the Village of Igiugig, Alaska were tethered to shore via a waterproof armored cable that conveyed power to the subsurface instruments and data from the instruments to the shore based telemetry system. The instruments were programmed to record data internally as well as to transmit data serially over the cables to the shore based system.

The system was in-place between November, 2016 and June, 2017. While the real-time data telemetry system was not successful and the remote power generation power system was only partially successful, the system design included sufficient redundant power in the form of internal instrument batteries to enable the collection of nearly three months of overlapping velocity and backscatter data (from November through February) and a record of acoustic backscatter strength spanning the entire ~150 day frazil ice season between November, 2016 and ~April, 2017.

The acoustic Doppler current profiler (ADCP) ceased recording data during a site visit in February during which communication to the ADCP was lost when personnel on-site were midway through re-programming the ADCP after the failure of the shore based remote power system. Based on battery bank voltages and ambient temperatures recorded by an on-site data logger, the remote power system functioned until mid-February just prior to the arrival of UAF personnel on-site, when very cold air temperatures (< -30 ^{o}C) caused the battery bank voltage to drop. An accumulation of ice from an icing event earlier in the deployment appeared to interfere with the generators ability to self-start and thus the generator was unable to recharge the battery bank. In addition, solar panels at the site were iced over and solar insolation was insufficient to clear the panels and/or deliver sufficient power to recharge the battery bank. While the generator was able to be restarted, UAF personnel on-site were not equipped to deal with the frozen batteries.

The results of the monitoring are summarized as follows: briefly, the sonars captured multiple time periods when frazil ice was present at the deployment site. Frazil was detected at the site beginning in early December when water temperatures first dipped below -0.1 deg. C. There is a ~2 week period in the record (from ~1/7/2017-1/22/2017) when frazil ice was continuously detected. Outside of this two week period, frazil is intermittently present. Later in the season, in late February, there appears to be enough solar gain during the day to warm water temperatures above the cutoff for frazil (~-0.2 deg. C) and there is a distinct diurnal signal in the backscatter and water temperature records. While the sonars are unable to definitively identify the presence of frazil ice, the increase in acoustic backscatter strength is correlated with periods when super cooled water was present at the site (temperatures below zero degrees Celsius). Both the ADCP and the Shallow Water Ice Profiler (SWIP) record water temperature. Note that video or physical sampling would be required confirm that the increase in acoustic backscatter is indeed frazil as well as to determine the accumulation rates of frazil on any submerged infrastructure to determine the risk frazil poses to hydrokinetic energy converters in this environment.

5 Monitoring Frazil Ice in the Kvichak River

5.1 Methods

5.1.1 River bed mooring, remote power / data telemetry system

A bottom mounted mooring was deployed on the bed of the Kvichak River from a ~10 m Bristol Bay fishing vessel, the F/V EG on November, 4, 2016 and recovered on June 24, 2017. The mooring was located at 59.32493 N, 155.91515 W (Figure 1). The shore based remote power / real-time data telemetry system was located on the river bank immediately adjacent to the mooring (Figure 1).

Figure 1. Location of Power System, Mooring, Igiugig School, ILC Office.

The mooring is shown in Figure 3. The ORPC owned ASL Shallow Water Ice Profiler (SWIP) is the rectangular, aluminum case on the side of the orange fiberglass mooring frame. The transducers of both the SWIP and the ADCP were 0.5 m above the bed. The University of Alaska (UAF) owned 1200 kHz Teledyne RD Sentinel acoustic Doppler current profiler (ADCP) used in the study is visible in the center of the frame. UAF provided the fiberglass Sea Spider mooring frame for this project. Figure 2 is a picture of the mooring when it was deployed in the Kvichak River. The image was taken from a drone equipped with a camera.

Figure 2. A picture of the remote power / data telemetry system and the mooring taken from a drone in May, 2017. The mooring location is circled in red. Floating ice is visible in the image flowing downstream.

Figure 3 . UAF personnel with the ADCP and SWIP mounted on an orange fiberglass "Sea Spider" frame. The instruments ready for loading on the F/V EG in Igiugig in November, 2016.

The remote power /real-time data telemetry is described in detail in Appendix B through D. Briefly, it consisted mainly of equipment that UAF already owned, including a 2,500W LP remote start generator, 2-80W solar panels, a 12V, 416A battery bank, power conditioning electronics and protection. The real-time data telemetry system consisted of a shore-based unit on the Kvichak River bank (a UAF owned 900 MHz Zlink Xtreme transmit radio and power electronics) and a local unit initially located at the Iliamna Lake Contractor's (ILC) office in Igiugig (a 900 Mhz Zlink Xtreme radio configured as a receiver). A laptop computer synced to a cloud based, Google drive and configured with a remote management application was meant to receive the data and then provide remote access to the laptop to researchers at UAF. The on-shore unit was meant to transfer data from the riverbank to the ILC office using a 900 Mhz line-of-site radio. Initial efforts in November 2016 to establish communication between the shore based transmit radio and the receive radio failed.

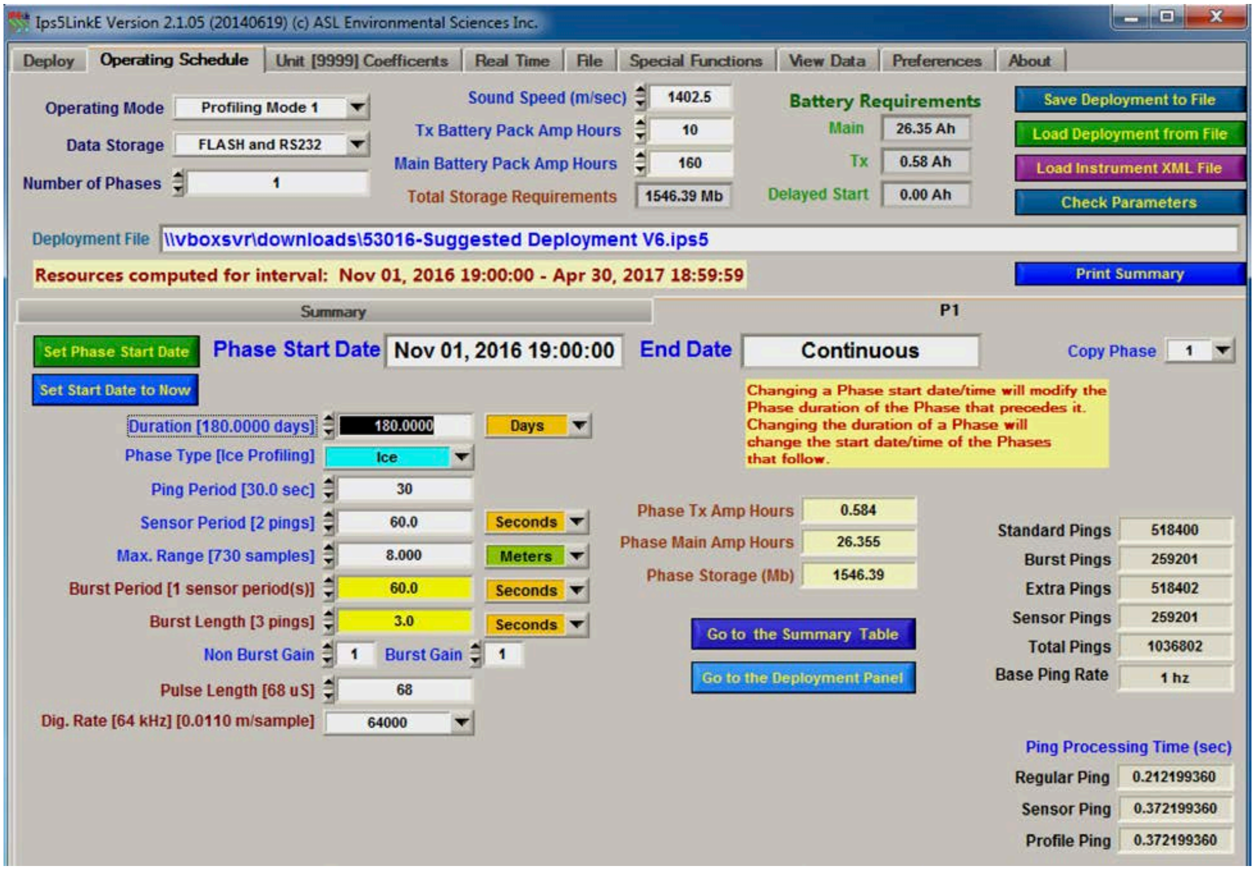
Between November and February, UAF purchased a Moxa NPort IA5450AI-T 4-port serial server and a Digi Xpress XEB09-CIPA 900 MHz Wireless Ethernet bridge with high gain antennae, to increase data throughput. UAF then assembled and tested a weather proof, protected, power electronics system that incorporated these two additional pieces of hardware. The Moxa serial server was meant to allow the Ethernet bridge to transfer data from both the ADCP and the SWIP over its wireless link. (The original system was not capable of transferring data from both sensors since it lacked the hardware required to host and aggregate data streams from the multiple serial devices on site, the ADCP, SWIP and Campbell Scientific datalogger.) The system was tested in Fairbanks with a second Teledyne ADCP and Campbell data logger and it performed well. Data was meant to be received at the Igiugig School with a second-high gain antenna and Ethernet bridge and stored on a laptop computer attached to the local network. Data would then be accessed and downloaded from any location with a network connection. The Igiugig School was chosen because it was closer to the river bank site than the ILC office, it was located on higher ground and there were fewer obstructions between the school and the telemetry system than between the telemetry system and the ILC office.

UAF personnel traveled to Igiugig in February, 2017 but before they were able to put the new system in place, they discovered that the power system had failed several days prior to their arrival.

5.2 Sampling Schemes

The SWIP was configured for 1 ping every 30 seconds; then 1 burst of 3 pings, 1 second each one. Each ping had 730 samples corresponding to 8 meters depth (Figure 4). This sampling scheme was developed by UAF with assistance from ASL. The SWIP ceases collecting data when its memory is full, thus the duty cycle was dictated by available memory (2 GB), predicted battery life and frazil ice behavior (ASL, pers. comm., 2016).

The ADCP was configured for 1 ping every 15 seconds where every ping was comprised of 23 depth cells of 0.25 m from 0.8 m to 6.30 m depth (Figure 5). Similar to the SWIP, the ADCP’s sampling was dictated by available memory (4 GB) and predicted battery life. Note, UAF utilized 1- Teledyne RD alkaline battery pack and 2-Lithium battery packs purchased for a completed project (but that were never used). The Lithium batteries were housed in an external battery case and the Alkaline battery pack was utilized as the internal battery. External lithium batteries were necessary to enable the ADCP to collect data for the full length of the anticipated ~6 month deployment.



Ips5LinkE Version 2.1.05 (20140619) (c) ASL Environmental Sciences Inc.

Operating Mode: Profiling Mode 1
Data Storage: FLASH and RS232
Number of Phases: 1
Sound Speed (m/sec): 1402.5
Tx Battery Pack Amp Hours: 10
Main Battery Pack Amp Hours: 160
Total Storage Requirements: 1546.39 Mb

Battery Requirements
Main: 26.35 Ah
Tx: 0.58 Ah
Delayed Start: 0.00 Ah

Deployment File: \\vboxsvr\downloads\53016-Suggested Deployment V6.ips5

Resources computed for interval: Nov 01, 2016 19:00:00 - Apr 30, 2017 18:59:59

Phase Start Date: Nov 01, 2016 19:00:00
End Date: Continuous
Copy Phase: 1

Changing a Phase start date/time will modify the Phase duration of the Phase that precedes it. Changing the duration of a Phase will change the start date/time of the Phases that follow.

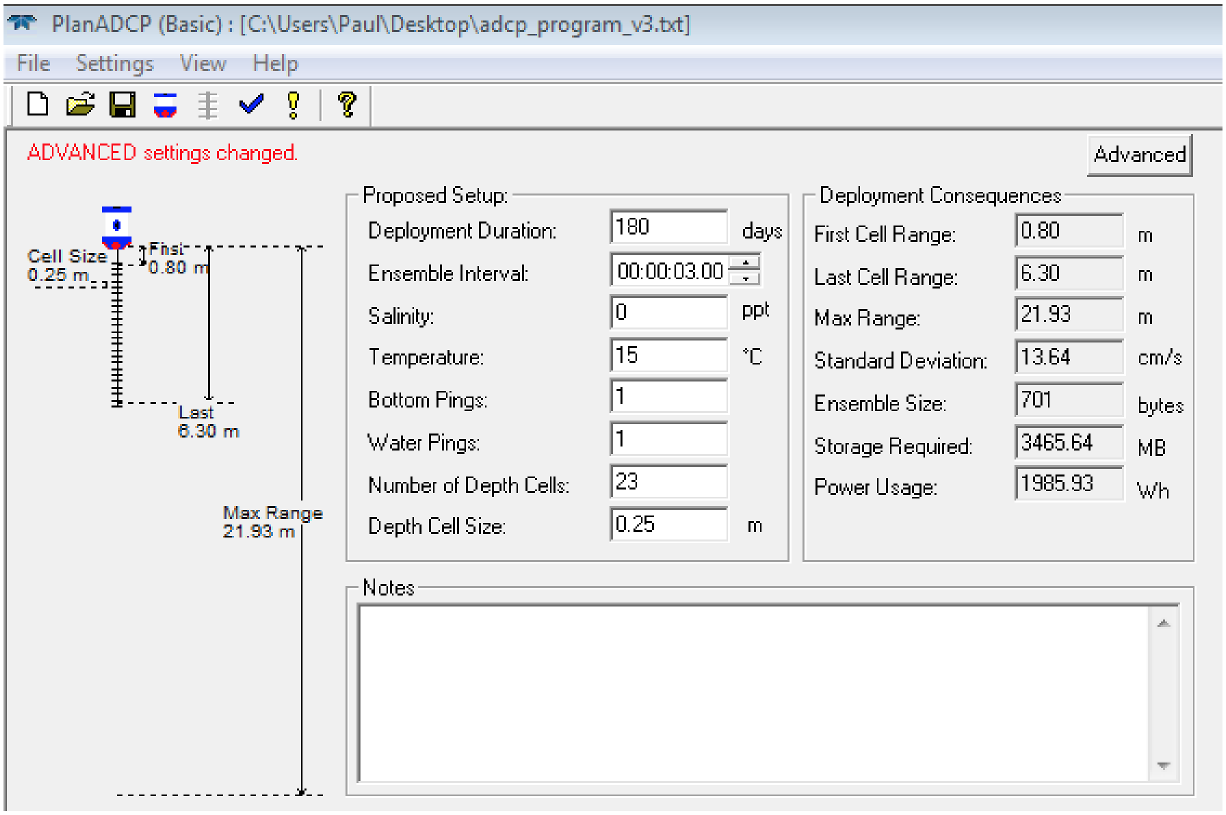
Duration [180.0000 days]: 180.0000 Days
Phase Type [Ice Profiling]: Ice
Ping Period [30.0 sec]: 30
Sensor Period [2 pings]: 60.0 Seconds
Max. Range [730 samples]: 8.000 Meters
Burst Period [1 sensor period(s)]: 60.0 Seconds
Burst Length [3 pings]: 3.0 Seconds
Non Burst Gain: 1
Burst Gain: 1
Pulse Length [68 uS]: 68
Dig. Rate [64 kHz] [0.0110 m/sample]: 64000

Phase Tx Amp Hours: 0.584
Phase Main Amp Hours: 26.355
Phase Storage (Mb): 1546.39

Standard Pings: 518400
Burst Pings: 259201
Extra Pings: 518402
Sensor Pings: 259201
Total Pings: 1036802
Base Ping Rate: 1 hz

Ping Processing Time (sec)
Regular Ping: 0.212199360
Sensor Ping: 0.372199360
Profile Ping: 0.372199360

Figure 4. Screenshot of SWIP Sampling Configuration.



PlanADCP (Basic) : [C:\Users\Paul\Desktop\adcp_program_v3.txt]

ADVANCED settings changed.

Proposed Setup:

Deployment Duration:	180	days
Ensemble Interval:	00:00:03.00	
Salinity:	0	ppt
Temperature:	15	°C
Bottom Pings:	1	
Water Pings:	1	
Number of Depth Cells:	23	
Depth Cell Size:	0.25	m

Deployment Consequences

First Cell Range:	0.80	m
Last Cell Range:	6.30	m
Max Range:	21.93	m
Standard Deviation:	13.64	cm/s
Ensemble Size:	701	bytes
Storage Required:	3465.64	MB
Power Usage:	1985.93	Wh

Figure 5. Screenshot of ADCP Sampling Configuration.

The SWIP records acoustic backscatter strength in counts. The SWIP used for this study is owned by ORPC and was used by UAF in a previous study in the Tanana River (J. Schmid, R. Tyler, pers. comm.). The conversion of the sonar signal from analog to digital and the characteristics of the SWIP's A/D board means the count scale ranges from 0 to 65536.

5.3 Results

5.3.1 Shallow Water Ice Profiler

Upon retrieval of the full data set from the SWIP's internal memory card in June, 2017, the SWIP data was converted to a Matlab compatible format using ASL's IPS5 software program. The data were then analyzed and plotted using Matlab routines developed by UAF.

Plots of acoustic backscatter strength measured in counts by the SWIP through time by month are shown in the following figures. Plots of temperature recorded by the SWIP for the same time periods are included as well.

In the following plots, acoustic backscatter strength measured by the SWIP is presented as color contours through time (x-axis) versus distance from the transducer (y-axis). The surface of the water is marked by high backscatter counts, exceeding 60,000 counts at a distance of ~5 m from the transducer. This is because the water-air as well as the water-ice interfaces strongly reflect the acoustic signals from the SWIP and the ADCP. This change in the location of the strong surface reflection is at least in part due to presence of ice at the surface over the mooring as well as the seasonally declining water levels. Note, the water depth begins at 5 m and drops to ~3.75 m at the end of the deployment in April. Average water depth over at the mooring during the deployment was 4.55 m while the max water depth was 5.3 m and the minimum depth was 3.6 m.

Early in the record when the water temperature is above freezing, periods of increased backscatter are attributed to turbulence (and air bubbles entrained at the surface by this turbulence) as well as by the resuspension of particles from the bed (e.g. Figure 6). Beginning in December (Figure 7), intermittent periods when frazil ice is present are marked by an increase in backscatter in the water column when the water temperature is below zero degrees Celsius. Frazil is present at the site beginning in early December through late January. In late January when water temperatures increase to greater than ~-0.2 deg. C, frazil is nearly absent until ambient temperatures drop again in mid-February (2/10-2/13 and 2/19-2/22).

Beginning in late February, there is a diurnal signal (day-night) in both the temperature and backscatter data (i.e. frazil ice presence). When the water temperature dips below zero beginning in December, the slight daytime warming is apparently enough to lead to a decrease in frazil ice. Note, that when the water temperature is low enough (-0.2 ^{O}C), this diurnal variation does not lead to a decrease in frazil (Figure 8); there is a ~2 week period during January, 2017 when the water temperature is low enough that frazil is present through the entire 2-week period. Just after this period, there is a thickening of the area of strong surface reflection indicating the presence of thickening surface ice cover (ADCP “bottom track” data corroborates this interpretation). The surface ice cover thickness abruptly changes on 1/26/2017.

The diurnal temperature/backscatter signal is especially prominent beginning in February (Figure 9) when day-time warming of the water due to solar insolation leads to periodic variations in the presence and concentration of frazil ice.

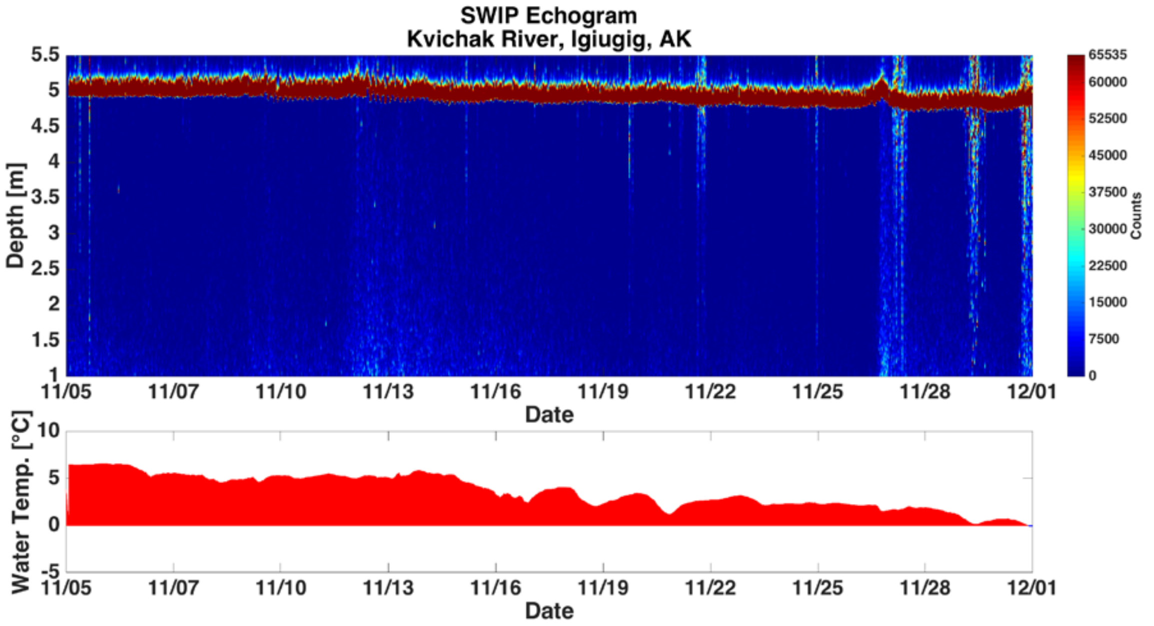


Figure 6. Top: acoustic backscatter strength in counts (color) through time versus distance from the SWIP transducer (y-axis) and Bottom: water temperature (degrees Celsius) for the period from 11/05/2016-12/01/2016.

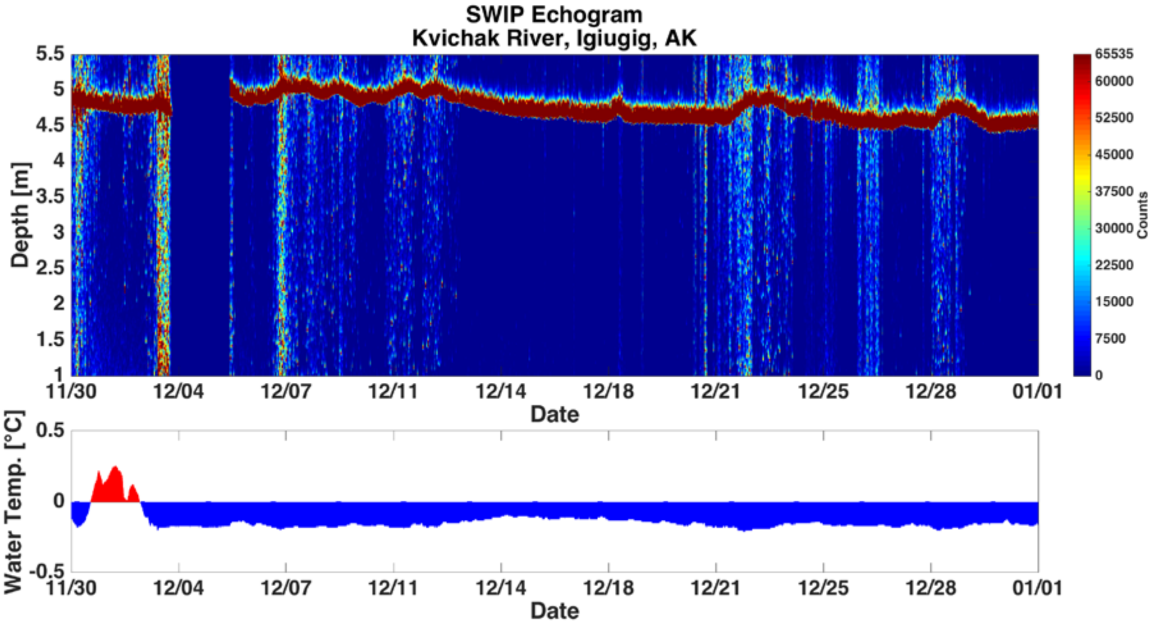


Figure 7. Top: acoustic backscatter strength in counts (color) through time versus distance from the SWIP transducer (y-axis) and Bottom: water temperature (degrees Celsius) for the period from 11/30/2016-01/01/2017.

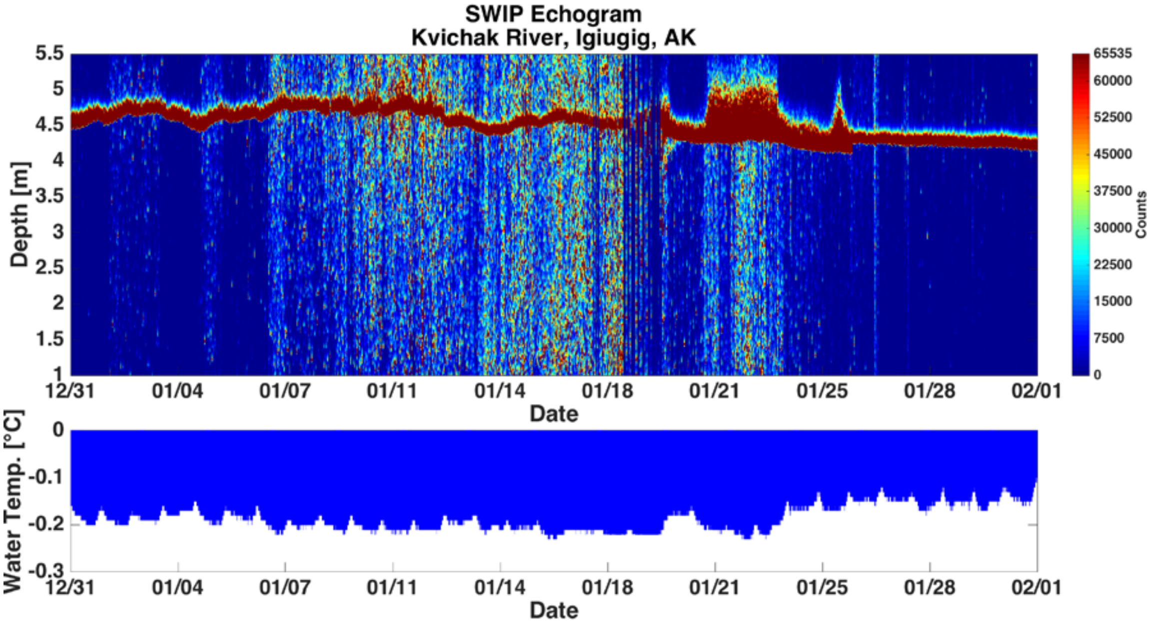


Figure 8. Top: acoustic backscatter strength in counts (color) through time versus distance from the SWIP transducer (y-axis) and Bottom: water temperature (degrees Celsius) for the period from 12/31/2016-02/01/2017.

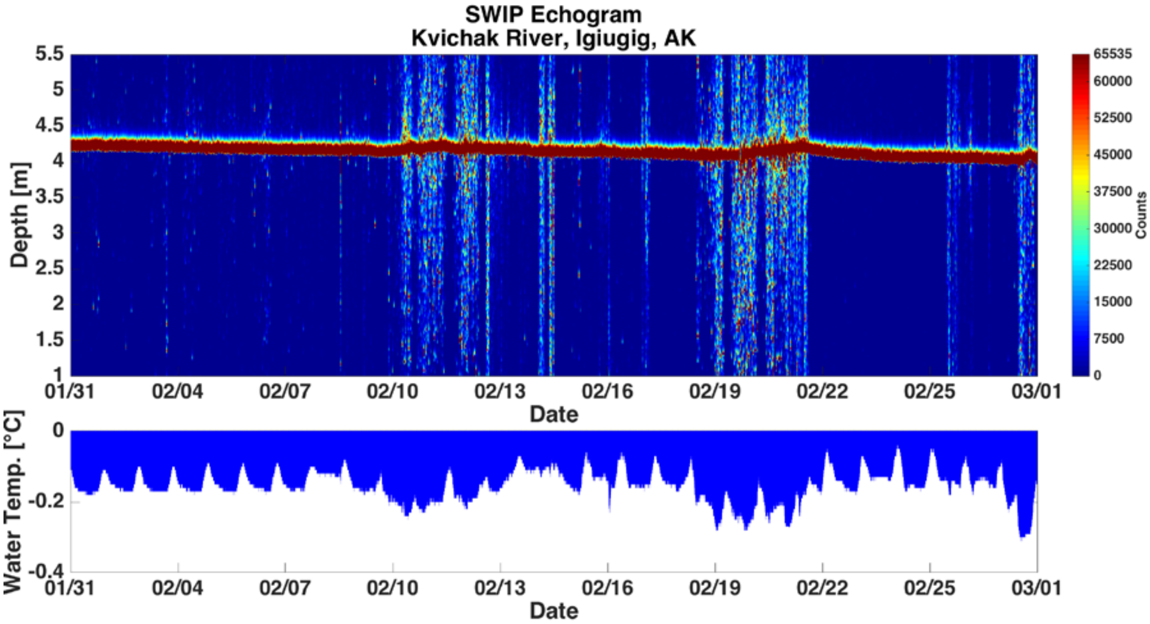


Figure 9. Top: acoustic backscatter strength in counts (color) through time versus distance from the SWIP transducer (y-axis) and Bottom: water temperature (degrees Celsius) for the period from 01/31/2016-03/01/2017.

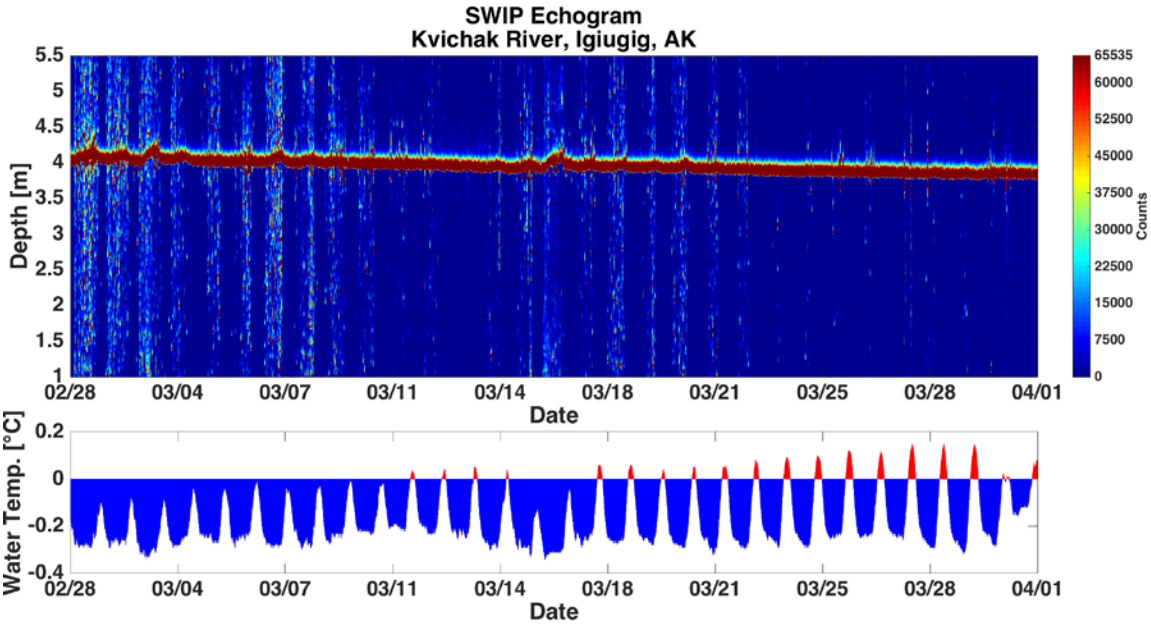


Figure 10. Top: acoustic backscatter strength in counts (color) through time versus distance from the SWIP transducer (y-axis) and Bottom: water temperature (degrees Celsius) for the period from 02/28/2017-04/01/2017.

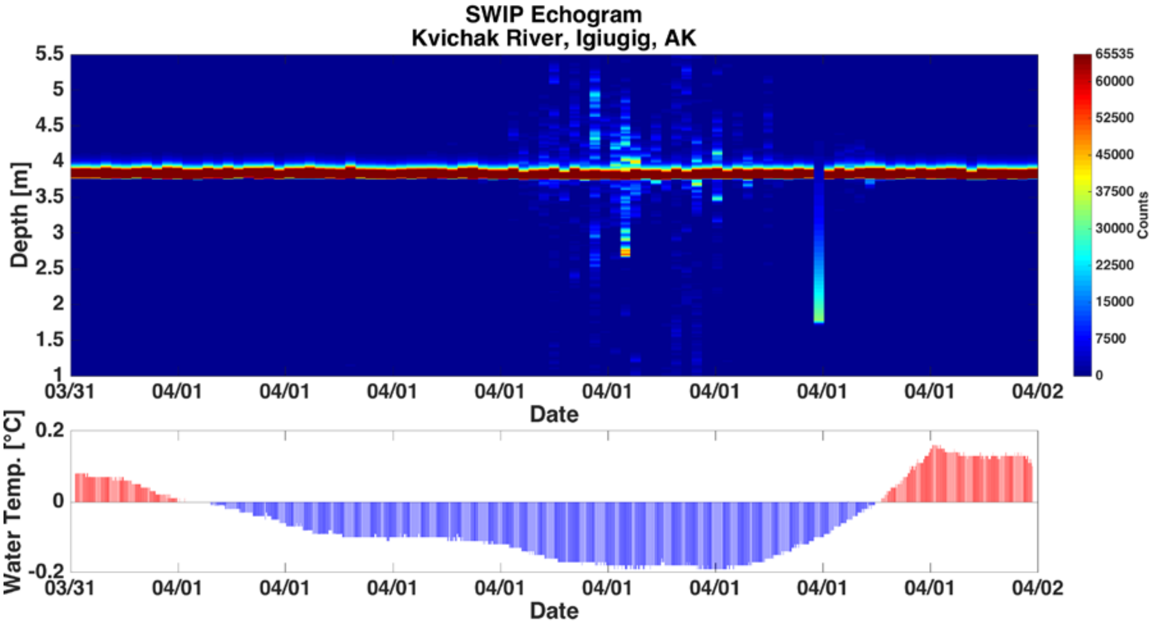


Figure 11. Top: acoustic backscatter strength in counts (color) through time versus distance from the SWIP transducer (y-axis) and Bottom: water temperature (degrees Celsius) for the period from 03/31/2017-04/02/2017.

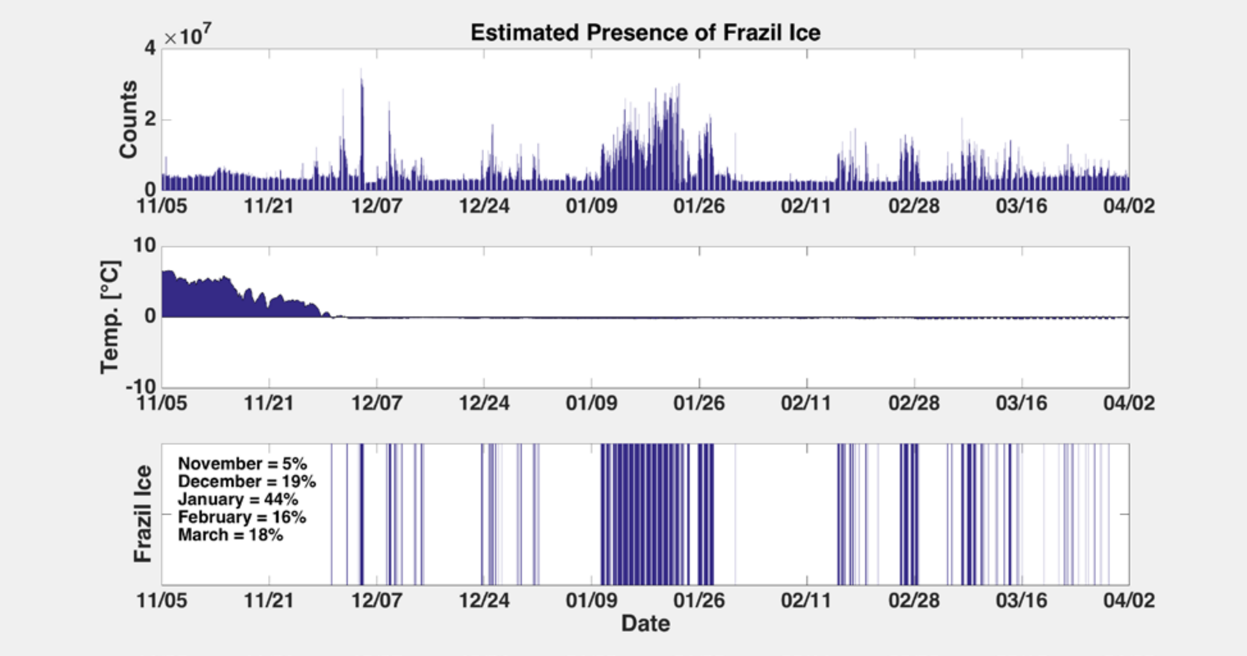


Figure 12. Summary of the presence/absence of frazil ice based on the SWIP measurements.

Figure 12 summarizes the presence of frazil ice over the deployment period based on the SWIP backscatter count and water temperature. Frazil is considered to be present at the site when water temperatures are below zero degrees Celsius and when the backscatter count exceeds the mean of the backscatter. Frazil was present for 5% of November, 19% of December, 44% of January, 16% of February and 18% of March (a total of 20% of the 6 month record).

5.3.2 Acoustic Doppler Current Profiler

Data from the acoustic Doppler current profiler is shown in Figure 13 through Figure 15 and described briefly here. At the beginning of the record the southward velocity is ~3 m/s and decreases to ~2 m/s in the latter part of the record. Vertical velocities at the site are smaller and average to ~0 m/s. Velocity at the deepest bin (1.5 m above the bottom averaged 1.24 m/s (191 deg. from North, T). At 3.5 m above the bottom (the shallowest bin for which there is a continuous record), the velocity averaged 1.4 m/s (184 T). The average vertically averaged velocity for the length of the ADCP record is 1.36 m/s (186 T). The vertically averaged velocity including the magnitude of the velocity are shown in Figure 14.

The ADCP was configured to measure the surface ice velocity using the bottom track feature. Ice velocities are only reported where the error velocity magnitude was less than 0.5 m/s. When error velocities exceed this threshold, it is unlikely that the ADCP is reporting valid velocities. Ice velocities during the period when the ADCP returned valid returns (late January through mid-February) was ~1.5 m/s. Based on the standard deviation of the velocity (Figure 5), ice velocities below 0.136 m/s are indistinguishable from zero and the ice is considered immobile. The ADCP returned valid ice velocities for 333 hours (13 days) during the deployment. There was immobile, anchor ice over the mooring for ~37 hours (~1.5 days). The presence of this immobile anchor (shorefast) ice over the mooring was intermittent and on average lasted for 22 seconds and the longest time that anchor ice was over the mooring was 20 minutes.

The ADCP also records acoustic backscatter strength (Figure 15). Additionally, we calculated the magnitude of the turbulent kinetic energy at a depth of 1.5 m. The water depth above the mooring drops throughout the ADCP record as does the magnitude of the velocity and TKE consistent with the trend towards decreasing water levels above the ADCP.

Surface ice thickness as measured by the SWIP for the period where the ADCP returned valid ice velocities are shown in Figure 15.

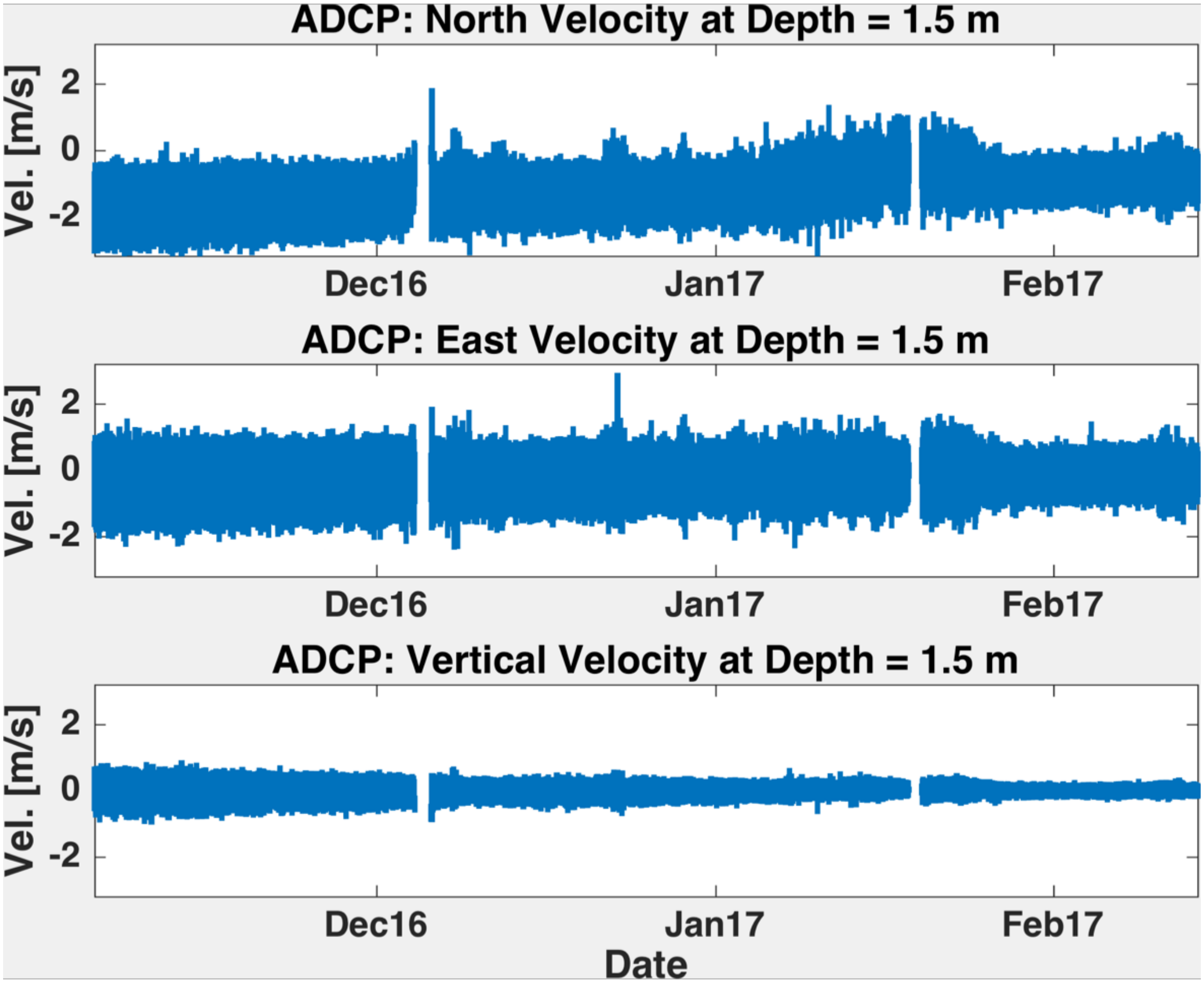


Figure 13. Water Velocity from the ADCP.

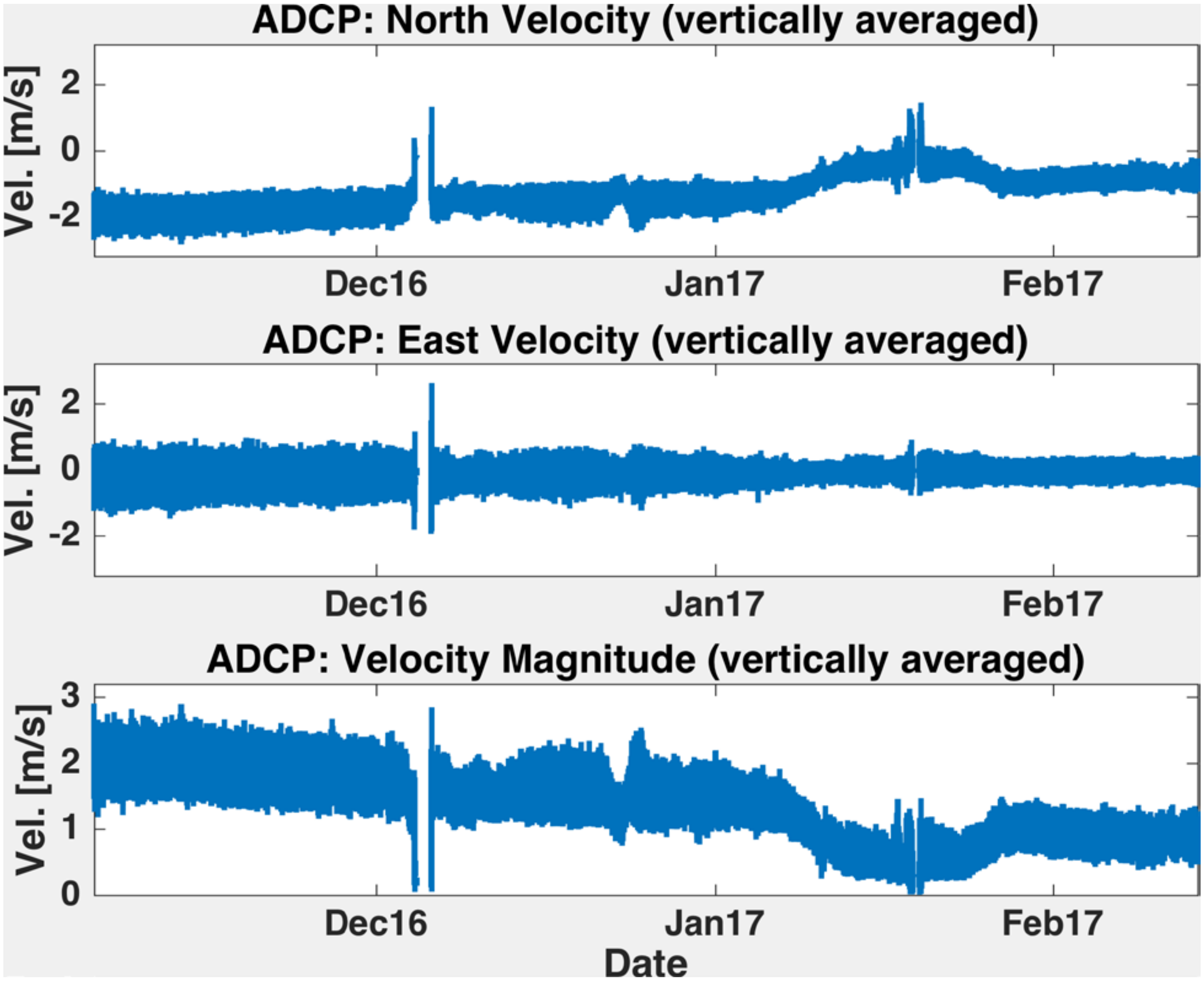


Figure 14. Vertically averaged velocities from the ADCP.

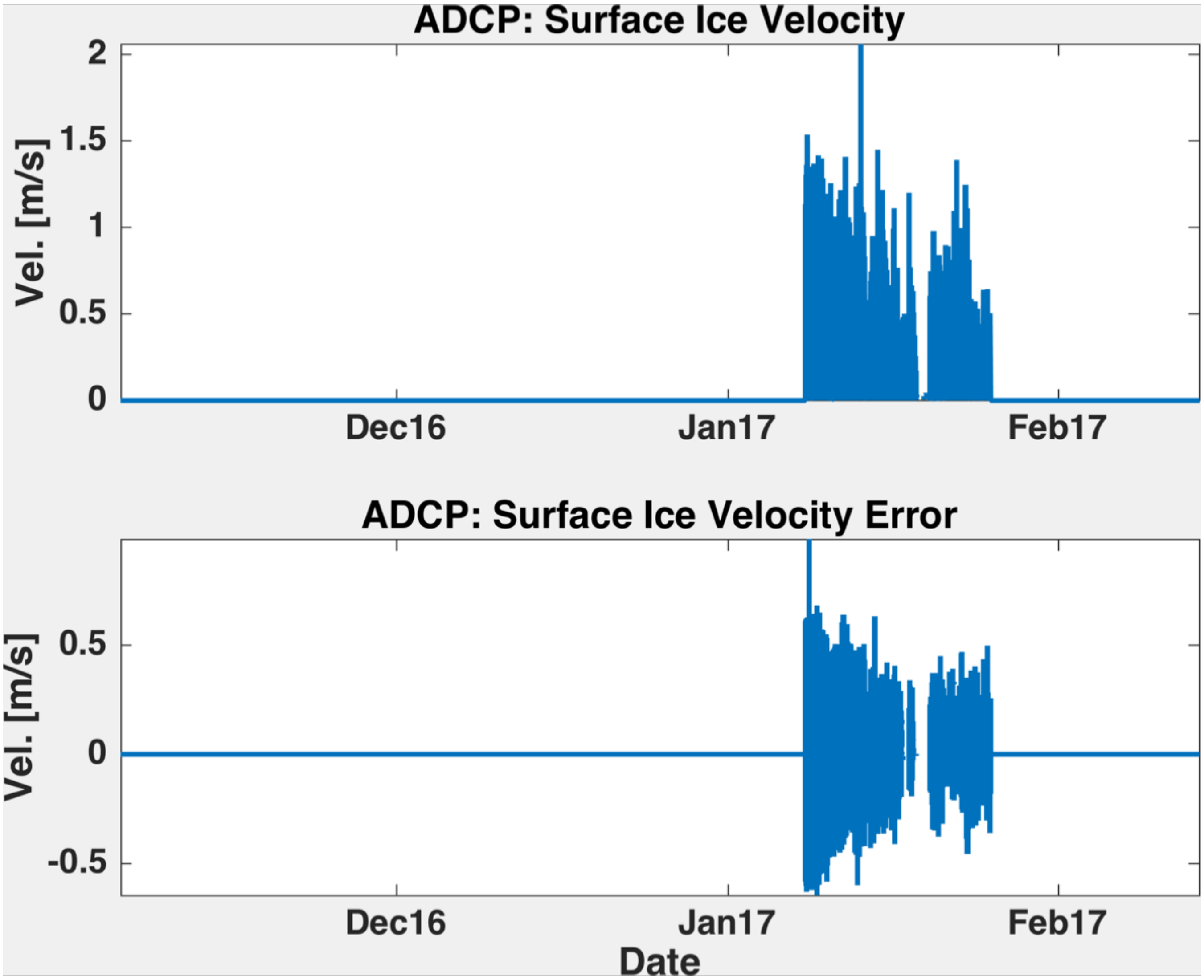


Figure 15. Surface Ice Velocity (top) from the ADCP Bottom Track and (Bottom) Bottom Track Error Velocity.

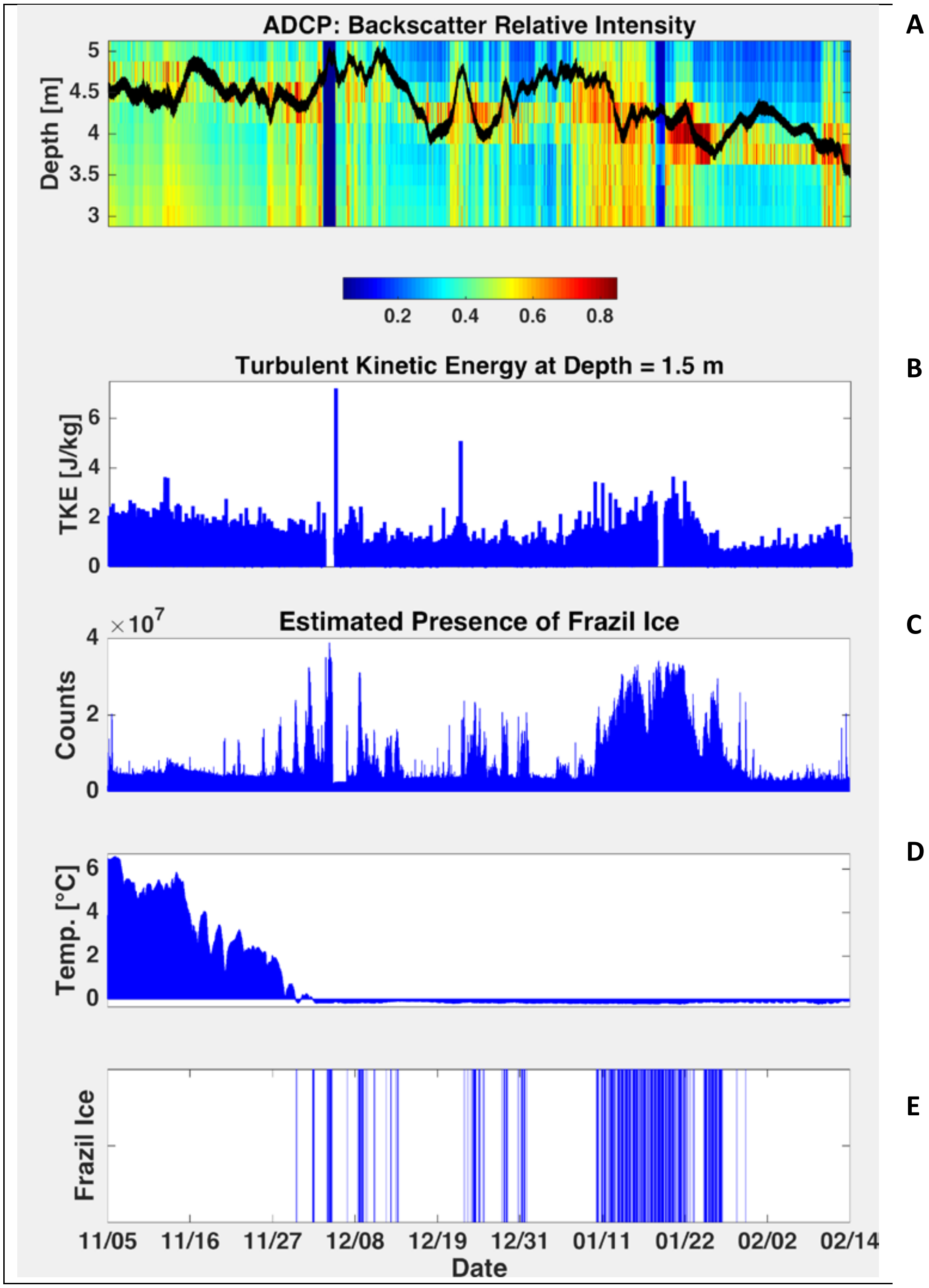


Figure 16. ***A)*** *Acoustic backscatter and* ***B)*** *turbulent kinetic energy from the ADCP.* ***C)*** *Frazil ice;* ***D)*** *Water temperature and* ***E)*** *presence of frazil ice from the SWIP. The distance to the surface based on the ADCP pressure record is shown in figure* ***A*** *as a black line.*

5.3.3 Power System

An onsite data logger (a UAF-owned Campbell CR6) recorded ambient temperature and battery bank voltage at the remote power system. Battery bank voltages are shown in Figure 17 while ambient temperatures logged by the CR6 are shown in Figure 18. Note the logger only measured temperatures through mid-February after which, the logger and power system were not operational.

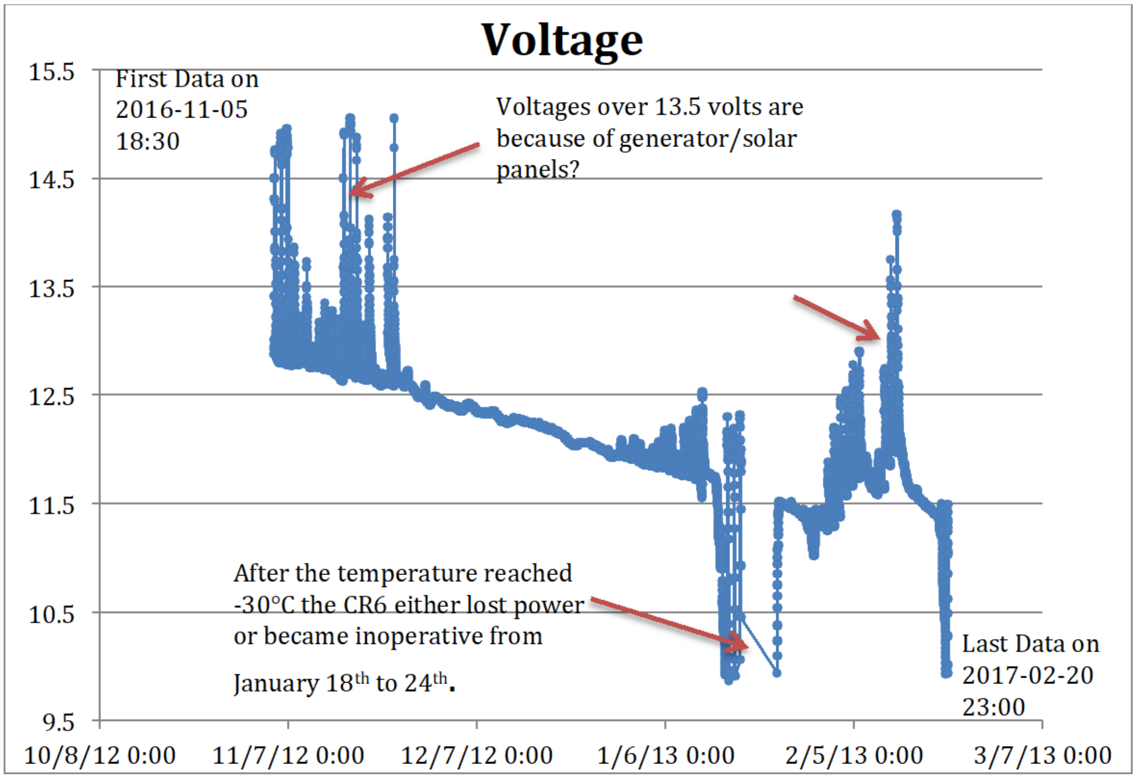


Figure 17. Battery Bank Voltage (V, y-axis) versus time (x-axis) recorded by the data logger.

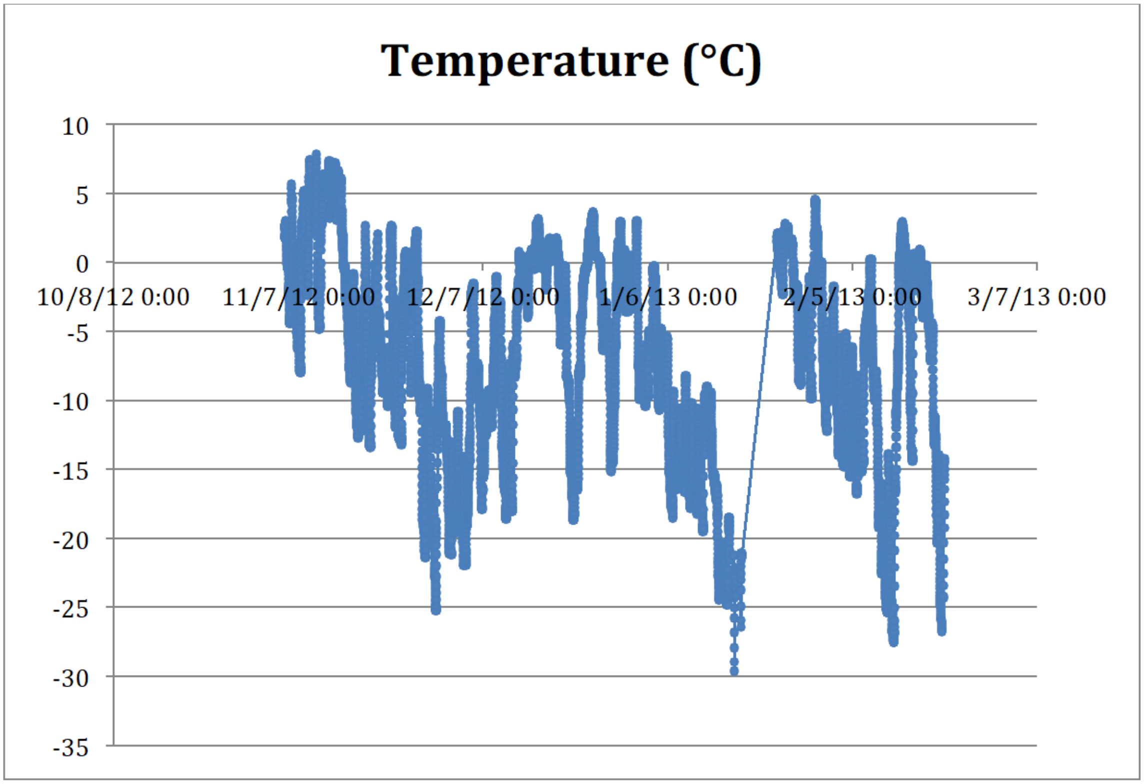


Figure 18. Ambient temperature (deg. C, y-axis) versus time (x-axis) recorded by the datalogger.

The battery bank voltage time series shows that the generator failed to start when required; the voltage set point for the generator to start was 11.5VDC and the battery bank was not depleted to that voltage until 1/15/2017 (72 days into the deployment). The contribution of solar early in the deployment before the dark days of December resulted in the battery bank voltage staying above the generator start voltage. Solar contribution was zero from 11/24-12/29/2016 possibly due to solar panel icing. When the battery bank voltage reached the generator start voltage for the first time it was accompanied by temperatures reaching -30°C as shown in Figure 18. This resulted in the generator not starting and battery bank voltage dropping under 10VDC. This was followed by three days of minimal solar contributions and then five days of the voltage being too low for the data logger to continue to operate (1/19-1/23/2017). On January 24, 2017 after temperatures rose above freezing, the battery bank voltage appeared to recover--most likely due to the solar panels--and the battery bank voltage settled at ~11.5VDC. Although this was the generator start voltage, the generator failed to start. After another warm temperature day of +5°C on 1/30/2017, the voltage increased again. It is assumed that the warm temperatures at this point allowed solar panels to de-ice and battery to resume charging. Solar charging continued from 1/30-2/11/2017 before another cold snap most likely caused icing on the solar panels and damage to the batteries that prevented charging. After 2/11/2017, battery voltage continued to decline until another cold snap was encountered on 2/19/2017 that put the power system fully out of commission.

5.4 Summary and Conclusions

Two acoustic instruments, an ASL Shallow Water Ice Profiler and a Teledyne RD Instruments 1200 kHz Workhorse acoustic Doppler current profiler provide a ~6 month record between Nov. 2016 and April 2017 of acoustic backscatter and water temperature from the Kvichak River adjacent to the Village of Igiugig. The temperature and backscatter data indicate frazil ice was present at the site beginning in December. The final episode of super cooled water and frazil ice was recorded in late March, 2017. Water temperatures in January were low enough that there is a ~2 week period when frazil ice was present at the site continuously (and throughout the water column). Beginning in late January, day-night variations in water temperature lead to decreased frazil during the warmer days. Frazil is present during 20% of the 6-month record.

Water velocities (and water level) at the site gradually declined over the deployment period to minimums in mid-February, 2017 at which time the ADCP stopped logging data. Turbulent kinetic energy at the site also declined throughout the deployment along with the seasonal changes in water velocities and water level. While the real-time data telemetry and remote power systems were not entirely successful, the overall data return from the instruments on the river bed was quite good and the instruments provided a robust record of conditions at the site during the periods when frazil was expected to be present.

6 Acknowledgements

Funding for this project was provided by the U.S. Department of Energy through the Igiugig Village Council. Additional funding for this project came from University of Alaska Fairbanks, Alaska Center for Energy and Power. This work would not have been possible without the support of the Igiugig Village Council and the residents of the Village of Igiugig. We also appreciate ORPC’s understanding of the challenges faced while working in remote Alaska communities

7 Appendix A: IVC River Ice Study Plan

Prepared by Dr. J. Kasper, Mr. N. Konefal and Mr. A. Cannavo, University of Alaska Fairbanks for ORPC, Inc.
October 11, 2016

As part of the US Department of Energy (DOE) funded Igiugig Village Council (IVC)-led project, the University of Alaska Fairbanks (UAF) will perform a study of over winter ice conditions in the Kvichak River at Igiugig, Alaska. UAF will deploy a mooring equipped with sensors to measure water column and surface ice velocities (a 1200 kHZ Teledyne RDI Workhorse Sentinel Acoustic Doppler Current Profiler) as well water column frazil ice and surface ice thickness (an ASL Environmental Sciences, Inc. Shallow Water Ice Profiler, or SWIP, owned by ORPC, Inc.). These sensors will be deployed by the first week of November 2016 and will be retrieved in May 2017.

1. Instrumentation:

The sensors will be mounted on an Ocean Science, Inc. “sea spider” fiberglass tripod and deployed on the river bottom in ~16 ft of water facing upwards. The instruments will be deployed near the location shown in Figure 19. The ADCP transmits sound at 1.2 MHz while the SWIP transmits a sound pulse at 542 kHz. The instruments and frame are shown in Figure 20.

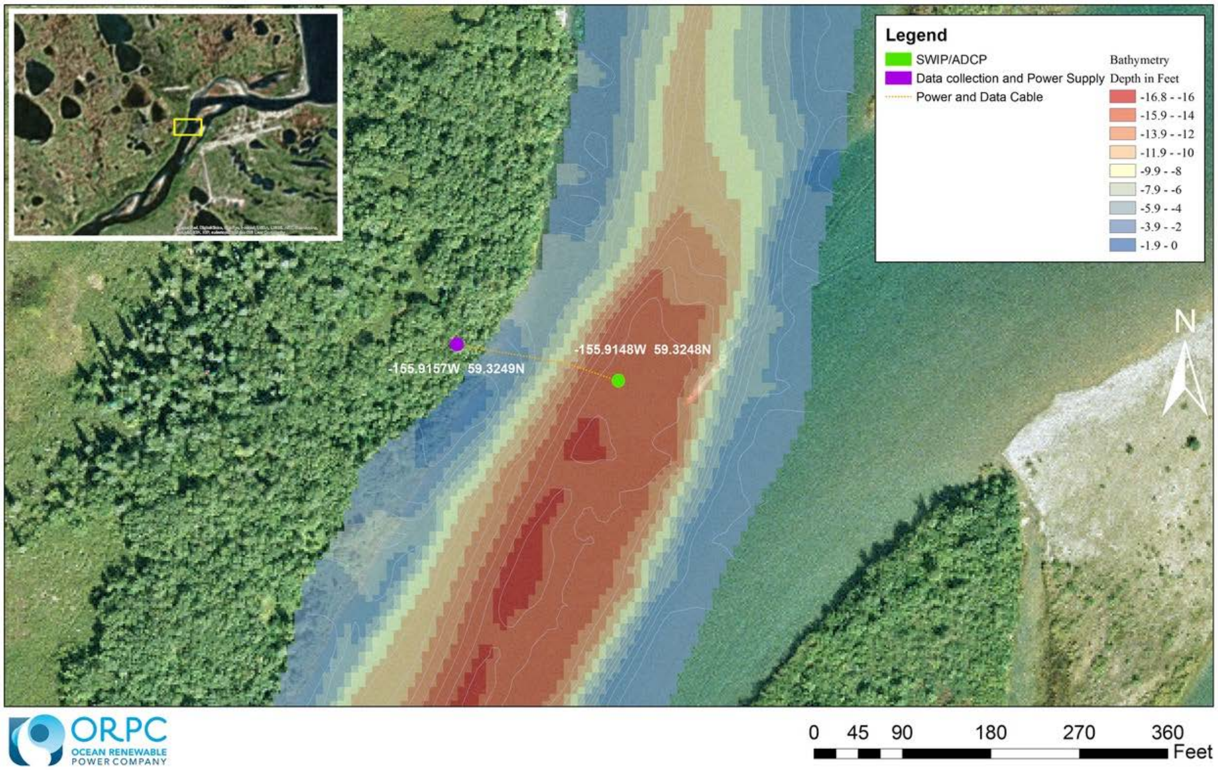


Figure 19 Map of SWIP/ADCP deployment in Igiugig on the Kvichak River.

The ADCP will be programmed to sample continuously at the maximum sampling rate (~1 Hz with ice tracking on, dependent on the water depth). Single ping data will be collected in beam coordinates and transformed to earth coordinates (N-S, E-W and vertical) during post processing. Collecting single ping data and applying coordinate transformations and ensemble averaging after the fact, allows the most flexibility in collecting and analyzing the data.

Ideally, the SWIP would be configured to burst sample at 1 Hz in profiling mode for 10 minutes at the start of every hour. This sampling rate is subject to change based on the throughput of the radio modem. Data throughput of the system will be verified prior to deployment.

Figure 20. Top Leftt: a TRDI Workhorse Sentinel ADCP. Image courtesy of TRDI, Inc. Top Right: An Ocean Science "sea spider" mooring frame. Bottom: An ASL Environmental Sciences SWIP with extended battery case. The Sea Spider frame will be equipped with 150 lbs of lead weights (50 lbs on each tripod leg) to keep the package moored to the river bed.

2. Data collection and power supply:

The shore based data and communication package will consist of a propane fueled autostart generator and two 80W solar panels with sufficient fuel to power the entire 6 month deployment. Propane is available locally in Igiugig and UAF owns an autostart propane generator. A small battery bank will be installed as well to allow for time to service the power system in case of failure. The power system design was carried out by Mr. Andrew Cannavo, an undergraduate mechanical engineering student from Bucknell University and an intern with UAF from May-August 2016. Mr. Cannavo's report is included as Appendix B. Instrument data, battery bank voltage and generator output will be logged on-site using a Campbell Scientific, Inc. datalogger. Additionally, a radio modem will be used to transmit the data in real time to a laptop computer located inside a nearby IVC facility, ~0.5 miles distant. The laptop will be synced to a cloud service. Data will be available in near real time for quality control, analysis and for monitoring the operation of the instruments. Estimated power usage are shown in Table 1. Estimated power usage for the instrumentation. The ADCP and radio modem are 24V instruments while the SWIP and data logger operate on 12V.. Note solar, wind and hydrokinetic generation were considered as well to power the instrumentation system. However, the solar resource during winter was too small to be economic similarly while the small design loads and variable winds in the region made finding a suitable, cost effective wind turbine for the system problematic. While a small hydrokinetic system was considered, since we have no experience operating commercially available units such as Ampair 100W Water Turbine from ABS Alaska, Inc. we did not consider this a reliable solution.

Table 1. Estimated power usage for the instrumentation. The ADCP and radio modem are 24V instruments while the SWIP and data logger operate on 12V.

Watt Calculation (24V instruments)		
Estimated Watt Demand	18.1	Watt-hrs
Hours expected to run	24	hour/day
Total daily usage	434.4	Watt-hrs/day
Amp-Hour Calculation		
Battery loss correction (static average loss)	443.088	Watt-hrs/day
System Voltage (DC)	24	Volts
Amp-hours per day	18.462	Amp-hrs/day
Watt Calculation (12V instruments)		
Estimated Watt Demand	5	Watt-hrs
Hours expected to run	24	hour/day
Total daily usage	120	Watt-hrs/day
Amp-Hour Calculation		
Battery loss correction (static average loss)	122.4	Watt-hrs/day
System Voltage (DC)	12	Volts
Amp-hours per day	10.2	Amp-hrs/day
Total Amp-Hours per day	28.662	Amp-hrs/day

The number of 20 Amp-hour batteries required for 7 days of power to allow for time to service the system in case of a failure is estimated as 3. Calculations for this are shown in **Error! Reference source not found.**.

Table 2. . Estimate of the number of batteries necessary for backup power.

Battery Bank Calculation		
Approximate backup power required	7	days
Amp-hour storage required	200.634	Amp-hrs
Assume 50% depth of discharge	0.5	
Required Amp backup	401.268	Amp-hrs
20 Hr battery amp rating (needed)	64	fraction
Number of Batteries (parallel)	6.2698125	
Number of Batteries (series)	2	
Rounded number of Batteries Needed	3	

3. In field Operations:

   a) Personnel:

At least two personnel plus a vessel operator will be on site for deploying the instrumentation. All personnel on the vessel deck participating in the deployment will have appropriate safety equipment including safety shoes and personal flotation devices, at a minimum. Before the deployment operation begins on-site personnel will perform a job safety analysis, i.e. they will walk through the deployment in order to identify and mitigate any safety risks.

   b) Deployment Equipment:

The instrument package will be deployed in early November from an IVC chartered vessel (Figure 6). The vessel will be equipped with a davit to aid in safely hoisting the ~200 lb mooring package (~1.2 m x ~1.2 m x ~0.7 m high) over the side of the vessel and for lowering the package to the river bed.

Figure 21. 22 IVC Chartered vessel for deploying the monitoring, package and data and communications packages

c) Operations:

In preparation for deployment the mooring, its cable and chain bundle, and a temporary surface float attached to the deployment line will be laid out on the vessel deck and prepped for deployment. The SWIP cable is reinforced, jacketed and weighted while the RDI ADCP cable is a standard neoprene data and communication cable. Both are equipped with waterproof, impulse-type connectors suitable for long-term underwater deployment. The RDI cable will be jacketed in a nylon sleeve for additional protection. The cable bundle will be wrapped with chain to provide weight as well strain relief.

The Vessel will transit to the deployment location and hold position based on GPS coordinates of the desired deployment location. Once the crew is ready deployment operations will commence by lowering the mooring with its temporary surface float and cable and chain bundle attached to the river bed. Once it has settled into position, the deployment location and time will be recorded using a handheld GPS unit. After the placement of the mooring package on the riverbed, power and data cables bundled with the chain will be run from the vessel to shore. The chain will be connected to a temporary ground anchor where the cable bundle makes landfall. After running the cable to shore, the surface float will be replaced with a large chain link which will be lowered to the riverbed downstream of the mooring package. This line will provide a safe means of dragging for the mooring during recovery if it is not possible to retrieve the mooring using the chain alone.

The data collection and power supply equipment will then be installed on shore and the system will be commissioned, with successful data collection confirmation.

At the conclusion of the study in May 2017, all equipment will be removed including the temporary ground anchor. This primary means to accomplish this will be by retrieving the chain at the shore and using it to pull the mooring from the riverbed and into the vessel.

4. Data Collection and Analysis:

Since the data will be available in near real time, data will be monitored daily to ensure the equipment is operating continuously. Plots of time series of velocity, suspended ice acoustic return strength (in counts), temperature, surface ice draft (calculated as the acoustically measured distance between the ADCP and the water surface minus the height of the water column as measured by the ADCP's pressure sensor) and surface ice velocity will be updated at least monthly. Data will be summarized in the final deployment month so that when the equipment is removed the data analysis will be complete as well. A draft report summarizing the results of the ice study will be delivered to IVC in early June allowing a final version to be complete by June 30, 2017.

8 Appendix B: Design of the shore power system

MEMO

To: Director Jeremy Kasper, AHERC
From: Intern Andrew Cannavo, AHERC
Subject: Design of a system for powering instrumentation for measuring river ice and velocities
Date: 15 July, 2016

Assignment (from Scope of Work):

"As part of the Igiugig Village Council led DOE project to deploy ORPC's Rivgen® hydrokinetic turbine in the Kvichak River near Lake Iliamna, AHERC is funded to complete a frazil ice study of the deployment site. The study requires the deployment of an Acoustic Doppler Current Profile (ADCP), a Shallow Water Ice Profiler (SWIP) and possibly an underwater time lapse camera system. Before deployment of these instruments, the costs associated with deploying the instruments in real time (preferred) versus in autonomous, internally logging mode need to be quantified."

Considerations (from Scope of Work):

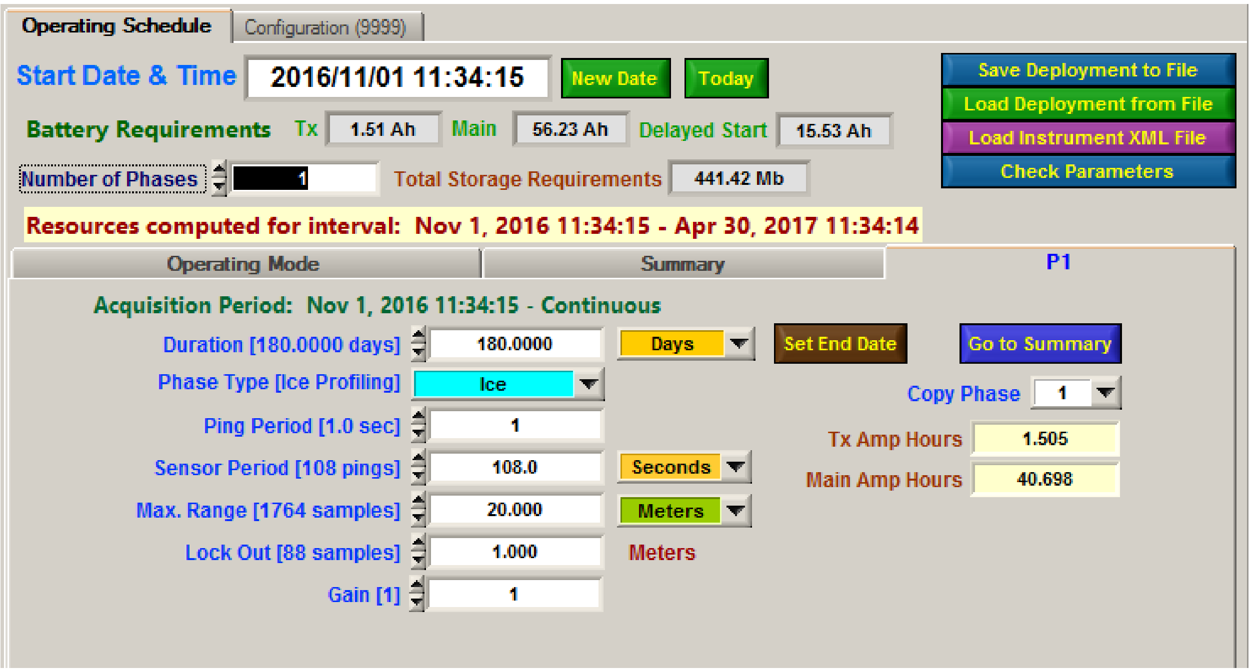
"Deployment in real time mode requires the purchase of a serial cable for conveying power from shore and data transfer from the bottom mounted ADCP to shore. (The SWIP is already equipped with the necessary cabling.) Additionally, the electrical load of each instrument needs to be quantified in order to determine the design of the power system. The electrical load will be determined by the sampling scheme of each instrument. Additionally, real time mode will require the use of a pair of radio modems to transmit data from where the instrument cables make landfall to an IVC owned building 0.5 miles distant from the site."

Scenario 1:

Both the ADCP and SWIP are capable of being deployed with internal data logging and operating in battery powered mode. The period of the study however is long, about 6 months, and being able to support the power and data loads for this length of a period will require the right sampling schemes and external batteries to supplement the internal battery pack of each instrument. While the sampling schemes can be made to fit both requirements of power and data for the intended time period, the amount of data they collect may not be optimal due to the infrequency of measurements.

Shallow Water Ice Profiler:

Using the IPS5Link River software that is used to deploy the SWIP, it was shown that using the standard sampling scheme for the instrument meets both our power and data requirements for a 180 study. It can be seen in Figure 1 that over the 180 day period 441 MB of data will be collected using only 56 amp hours of power. The typical internal battery used to deploy with the SWIP has about 120 amp hours. Of the estimated 56 Ah use, this leaves a considerable margin of unused power. If deploying the SWIP at the start study is done, an additional 15 Ah of power will not be used in delaying the start of data collection, reducing power needs even more.



Start Date & Time 2016/11/01 11:34:15

Battery Requirements Tx 1.51 Ah Main 56.23 Ah Delayed Start 15.53 Ah

Number of Phases 1

Total Storage Requirements 441.42 Mb

Resources computed for interval: Nov 1, 2016 11:34:15 - Apr 30, 2017 11:34:14

Acquisition Period: Nov 1, 2016 11:34:15 - Continuous

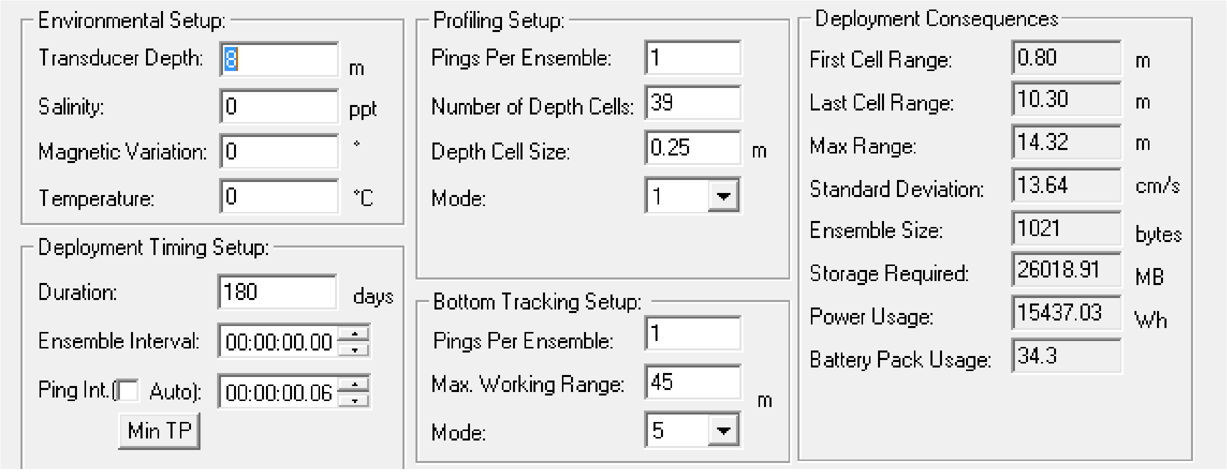
Duration [180.0000 days] 180.0000 Days
Phase Type [Ice Profiling] Ice
Ping Period [1.0 sec] 1
Sensor Period [108 pings] 108.0 Seconds
Max. Range [1764 samples] 20.000 Meters
Lock Out [88 samples] 1.000 Meters
Gain [1] 1

Copy Phase 1
Tx Amp Hours 1.505
Main Amp Hours 40.698

Figure 23. *Example sampling scheme for the SWIP*

Acoustic Doppler Current Profiler:

The software used to program the ADCP for deployment, PlanADCP, allows full user control over the conditions it will see and characteristics necessary for the deployment. For a deployment of six months, the time period of the intended frazil ice study, a measurement of 1 ping at a frequency of 10 Hz will provide more than sufficient data. This amounted to a power usage of about 85 Wh per day and 26 GB of data over the course of the 180 days. Using this amount of data and power means the ADCP could not be deployed internally with the current settings, but for the purpose of the study this frequency of measurements is required. A hybrid between internal and externally driven will have to be created for a successful deployment.



Environmental Setup:

Transducer Depth: 8 m

Salinity: 0 ppt

Magnetic Variation: 0 °

Temperature: 0 °C

Deployment Timing Setup:

Duration: 180 days

Ensemble Interval: 00:00:00.00

Ping Int.(☐ Auto): 00:00:00.06

Profiling Setup:

Pings Per Ensemble: 1

Number of Depth Cells: 39

Depth Cell Size: 0.25 m

Mode: 1

Bottom Tracking Setup:

Pings Per Ensemble: 1

Max. Working Range: 45 m

Mode: 5

Deployment Consequences

First Cell Range: 0.80 m

Last Cell Range: 10.30 m

Max Range: 14.32 m

Standard Deviation: 13.64 cm/s

Ensemble Size: 1021 bytes

Storage Required: 26018.91 MB

Power Usage: 15437.03 Wh

Battery Pack Usage: 34.3

Figure 24. Example sampling scheme for deployment scenario.

Scenario 1 Summary:

While the data collection schemes for the instruments being internally logged are not be ideal for the intention of the study, they do show that it is at least plausible to deploy them for the 180 day period and to be both internally powered and store data. While this would be good for the independence of the study, there are some other considerations. Internally logging the data would mean it would not be accessible until the end of the study. This could mean that if something would to happen that would hinder or stop data collection altogether, it would not be known until the data was retrieved. The potential loss of data is great since it would not be monitored remotely. Remote monitoring of the data could recognize a problem with the data after only a few days and address the issue. The frequency of data required for the purpose of the study is also large, especially for the ADCP. The sampling scheme shown above for the ADCP showed that it was not possible to internally manage the instrument for the course of the 180 day period. Thus, a hybrid plan must be achieved between internally and externally powering the system.

Scenario 2:

Analysis:

In order to deploy this system in real time mode, meaning constant data collection over the designated period of study, there are two main considerations. These being how to power the system during this time period and how to effectively transmit the collected data. Through the use of a power system consisting of a battery bank and some sort of recharge device (i.e. solar array, wind turbine, hydrokinetic turbine, or generator) the instruments can be powered. The use of cabling, Campbell data logger, and radio modem will transmit data from the SWIP and ADCP to shore, couple the data, and then transmit it the half mile from the site through the radio and to an offsite computer.

Power Calculations:

In order to determine the power required to run the instruments and associated system, estimates were made for individual device's consumption based on the maximum possible usage for the radio modem and data logger. The estimates for each instrument were the power each would draw due to a sampling scheme that allowed for maximum data collection. **Error! Reference source not found.** shows the calculated power demands for both the 24 V powered devices (ADCP and radio modem) and the 12 V devices (SWIP and data logger).

Table 3. Power Demand of Instruments

Watt Calculation (24V instruments)		
Estimated Watt Demand	9.37	Watt-hrs
Hours expected to run	24	hour/day
Total daily usage	224.88	Watt-hrs/day
Amp-Hour Calculation		
Battery loss correction (static average loss)	229.3776	Watt-hrs/day
System Voltage (DC)	24	Volts
Amp-hours per day	9.5574	Amp-hrs/day
Watt Calculation (12V instruments)		
Estimated Watt Demand	0.568	Watt-hrs
Hours expected to run	24	hour/day
Total daily usage	13.632	Watt-hrs/day
Amp-Hour Calculation		
Battery loss correction (static average loss)	13.90464	Watt-hrs/day
System Voltage (DC)	12	Volts
Amp-hours per day	1.15872	Amp-hrs/day
Total Amp-Hours per day	10.71612	Amp-hrs/day

While these power requirements are larger estimates for the instruments they are still relatively low in terms of daily usage. Ideally, a renewable device would be able to power the system continuously with a battery bank used as backup power. Taking a look at the number of batteries required for a given number of days of sufficient power (**Error! Reference source not found.**) gives a safe working power allowance for the system in the case something the bank isn't able to be continuously powered.

Table 4. Examining the number of batteries necessary for sufficient power

Battery Bank Calculation		
Approximate backup power required	7	days
Amp-hour storage required	229.37	Amp-hrs
Assume 50% depth of discharge	0.5	
Required Amp backup	458.74	Amp-hrs

20 Hr battery amp rating (needed)	85	fraction
Number of Batteries (parallel)	6	
Number of Batteries (series)	2	
Rounded number of Batteries Needed	3	Series/parallel

Power Recommendations:

Based on power requirements of about 300 W-h/day for the system in question

Battery Bank:

The battery bank will be made up of 8 12V batteries connected in series/parallel to make the bank 24V. It was decided to increase the number of batteries from the calculated 6 (Table 4) to 8 in order to account for the lower power availabilities from the cold temperatures likely to be encountered. This bank is thus made up of 8 batteries connected in series in pairs of 2 to create the 24 V power. These 4 pairs are then connected in parallel to increase the available power of the battery bank to about 400 Ah based on standard 12 V battery ratings (Table 5).

Table 5. Determining the power of the battery bank

Battery Bank Capacity		
Number of 12 V Batteries	8	batteries
Batteries in Series/Parallel configuration	4	pairs
Battery Bank Voltage	24	Volts
Available Power (20 hr)	85	Amp-hrs
Current	4.25	Amps
Current used daily	102	Amp-Hours
Power of Bank	408	Amp-Hours

Solar:

Having two 80W solar panels available, powering the instruments with solar energy is the first thing to examine. These power ratings given by the manufacturer for the panels were from testing of sun conditions at 1 kW/m^2 test conditions. For Igiugig however, these conditions are often unlikely. Because the test period for these instruments occurs in the winter, the limitation for this power option is already cut to about 4 hours of sun per day (Figure 3). Based on preliminary power calculations, this could still provide the necessary power for all the instruments. However, examining the solar irradiance data for the area around Igiugig, found from the National Renewable Energy Lab's NSRDB Data Viewer, the average direct solar irradiance averages to about 2.5 kWh/m^2/day (Figure 26). This translates to only about 1/10 of the available power, 100 W/m^2, that the panels are rated for.

Based on this data it seems that solar will not be an adequate stand-alone power source for the instrumentation required in this system. There is also about 50% cloud cover in the winter time when the study is to be conducted and snow is prevalent. This would require the panels to be swept off if covered, reducing the independence of a solar system even further.

However, since the study is over the course of 6 months, the last half of the study could provide adequate sun to offset the overall power consumption of the system. Since the solar panels and equipment are already available to us they should be incorporated into the power system to be created in order to help offset power needs when the sun increases later in the study. The low power requirements of the devices should make any solar production relatively significant though later in the study. Even at a tenth of the available power production of the panels due to the low solar irradiance, 16W of power for a couple hours a day could provide the required 10W/hr for the instruments. The remaining 6W of power could be used, while minimally, to recharge the battery bank and offset propane use.

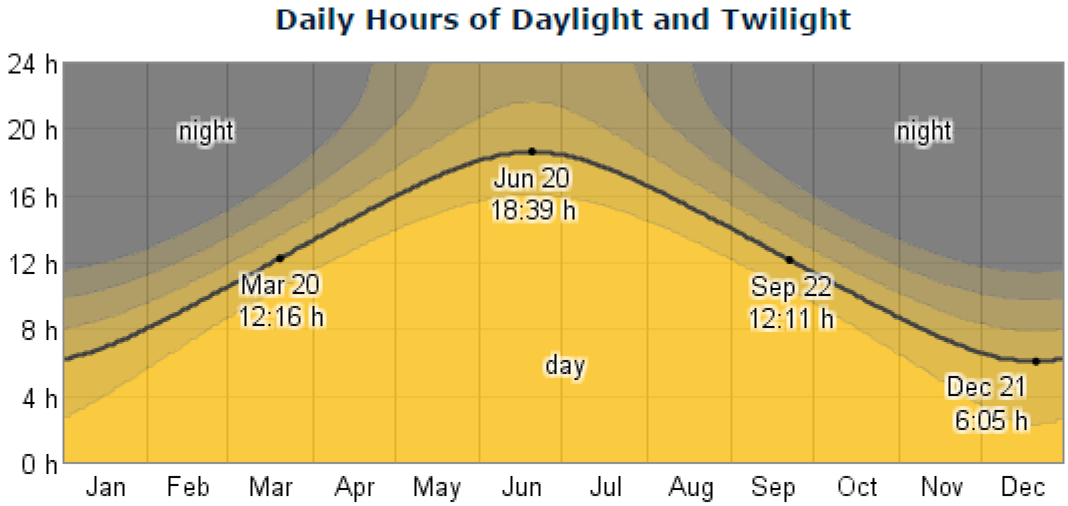
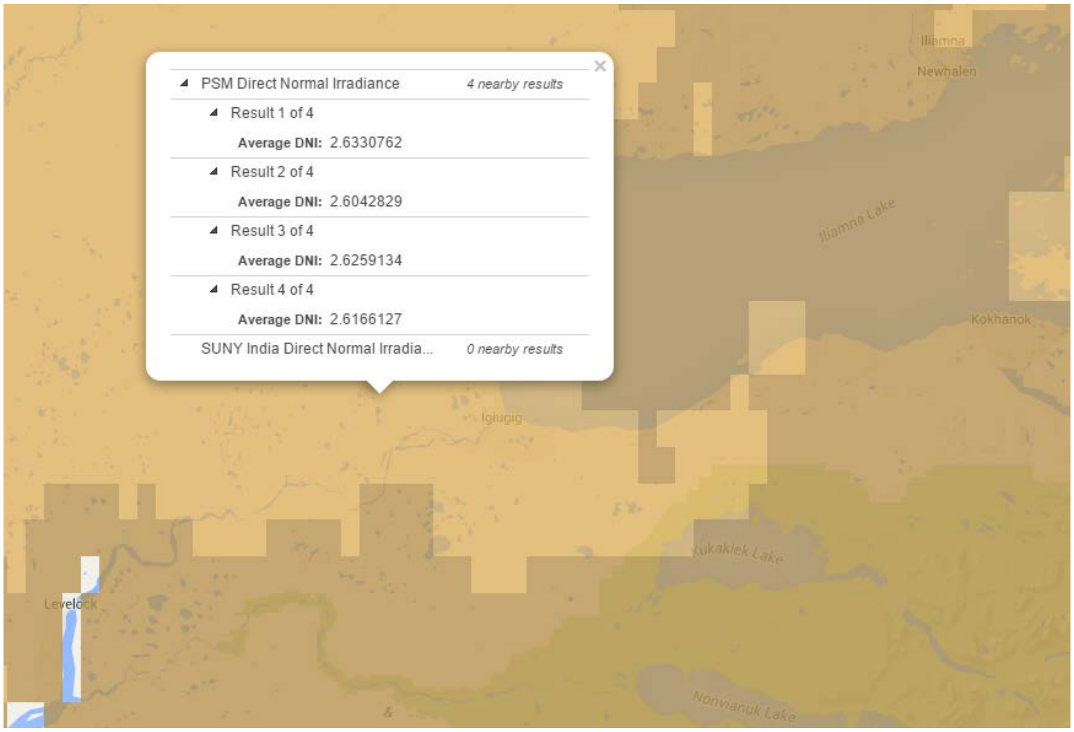


Figure 25. . *(https://weatherspark.com/averages/32974/Igiugig-Alaska-United-States)*



PSM Direct Normal Irradiance *4 nearby results*

Result 1 of 4

Average DNI: 2.6330762

Result 2 of 4

Average DNI: 2.6042829

Result 3 of 4

Average DNI: 2.6259134

Result 4 of 4

Average DNI: 2.6166127

SUNY India Direct Normal Irradia... *0 nearby results*

Figure 26 . *(https://maps.nrel.gov/nsrdb-viewer/)*

Wind:

The winter time is the peak of the year for wind speeds. Igiugig sees its highest average wind speeds at this time when the study is to be conducted. As seen in Figure 5, the average daily wind speed is about 10 mph, with a range from 2 – 17 mph during the winter months. With this large range of wind speeds a turbine with a low cut in speed would be required to ensure reliable power throughout the range of velocities. Not already having a turbine that fits these requirements would mean one would have to be purchased and installed. One such turbine that fits these requirements is the Bergey XL 1, offered from Remote Power Inc; it has a cut in speed of 5.6 mph and a power rating of about 1300 Watts. The price of the turbine itself is about $4,250 not including the cost of the tower or installation costs. For the purpose of this study, these costs seem high and unnecessary expenses to complete it effectively.

Given the high cost of having to buy new equipment to power the system and the general unreliability of wind, using it as an effective resource to meet the power needs of the system during the course of the study seem unlikely.

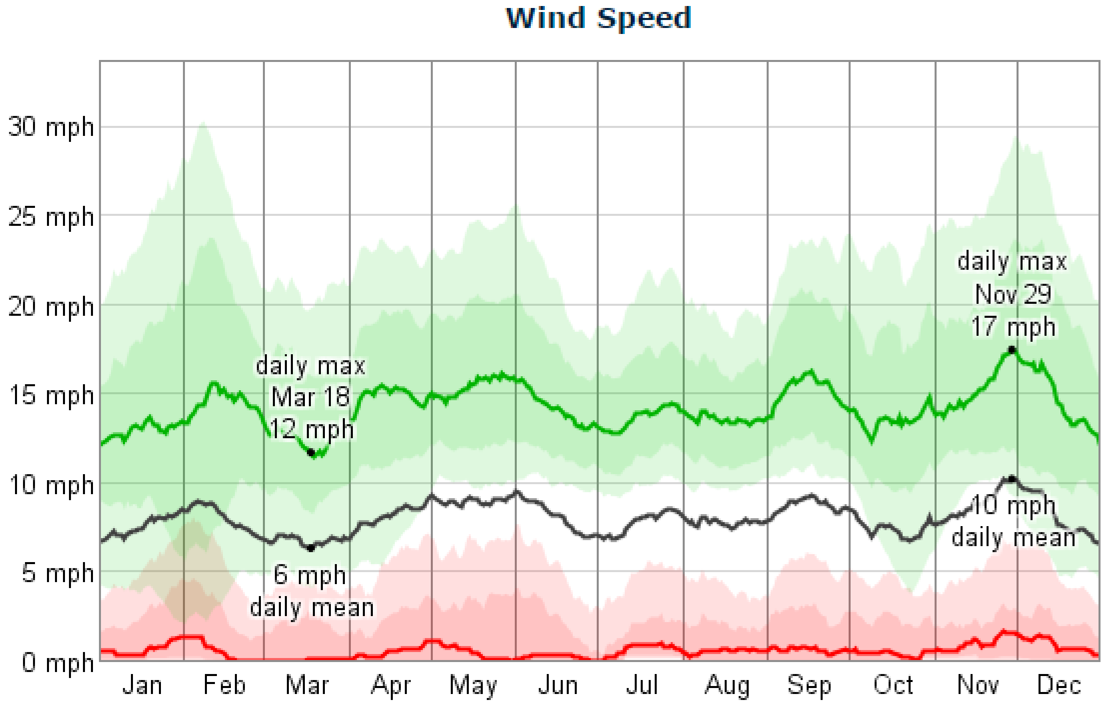


Figure 27. *(https://weatherspark.com/averages/32974/Igiugig-Alaska-United-States)*

Hydro:

Being at the mouth of the river leading from Lake Iliamna, the use of a hydrokinetic turbine could be significant. One such turbine is the Ampair 100W Water Turbine from ABS Alaska, Inc. This 100 Watt turbine can provide up to 4 amps per hour. The amp requirement of our system is only about 1.25 amps per hour, but the 4 amp rating is the maximum it can produce. There is a recommendation for the turbine that water speed be at least 1.8 m/s and be at a depth of at least 16 inches or else the power production of the turbine will be negligible. Not knowing the conditions for the river at Igiugig leaves the question of whether these requirements can be met.

Given the troubles encountered at Nenana with the 5kW New Energy turbine these minimal requirements, especially velocity, seem like they could be a problem. The small amount of power the turbine is rated for could conceptually meet our consumption needs, but that was for ideal conditions at the turbine, something we most likely will not have. Since the system will be deployed over the winter, water velocities will likely be reduced and the introduction of frazil ice could introduce other problems to the performance of the small turbine. With a cost of $2,200 and the associated risks of unreliability, using a marine turbine such as this one from ABS does not seem like an effective, independent solution to powering the system.

Autostart Generator:

The most reliable of the options available to us to power the system would be through the use of an autostart generator. Recommendations from Greg Egan of Remote Power Inc. suggested this course of action due to the low power requirements of our system. Through the use of a battery bank, needed regardless of the power option chosen, the generator would only need to be turned on every 4 or 5 days for about 5 hours (**Error! Reference source not found.**) in order to recharge the batteries spent. This interval could be set and then the only involvement necessary would be someone needed to refill the propane tanks every few months depending on the size of the tank. Through the use of a propane autostart generator and tanks storing propane onsite, there is the possibility of the system still being able to sustain itself throughout the testing.

Using the generator as the means to power the system seems to be the most reliable of the power methods stated, as it does not have to rely on unsteady environmental conditions for power production. The cost would be minimal as we already have the autostart generator and the system for the instruments would be greatly simplified down to only distribution boxes and a DC-DC converter for the two different power requirements of the two instruments. The battery bank will no longer be used for backup power, but for powering the instruments with the generator recharging the bank periodically. While the cost is reduced and the system is greatly simplified, the power source is not renewable. However, in the interest of completing the study and having reliable and consistent data throughout the test period, this method seems like the most reasonable option.

Table 6. Amount of fuel needed for 180 day study.

Depletion and Charging		
Available Power (60% availability)	244.8	Amp-hrs
Amp-Hours per day Used	10.71612	Amp-hrs/day
Assume 40% Depth of Discharge	0.4	
Days before depletion	9.137635637	days
Power of Bank	9792	Watts
Charging Capacity of Generator	2500	Watts/hr

Assume 80% efficiency	2000	Watts/hr
Full capacity recharge time	4.896	Hours
Fuel Consumption Rate	2.3	lb/hr
Fuel used per recharge	11.2608	lbs
Number of Recharges over 180 day study	19.69875	recharges
Fuel used over 180 day study	221.823684	lbs

After considering the inclusion of the solar panels into the system, the power consumption calculations were redone (Table 7). Assuming only a tenth of the rated power production of the panels and only an average of 3 hours of operation per day over the course of the 180 day period reduced fuel consumption of propane to about 180 lbs (Table 8)This means that coupling two 100 lb propane tanks would give enough fuel to power the system throughout the whole study.

Table 7. Power consumption after considering production from solar panels

Corrected Power Consumption (with Solar Panels)		
Estimated Solar Production	16	Watt
Average Hours of Sun over 180 days	3	hour/day
Daily Solar Production	48	Watt-hrs/day
Voltage	24	Volts
Amp-Hours per day	2	Amp-hrs/day
Total Amp-Hours per day (original - solar power produced)	8.71612	Amp-hrs/day

Table 8. Fuel Consumption after considering offset power produced from solar panels.

Corrected Depletion and Charging (with Solar Panels)		
Available Power (60% availability)	244.8	Amp-hrs
Amp-Hours per day Used	8.71612	Amp-hrs/day
Assume 40% Depth of Discharge	0.4	
Days before depletion	11.2343566	days
Power of Bank	9792	Watts
Charging Capacity of Generator	2500	Watts/hr
Assume 80% efficiency	2000	Watts/hr
Full capacity recharge time	4.896	Hours
Fuel Consumption Rate	2.3	lb/hr
Fuel used per recharge	11.2608	lbs
Number of Recharges over 180 day study	16.0222794	recharges
Fuel used over 180 day study	180.423684	lbs

System Diagram:

The diagram shown in Figure 28 is the system design for use with the autostart generator and integrated solar panels. The generator is connected to the 24V battery bank and recharges it at set intervals as it is depleted. Using at most 15 Ah of power a day and assuming 60% of available power due to the cold temperatures means the bank could power the instruments 9 days before having to be recharged by the generator.

From the bank the instruments are connected as the load. There is a fuse and switch on the positive power cable for protecting the instruments and the DC-DC converter converts the power from the 24V of the battery bank down to 12V for the SWIP and Campbell logger. The rest of the instruments can be powered directly with 24V.

The incorporation of the solar panels was done due to the fact that the panels and associated equipment are already available to us. The panels may not provide considerable power until later in the deployment when daily sun increases. However, since the power requirements of our system are so low, they could offset the amount of propane used to run the generator considerably as the daily sun increases. With two 100 pound tanks of propane onsite and the addition of the solar panels to supplement the generator, the whole 180 day deployment could be achieved without having to have any tanks refilled or replaced.

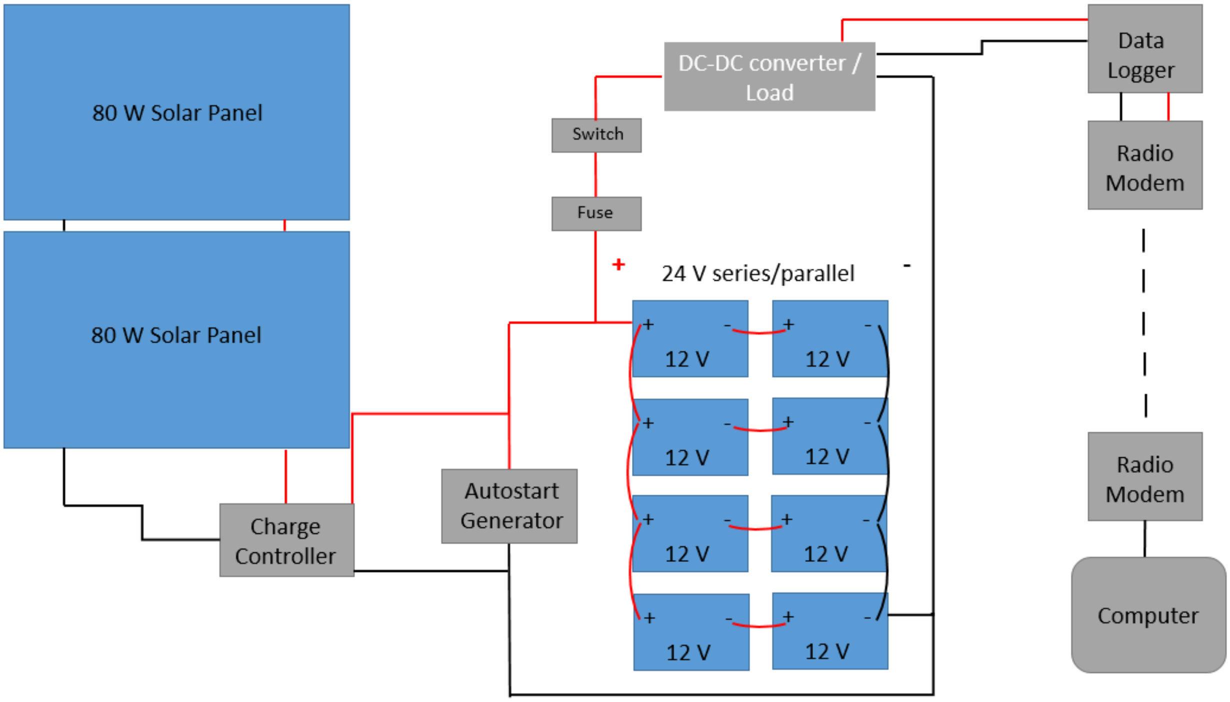


Figure 28. System Diagram for system with autostart generator supplemented with solar panels

Recommendation:

Adjusting the sampling scheme so that less frequent measurements are made by the instruments could reduce the power demands of the system from the max estimated in scenario 2. Since the time period of the study is so long, less frequent measurements would have significant impact on the power, but coupling the system with the external battery bank should reconcile this issue. However, the purpose of the study requires a larger sampling scheme for both instruments.

Externally powering the instruments and offloading the data through the use of the data logger and modem to a computer is thus necessary.

To get the most reliable system and thus the highest possibility of complete data over the course of the 180 day study it is recommended to use the propane autostart generator system with onsite propane storage tanks to externally power the instruments and offload data to the offsite computer. Coupling this power source with the two available solar panels will allow for offset power production from the generator later in the term of the study, as more sun becomes available. Installing internal battery packs to the instruments can also be done in order to provide backup power if required in the case of a drained or malfunctioned battery bank. Both instruments are cabled with RS422 connections, allowing simultaneous power and data transmission. The use of this external powered system allows the data collected from the instruments to be coupled through the use of the Campbell data logger and transmitted with a radio modem offsite. The use of the data logger will also allow the monitoring of the power and charging of the battery bank. Overall, this system seems to be the most efficient and independent of all the options examined while still providing the large amount of data required for the purpose of studying the frazil ice in the river.

9 Appendix C: Power Calculations

Table 9. Power calculations for the remote power/real-time data telemetry ice monitoring system.

Watt Calculation (24V instruments)		
Estimated Watt Demand	9.37	Watt
Hours expected to run	24	hour/day
Total daily usage	224.88	Watt-hrs/day
Amp-Hour Calculation		
Battery loss correction (static average loss)	229.3776	Watt-hrs/day
System Voltage (DC)	24	Volts
Amp-hours per day	9.5574	Amp-hrs/day
Watt Calculation (12V instruments)		
Estimated Watt Demand	0.568	Watt
Hours expected to run	24	hour/day
Total daily usage	13.632	Watt-hrs/day
Amp-Hour Calculation		
Battery loss correction (static average loss)	13.90464	Watt-hrs/day
System Voltage (DC)	12	Volts
Amp-hours per day	1.15872	Amp-hrs/day
Total Amp-Hours per day	10.71612	Amp-hrs/day

Battery Bank Capacity		
Number of 12 V Batteries	8	batteries
Batteries in Series/Parallel configuration	4	pairs
Battery Bank Voltage	24	Volts
Available Power (20 hr)	85	Amp-hrs
Current	4.25	Amps
Current used daily	102	Amp-Hours
Power of Bank	408	Amp-Hours

Depletion and Charging		
Available Power (60% availability)	244.8	Amp-hrs
Amp-Hours per day Used	10.71612	Amp-hrs/day
Assume 40% Depth of Discharge	0.4	
Days before depletion	9.137635637	days
Power of Bank	9792	Watts
Charging Capacity of Generator	2500	Watts/hr
Assume 80% efficiency	2000	Watts/hr
Full capacity recharge time	4.896	Hours
Fuel Consumption Rate	2.3	lb/hr
Fuel used per recharge	11.2608	lbs
Number of Recharges over 180 day study	19.69875	recharges
Fuel used over 180 day study	221.823684	lbs

24 V Instruments Usage		
ADCP	3.57	Watt-hrs
RF Modem	5.8	Watt-hrs
12 V Instruments Usage		
SWIP	0.232	Watt-hrs
Campbell Logger	0.336	Watt-hrs

Corrected Depletion (with Solar Panels)		
Estimated Solar Production	16	Watt
Average Hours of Sun over 180 days	3	hour/day
Daily Solar Production	48	Watt-hrs/day
Voltage	24	Volts
Amp-Hours per day	2	Amp-hrs/day
Total Amp-Hours per day	8.71612	Amp-hrs/day

Battery Bank Capacity		
Number of 12 V Batteries	8	batteries
Batteries in Series/Parallel configuration	4	pairs
Battery Bank Voltage	24	Volts
Available Power (20 hr)	85	Amp-hrs
Current	4.25	Amps
Current used daily	102	Amp-Hours
Power of Bank	408	Amp-Hours

Depletion and Charging		
Available Power (60% availability)	244.8	Amp-hrs
Amp-Hours per day Used	8.71612	Amp-hrs/day
Assume 40% Depth of Discharge	0.4	
Days before depletion	11.2343566	days
Power of Bank	9792	Watts
Charging Capacity of Generator	2500	Watts/hr
Assume 80% efficiency	2000	Watts/hr
Full capacity recharge time	4.896	Hours
Fuel Consumption Rate	2.3	lb/hr
Fuel used per recharge	11.2608	lbs
Number of Recharges over 180 day study	16.0222794	recharges
Fuel used over 180 day study	180.423684	lbs

10 Appendix D: System Block Diagram

A block diagram of the remote power / data telemetry system and sonars is shown below (Figure 29).

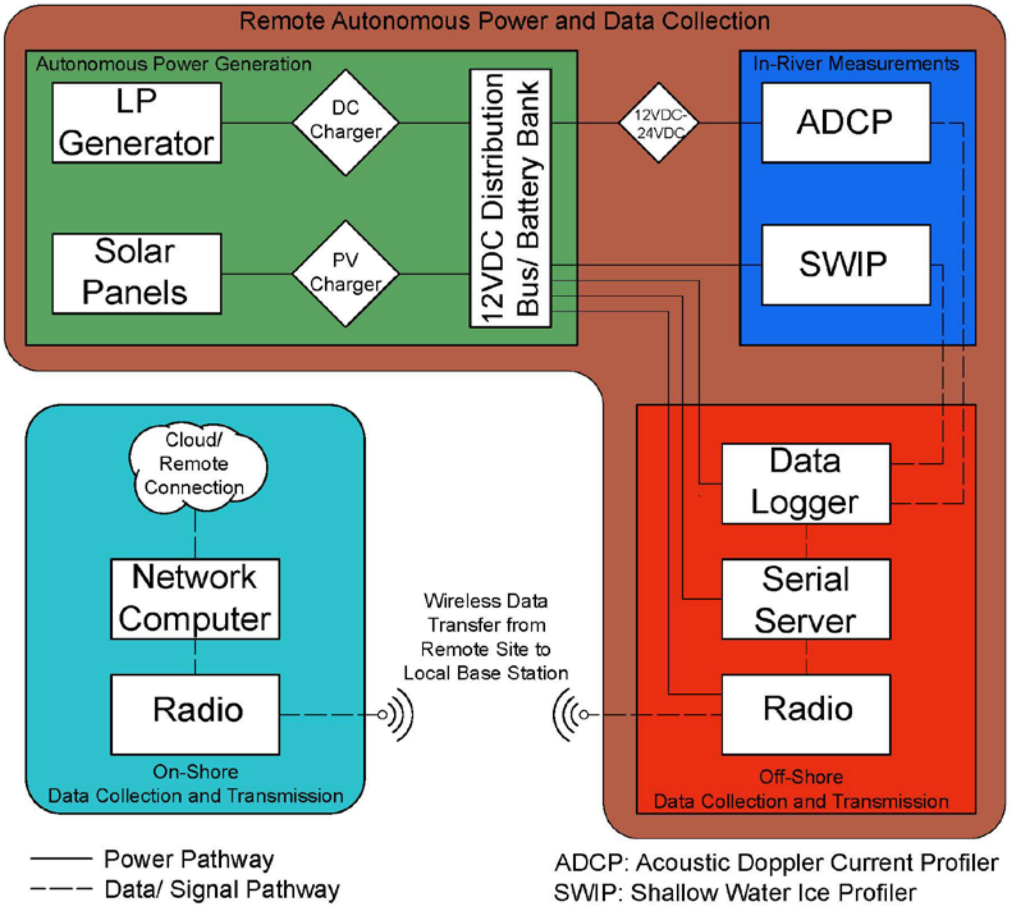


Figure 29. Block diagram of the remote power / data telemetry system.

11 Appendix E: June, 2017 Recovery Plan

Igiugig Recovery Plan

Dates: 6/23-6/25/2017
Location: Igiugig, AK
Participants: Nick Konefal and Jeremy Kasper

Overview:

UAF researchers Nick Konefal and Jeremy Kasper will travel to Igiugig, AK to recover a mooring from the Kvichak River. An ADCP and SWIP are mounted to the mooring and are being removed as the project has ended and data needs to be recovered. In addition to the mooring, on shore equipment will be retrieved and all equipment will be prepped for shipping back to Fairbanks.

Recovery Plan

6/23/2017

- Travel to Anchorage via Alaska Airlines (~9am) and then Anchorage to Igiugig (~1pm) arriving in Igiugig around 2:30pm
- Once Karl's boat has been launched and he is ready we will start the process for removing the mooring

1) Safety talk and plan overview with recovery crew
2) Load necessary recovery equipment on boat (See attached list)
3) Drag grapple for mooring drag line
    a) Attach one side of line to the grappling hook and the other to a cleat on the boat.
    b) Attach davit hook/ shackle to grappling hook
    c) Position boat to the side of the expected drag line position (side will depend on which side of the boat the davit is on
    d) Use davit to lift grappling hook and swing over side of the vessel
    e) With one person on the davit remote and the other letting out the grapple line, lower the grappling hook into the water until the hook is on the bottom of the river
    f) Move boat perpendicular to drag line/river and drag grapping hook over the dragline. Continue until the grapple has passed the dragline areas by ~20'-30'.
    g) Pull up in the grapple using the davit and determine if the dragline has been successfully grabbed. If it has not repeat step f and g.
    h) Once the dragline has been brought above water with the use of the grapple and davit, tie a line through the shackle at the end of dragline and secure to the boat making the

line tight. This will allow the tension on the davit line to be released and grapple to be removed from the drag line
   i) Swing the davit back over the boat and release the grapple from the davit hook
   j) Tie a slipknot around the dragline at the lowest point possible
   k) Connect the davit to the slipknot and lift the dragline using the davit
   l) Tie off the new slack in the dragline to the cleat to secure the load
   m) Lower the davit to release tension on the davit line
   n) Remove slipknot from dragline
   o) Repeat steps j-n until mooring is out of the water
   p) If possible, swing mooring on to the deck of the boat
4) Once the mooring has been brought onboard/ out of the water, work the boat back to shore pulling in the armored cable. This should be able to be done by hand using two bodies.
5) Once the boat has reached the shore where the armored cable lands, detach the cable from the shore and bring the rest of the cable on the boat.
6) While on the far bank, recover the rest of the equipment. The wooden frame should be light enough that we don’t need to take it apart at this point and can lift it on to the boat.
7) Once all equipment is recovered from the far side of the river, return to the Igiugig side and unload the equipment
8) Once all the equipment is on shore it can be disassembled and prepped for shipping.

6/24/2017

- Disassemble equipment and prep for shipping

6/25/2017

- Depart Igiugig around ~2:30pm on Dena’ina Air, arriving Anchorage around 4pm. Depart Anchorage ~6PM arriving into Fairbanks around 7pm.

Recovery Equipment

1) Davit
2) Davit Adapter
3) 2- 12V Batteries for Davit
4) Battery connections
5) Davit control box/ remote
6) Grapple
7) Large shackle for grapple
8) Line for grapple
9) Shackle for davit
10) Smaller line segments for making slipknots
11) Socket set

12) Electric Drill+ spare batteries+ charger

13) ADCP CASE?? (May be in Igiugig already)

Shipping Materials

1) 2x Empty action packers for equipment
2) Tape
3) Sharpies for labeling

Items to be shipped back

1) Davit	SHIP
2) Davit Adapter	SHIP?
3) Grappling Hook	SHIP
4) 3x-40lb propane tanks	LEAVE?
5) Wooden stand	LEAVE
6) Z-link antenna	SHIP
7) Inverter Box	SHIP
8) Generator	SHIP
9) Power supply box	SHIP
10) Spider frame	SHIP
11) ADCP	SHIP
12) SWIP	SHIP to ORPC
13) ADCP Cable	SHIP
14) SWIP Armored Cable	SHIP to ORPC
15) 2 Float Coats	SHIP
16) Propane hoses/accessories	SHIP
17) Wires/ accessories	SHIP

12 Appendix G: Pictures from the Field

Figure 30. The F/V EG ready to deploy the instruments in the Kvichak River.

Figure 31. UAF personnel with the remote power/data telemetry riverl ice monitoring system on the bank of the Kvichak River, downstream of the Village of Igiugig, Alaska, November, 2016.

Figure 32. View of the remote power/real-time data telemetry river ice monitoring system from the Kvichak River, November, 2016.

Figure 33. Power System with Solar Panels, November, 2016.

Figure 34. Remote power and data telemetry system, November, 2016.

Figure 35.Equipment packaged for initial shipment to Igiugig prior to the November, 2016 deployment.

Figure 36. Approaching the site of the remote power/real-time data telemetry river ice monitoring system from downstream in February, 2017. A shelf of shorefast ice extends from the bank.


Figure 37. Looking downstream on the Kvichak River from the remote power/data telemetry system, February, 2017.

Figure 38. UAF personnel working on the remote power/real-time data telemetry system in February, 2017.