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SESSION 43

EMERGING TECHNOLOGIES AND THEIR APPLICATIONS FROM THE DEPTH OF THE OCEAN, TO THE DEEP ANTARCTIC FIELD AND SPACE

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New Ship - New Possibilities

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The first explorers of Antarctica ventured to the continent via ship and on the way collected large amounts of scientific data. Still to this day, large proportions of Antarctic research is done on vessels in the waters in and around the continent. With the RRS Sir David Attenborough the British Antarctic Survey is continuing the tradition of ocean exploring in the Southern Ocean. The new vessel brings with it new technology, new opportunities, and inspiration for both its first users as well as future generations. Capabilities of the ship includes, but are not limited to, seismic operations, piston coring, full ocean depth camera systems, Remotely Operated Vehicle (ROV) operations, Automated Underwater Vehicle (AUV) operations, acoustics, trawling, fishing, helicopter operations, and subsea fibre optic cables. The ship itself contributes new technology, but its main purpose is to enable the research that is undertaken on it to be ground-breaking and innovative. How does one facilitate this? A good working relationship between scientists, researches, engineers, and ship's personnel. Future-proofing and modular thinking – making sure there is room to solve problems we might yet not have thought about. With the RRS Sir David Attenborough, the British Antarctic Survey are welcoming in a new age of research. This talk will explore the technological capabilities of the new ship, but crucially how to facilitate and future-proof this research through modular thinking.

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Advanced capabilities and innovation for Australia's dedicated blue-water research facility

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The Marine National Facility (MNF) provides a blue-water research capability to the Australian research community and their international collaborators. The MNF is funded by the Australian Government and owned and operated by CSIRO on behalf of the nation. The facility comprises the ocean class Research Vessel Investigator; a package of scientific equipment and instrumentation; a collection of marine data; and the expertise to manage an ocean-going research platform and support vessel users. The research delivered from MNF voyages provides important information to directly support government, industry and other stakeholders in making evidence-based decisions to enhance the long-term viability and prosperity of the Australian marine environment, industries and society, bridging the Australian and Antarctic regions. Doing research in the world's third largest marine estate is challenging. Researchers must have access to the most advanced and fit-for-purpose infrastructure to remain at the forefront of global marine and atmospheric research. The MNF is responsible for maintaining its science capabilities and upgrading them as required, as well as for expanding in response to new and emerging technologies and needs. It also offers significant opportunities for advancing technology development for novel marine science systems and technological solutions that can support the growing blue economy. The MNF has developed a 25-year Capability Investment Framework for the identification, prioritisation, procurement and review of capital investment through the remaining life of RV Investigator and beyond. The Framework identifies gaps in marine research infrastructure capability in Australia and proposes a roadmap for securing investment towards acquiring high-value strategic capabilities.

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How accurate are chlorophyll a fluorescence measurements from Biogeochemical-Argo profiling floats in the Southern Ocean?

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The Biogeochemical Argo (BGC-Argo) program has increased sampling of chlorophyll a in the Southern Ocean, filling the limited capabilities of ship-based sampling. The program has led to large-scale deployments of profiling floats equipped with in-situ fluorometers, measuring chlorophyll a fluorescence from live phytoplankton cells. As measurements are not performed ex-situ on extracted pigments, yields of chlorophyll a fluorescence (i.e. the ratio of absorbed light to emitted light) leads to the variability of the fluorescence-to-chlorophyll a concentration ratio. Regional corrections for this variability are sometimes performed by linearly regressing fluorescence against chlorophyll a concentration.

In the Southern Ocean, yields of chlorophyll a fluorescence are much higher than the rest of the world, and can change dramatically across fronts. Additionally, the effects of non-photochemical quenching of daytime fluorescence can reduce accuracy if not properly corrected. In the wake of the incorporation of BGC-Argo measurements into the validation of biogeochemical models and satellite-derived chlorophyll a concentration estimates, it is timely to review the accuracy of these measurements.

In this context, I will present here the variability of chlorophyll a fluorescence to chlorophyll a concentration ratios from a large aggregation of ship-based data. From this, I will explore the implications of this variability on the accuracy of BGC-Argo measurements and possible methods for correcting chlorophyll a measured from the BGC-Argo fleet.

This work is a collaboration between Australia (UTAS-IMAS) and France (CNRS-IMEV-LOV), supported by the SCAR Fellowship program and the Antarctic Gateway Partnership.

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Southern Ocean data: A community effort to build a data ecosystem

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The Southern Ocean Observing System (SOOS, https://www.soos.aq/) bridges oceanographic and polar science programs, and is one of the most intensely international scientific communities, thanks to the logistical challenges of conducting science in these remote waters. The users of Southern Ocean data are therefore highly heterogeneous in terms of their needs and expertise.

Serving such a diverse research community requires data management systems that are flexible and focus on integration of existing data products, rather than trying to duplicate existing work. Fortunately, new data sharing technologies are emerging that allow us bridge many of those gaps. The Southern Ocean Observing System is working with both the science and data communities to design an ecosystem of data management tools, catalogues, and systems for polar oceanographic research. It also requires a cultural change among science programs - one that generates FAIR data (Findable, Accessible, Interoperable, and Reusable) at the heart of scientific activities.

Key components of the SOOS data vision include data and metadata discovery tools, fieldwork coordination tools, and linking data collections with analysis tools. Just as important are the people and communities who develop, link, and use these components. We will share our experiences in working with EMODnet Physics to develop SOOSmap - a portal to explore, graph, and download curated spatial datasets of key observations. We will also focus on the challenges and need for a federated metadata search tool to improve access to a much broader range of polar oceanographic data than can be served directly through SOOSmap.

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Hybrid Autonomous Underwater Vehicle for biological sampling of Antarctic sea bed.

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Robotics technologies have a key role in the exploration of Antarctica. Usually Remotely Operated Vehicles (ROV) are used to explore and get biological samples from the seabed. Deploying a ROV to reach depths greater than 1000 m at the South Shetland Islands requires a large logistic support to handle the umbilical cable and energy requirements, typically the ROV is deployed from an oceanographic vessel. Our approach is based on small Autonomous Underwater Vehicle that can perform some tasks of an ROV without human intervention like get close images of a scientific point of interest and collect biological samples from the seabed. A man-portable Hybrid AUV was developed as a test stand for a computer vision and Artificial Intelligence systems to perform some complex tasks of a ROV with human operators like identify sites of scientific interest and make parking strategies to collect underwater samples. The hardware-software architecture is based on low cost FPGA and ARM processor development boards to implement an Inertial Guidance System, Computer Vision, Stochastic Optimization and Convolutional Neural Networks. The software is coded by VHDL language running on an FPGA and C/C++ scripts running on an Embedded System. The AUV was deployed during the Ecuadorian Expedition 2018-2019 to Pedro Vicente Maldonado Scientific Station, making a photogrammetric survey and biological sampling in the submareal zone. A future work is to install this software on a man-portable AUV rated for 6000 m that is under development to get deep sea samples near to the South Shetland Islands.

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A Modular Autonomous Biosampler (MAB): Multi-platform system for distinct biological size-class sampling & preservation of sea ice and water column communities.

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We know little about the succession and maintenance of the biological community intimately associated with sea ice. This is due to our inability to efficiently and reproducibly sample the underside of the ice and water column throughout the year. What is needed is an instrument that can be adapted to multiple mobile platforms (e.g. AUVs, Gliders, etc.) servicing a range of applications across the Antarctic biological oceanographic community. The unit should be able to sense its environment, operate autonomously, and collect large numbers of discrete samples from multiple size classes that are preserved in situ.
We present the results of a 3-year development program aimed at building and fielding a low-cost, high-sample-capacity modular, autonomous biological sampling device. The presentation will focus on the development of a standalone unit that has been designed specifically for Antarctic deployment. We will present the specific design criteria that has guided the MAB development including: 1) The ability to collect 150 samples in each of any 3 size classes including bacteria (0.2µm); 2) The preservation of each individual sample in a fixative conducive to standard biological systematics and genetic analyses; 3) The ability to sterilize the water flow path between each sample; 4) The ability to detect and react to filter clogging; 5) The development of an environmental sensor module that will enable integrated “smart” sampling on the moorable unit; 6) the design of a retractable spooled intact umbilical that enables the system to sense, sample and profile the water column underlying the sea ice.

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Small-sized photovoltaic panels based on natural dyes at the antarctic Artigas Base.

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Dye-sensitized solar cells (DSSC) constitute an alternative to conventional photovoltaic-silicon cells. Based on the use of coloured dyes as photosensitizers, they can harvest the light in the visible range of the spectrum to generate an electric current.
The use of natural dyes shows efficiencies values up to 2 %.
In this work, we assembled two small panels based on anthocyanins extracted from Erythrina Crista-Galli flowers, the Uruguayan national flower. In one panel DSS cells were connected in series (7 cells, 5 cm2 total area), and in the other were in parallel (13 cells, 9 cm2 total area). In the latter, a 5 k resistance was included in the external circuit to allow the calculation of the generated power.
Individual performance of the cells was checked previous to panels' assembly. Panels were installed indoors in the Uruguayan Antarctic Base and remotely monitored since March 2019.
Potential values were evaluated across the hours of the day and during the different seasons. The results were also compared with irradiance values.
These alternative small panels could be used to supply small scientific measuring devices at Antarctica. As far as we know, this is the first time that DSSCs were installed on this Continent.

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A portable optical communications ground station for high rate data link to Antarctica

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Transmission of data from the Antarctic continent is reliant on radio transmission to satellites which limits the amount of data that can be sent across the world. The remoteness and harsh conditions of Antarctica mean a physical fibre link is not possible. Free space optical communications is a method which could provide a high rate data link in remote locations such as Antarctica.

The Research School of Astronomy and Astrophysics (RSAA) at the Australian National University (ANU) is developing a portable ground station which can be used for optical communications in Antarctica. Data is transmitted from the ground station to a satellite which will be developed to support the mission. The satellite will downlink data to a network of stations positioned across Australia and New Zealand. The ground station network provides diversity in receiver sites that will reduce downtime of the system due to poor weather.

The development of optical communications to Antarctica could enable data rates over 10 times larger than is currently available. This would allow real time transmission of scientific data to the world which could transform how science is done in Antarctica.

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Expanding the Reach of Science Under Ice: Opportunities for Custom Sensor Integration on Icefin

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Icefin is an ROV/AUV designed to relax the significant constraints that ice cover puts on polar science. Meters to kilometers thick ice has historically limited scientific data, particularly in remote areas of ice sheets. Icefin meets this challenge by fitting through ice boreholes. While most borehole equipment can only move vertically, Icefin can precisely explore along transects from the ice interface to the seafloor limited only by its tether and stored energy, with typical round-trip missions of 2-4km, expanding the reach of science equipment. Thus far, Icefin has collected a range of scientific data over three years of deployments through sea ice as well as through 600m of ice at the Kamb Ice Stream and Thwaites glacier. Icefin includes a flexible science bay that has been designed to enable us to develop instruments and work with instrument providers to achieve more science. In addition to integrating 10 different kinds of off the shelf science sensors for use on the vehicle, we are currently developing standards for instrument integration to streamline incorporating existing and new scientific equipment. Currently we are developing a water sampler, digital holographic microscope, and sampling arm in our lab, as well as working with a team designing a novel instrument to investigate supercooling. Our continued development of Icefin gives us a unique insight into best practices for power and communications interfaces. Here, we hope to share our insights and discuss new ideas with the scientific community presented with similar challenges, and to encourage future collaboration with Icefin.

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Polar Thematic Exploitation Platform: A shared virtual environment for finding and using Earth Observation data over the polar regions.

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We propose a talk about the Polar Thematic Exploitation Platform (www.polartep.io).

Earth Observation (EO) has a unique and important role in the polar regions as the only consistent source of regular, year-round, calibrated regional scale data for the polar regions. However the volume and variety of EO data available for the polar regions is growing rapidly, providing opportunities for more complex applications by polar scientists. This trend is forecast to continue given plans for new polar focused satellite instruments, including new Copernicus Sentinel expansion missions. This situation is not limited to the polar regions and other domains face the same challenges of increasing data volume and how to fully process, analyse and exploit them.

As a result, novel cloud-platforms have emerged to provide online research environments collocating data and processing capabilities, plus development, analysis and visualisation tools. These platforms offer a solution to the challenge of exploiting greater volumes of EO data and dramatically simplifying access for a wider range of polar scientists, without requiring local computing infrastructure.

The Exploitation Platforms established by the European Space Agency, include the Polar Thematic Exploitation Platform. This presentation will describe Polar TEP capabilities and planned evolution, covering available polar EO datasets, toolboxes and processing capabilities, plus functionality to allow deployment of user defined workflows. We will also outline new PTEP features which allow easier batch and automated scheduled processing of large data volumes and integration of machine learning workflows; all using the recently established European DIAS (Data and Information Access Services) data platforms.

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Harnessing the Data Revolution to Characterise Seafloor Communities Adjacent to the Larsen C Ice Shelf, western Weddell Sea, Antarctica: A Citizen Science Inclusive Approach to Accelerate Analysis to Inform Ecosystem-Based Marine Management

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Manual interpretation of remotely-captured seafloor imagery is the principal method of generating information to characterise benthic communities and ecosystems, including establishing baselines. The method is exceptionally time-intensive; with researchers also having to balance such appraisals with other competing commitments. As the capacity to capture data is increasing, both technology- and storage-wise, we are facing a "data deluge", with potentially important findings hidden in the heap.

Without evaluation of imagery, drivers of compositions and distributions cannot be discerned, nor potential changes in ecological systems with environmental changes predicted.

Given the current rate of environmental change, both globally and Antarctic-specific, the existing time-lags, between acquisition and results-provisioning, used to inform conservation and ecosystem-based management decisions, are concerning. It is vital that the evidence-base is provided in a more timely manner.

Looking towards solutions, the harnessing of people-power, in particular citizen scientists, may provide an effective means to resolve issues. Co-benefits would include increasing public awareness, galvanising interests in Antarctica on the whole, and raising the profile of its relatively unknown seafloor ecosystems and inhabitants.

It can be envisaged that a conceptual approach incorporating a crowd-sourcing platform coupled with machine learning (automation) may facilitate in combatting the above-mentioned bottleneck, and expedite future seafloor evaluations; in the best-case scenario process-wise bypassing manual interpretation.

This approach, interweaving disciplines, emerging technologies and public-participation, is first applied to seafloor imagery collected during the SA Agulhas II Weddell Sea Expedition 2019 to the Larsen C ice shelf, and represents a progressive step in seafloor imagery analysis.

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Direct Evidence of Nitrate Aerosol Formation in Summer Antarctic Stratosphere Obtained by a Balloon-Assisted Unmanned Aerial Vehicle

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The system for the stratospheric aerosol observation and sample-return in Antarctica using the combination of a rubber balloon and an Unmanned Aerial Vehicle (UAV) has been developed. The balloon-UAV system reaches 20km to 30km in altitude, but it becomes difficult for the UAV to directly glide back autonomously after separating from the balloon at higher altitudes because the aerodynamic characteristics necessary for the control system design at higher altitude is difficult to obtain. In order to avoid the problem, the two-stage separation method is proposed in which the UAV first descends down to a flyable altitude of the UAV by a parachute after separating from the balloon, then it separates the parachute for autonomous gliding back to the released point. An optical particle counter and an aerosol sampler installed in the UAV were launched on January 24, 2015 from S17 (69.03 S, 40.09 E, 607 m a.s.l.) near Syowa Station in Antarctica. A stratospheric aerosol layer composed of three sub-layers is quite distinctive compared with a typical stratospheric aerosol layer, which suggests the effect of the eruption of Mt. Kelut on February 14, 2014. An electron micrograph of the stratospheric aerosol sampled at 22km in altitude suggests the existence of nitrate particles with sub-micrometer diameters in spite of the high temperature around -45 degrees Celsius at the sampled altitude. They also show that the balloon assited UAV system is a useful method for polar upper atmospheric research.

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Thermal response of antarctic plants using an automatic sensors actuators network

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The study presented in this work is a continuation of a research conducted in Maritime Antarctic, which investigates the effects of the future warming scenario on the only two vascular plants inhabiting Antarctica: Deschampsia antarctica and Colobanthus quitensis. Until the moment, the methodology used to simulate future warming involves the use of a passive warming system: Open Top Chambers (OTCs). This system enables average temperature increases of OTCs microenvironment in about 4°C compared with open site (OS). However, the OTCs has its effect only during the day, while during the night, the temperatures inside them are almost equal or even lower than OS (Minimum Night Temperature registered 2015-2016 summer season: -3,6°C OS vs -4,8°C OTC). This OTC artifact is contrary to the predictable asymmetric warming, which is the tendency to an increase in the daily minimum temperature than in the daily maximum temperature; and this could be the reason to there is no effects on the freezing tolerance of both species along the antarctic growing season. Laboratory results indicated that D. antarctica, only cold deacclimated, when night temperature increase; though, these short terms periods has not effect in C. qiutensis. However, long term studies must be performed to fully comprehend the warming effect in these plants physiologies. To fill this gap an active nocturnal warming system was elaborated and implemented. This paper reveals some of the design and implementation issues, together with the result of thermal response measurements of both species in the vicinity of the Polish Antarctic Station “Arctowski”.

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Airborne comprehensive observation on aerosol transportation into the Antarctic interior using UAV

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Atmospheric circulation transports aerosols (fine particles in the air) into the Antarctic interior, and the aerosols accumulate on the ice sheet, which can modify climate and are the sources of climatic markers found in ice cores. The climatic markers reflect the principal atmospheric circulation pattern in those ages. For understanding the past atmospheric circulation, it is important to know how aerosols are transported into the Antarctic interior with atmospheric circulation in the present age. Thus, in order to identify the transportation mechanism of aerosols in the lower troposphere from the ocean onto the ice sheet, a field operation was carried out at inland observation site S17 (69°02’ S, 40°04’ E) on the ice sheet for 45 days in the 2016/17 summer season. UAV (Unmanned Aerial Vehicle), called Kite-plane, was employed for observing spatial and temporal variations in distribution of aerosols between S17 and a coastal area about 20 km away. Full-course return flights were carried out 11 times among 24 times of the observation flights during this field operation. The success of the comprehensive scientific observation employing UAV is a first for JARE.
The data show different transportation mechanisms of aerosols from the ocean onto the ice sheet. In one case, the number of particles are larger in the lower boundary layer only on the coastal side. In another case, large numbers of particles only in the upper layer were found, which can transport aerosols to the Antarctic interior.

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Data management in MOSAiC – Challenges of the Multidisciplinary drifting Observatory for the Study of Arctic Climate

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During the MOSAiC expedition, the German research icebreaker Polarstern spends a full year drifting through the Arctic Ocean. Scientists from 20 countries participate in the largest polar expedition in history exploring the Arctic climate system. The experiment covers a large suite of in-situ and remote sensing observations of physical, ecological and biogeochemical parameters to describe the processes coupling the atmosphere, sea ice, and ocean.

In addition to forefront instrumentation and observational techniques, proper data management is essential for large and complex projects and field programs. Key elements are agreements on consistent sampling strategies, the possibility to monitor the data flow, to facilitate near real-time processing, and analysis and sharing of data during and long after the expedition. Furthermore, data publication and documentation are crucial for such a collaborative effort and will build the legacy of the project and finally take climate science to the next level.

We adapted our modular research data management framework O2A “Data flow from Observations to Archives” to meet the expedition requirements and ensure central data archival for generations to come. Researchers register all necessary sensor metadata beforehand. Essential metadata of scientific actions in the field are ingested immediately with the FloeNavi, a novel system enabling navigation on a drifting ice floe. O2A provides tools to automatize data ingestion, monitor the data flow and process, analyze and publish data. Integration of ship- and land-based components and a shared storage ensure seamless continuation of collaboration during and after the expedition laying the fundamentals for numerous data publications.

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Implementation of an Eolic turbine in Antarctica

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The objective of this project is the design and manufacture of a Wind Turbine prototype in Colombia for its implementation in Antarctica. Taking advantage of extreme wind currents, which are abundant and constant throughout the year, being a friendly energy with the environment and the best option when implementing a Colombian Antarctic base, contributing to the policies of the Antarctic treaty, being a model of development for the country as pioneers in the field of implementation of renewable energies and in turn, managing to mitigate the logistical impact of fossil fuels, a task that requires excessive labor and many hours of flight which are unnecessary before the possibility of using an Aeolian Turbine, saving high costs of these operations. During the month of December of the year 2015 there was a participation in the Antarctic Base of Marambio with the objective of identifying in what and how much electrical energy is consumed, as well as a preliminary measurement of winds with a portable weather station, the previous thing to design the Turbine prototype which was implemented for the current year 2018 in the Antarctic Base of Marambio, obtaining positive results with Polar winds of 40 knots, temperatures of -50ºC and generating between 3 and 5 KW, being the implementation of it a great success since a challenge and experience for the deployment of the generator from Colombia and its installation. Both missions are possible thanks to the collaboration of host country Argentina.

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The Ice-o-pod: A custom built Remote Operated Vehicle for conducting quantitative benthic photographic surveys through sea ice.

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Monitoring change in remote marine communities can be logistically challenging, particularly where sea ice exists for most of the year. In early summer, coastal Antarctic sea ice is thick, providing a reliable work platform from which to access benthic habitats. Underwater visibility is at its best at this time of year, ideal for conducting video and photographic surveys of benthic communities using a Remote Operated Vehicle (ROV). In the Vestfold Hills near Australia's Davis Station we drilled a 40 cm diameter hole in the sea ice through which a 35 cm wide custom designed and built ROV, nicknamed the Ice-o-pod, accessed sea floor habitats. An altimeter allowed constant adjustment to achieve a consistent flight 1 m above the sea floor. Two downward facing GoPro cameras collected video and photo imagery including scale points projected onto the sea floor from an independent laser unit. We conducted down-slope and across-slope photographic transects at ten sites with the resulting quantitative analysis of photoquadrats documenting complex, diverse marine invertebrate communities associated with a variety of sea floor habitat types. The combination of through ice access using a small, portable, hand-held auger drill and an ROV deployable through the resulting narrow hole proved logistically successful, requiring relatively little equipment which was easily transported and operated by a minimum of two people. The malleable nature of current ROV technologies provides potential to refurbish and add additional technologies to meet and expand future research needs and possibilities.

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The Polar Climate and Weather Station (PCWS): A New Electronics Core for Observing the Meteorology and Climate over the Antarctica Surface

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2020 marks the 40th anniversary of the establishment of the Antarctic Automatic Weather Station (AWS) network. The modern day network is populated by contributions from many national Antarctic programs and groups from around the world. Over the years, the equipment that makes up an Antarctic AWS has evolved. Original AWS systems where often institutional built, home-made systems and today's modern network is primarily commercial-off-the-shelf. This project focuses on the development of a new electronics core for the future, using readily available components, and tested for Antarctic application. This effort does not develop new sensor systems, but does utilize proven sensor sets and enable the expansion of sensors to be standard on the PCWS. To ensure the observations are climate worthy, multiple temperature sensors will be installed at standard height following what is found in other climate observing networks such as the US Climate Reference Network, and opposed to the single sensor which is currently ubiquitous across the Antarctic. This effort is a student-centric effort at all levels of this project, from proposal, to development, onto execution, and ending with deployment of the first running system. With project successes, more work remains. This presentation outlines the PCWS project, its status and future.

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Antarctic Deep Field Deployments and Design of the Icefin ROV

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Icefin is a remotely operated under water vehicle (ROV) designed with a focus on portability and modularity for exploring ice environments. We are able to explore extremely remote areas of the Polar Regions here on Earth with Icefin and its various payloads, developing both engineering technologies and scientific hypotheses to one day explore the ocean worlds of our solar system. Icefin was developed specifically for borehole deployments and is outfitted with oceanographic sensors, biogeochemical sensors, multibeam sonars, and an array of imaging systems. The Icefin prototype was deployed through sea ice off McMurdo Station in 2014. Since the vehicle's redevelopment in 2017, Icefin has spent over 160 hours exploring ice covered ocean. Icefin enables several novel operations scenarios that permit the vehicle to conduct missions ranging from glider-like ocean surveys to sonar collection, while allowing the vehicle to hover and explore interfaces directly. In 2019, we built a second vehicle to facilitate simultaneous field deployments under the Ross Ice Shelf and Thwaites Glacier. Between the two campaigns, Icefin completed 50 hours of diving and surveyed 17km over 8 missions through 600m of ice. Icefin explored both the grounding zone of Thwaites Glacier, swimming into a water column only 0.5m high, and profiled a 50m tall basal crevasse under the Ross Ice Shelf. Icefin details will be presented, along with lessons learned and results of deep borehole deployment. We hope that by sharing our experiences and design decisions with the community, the possibilities in this area can be advanced through collaboration.

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Shallow-water scavengers of polar night and day – an example of a time-lapse photography study from the Arctic

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Scavengers being a link in the nutrient and energy circulation are an important part of benthic communities worldwide. Highly seasonal environments with prolonged periods of total darkness during winter and only short but intense production events during spring/summer, such as polar seas, are regions where necrophagy is a frequently used strategy. In contrast to Antarctica, however to date there is very little works describing shallow-water scavenging assemblages from the Arctic, especially those from the polar night. We traced the decomposition of two different bait types (cod Gadus morhua, and chicken meat) during polar night and polar day at 14 m depth in Kongsfjorden, Spitsbergen Island (78° N) with specially designed time-lapse photography systems equipped with small baited traps. A total of 31 taxa were identified from photographs. In most of the cases buccinids (B. undatum, B. glaciale.) and lyssianasid amphipod Onisimus sp. were the first species at bait. The latter species made up 88% of the total number of animals counted, however it occurred infrequently (55%) mostly during winter. The most frequent species were buccinids, hermit crab Pagurus pubescens and another representative of Amphipoda, Anonyx sp. PERMANOVA analyses indicated a clear differences between the investigated seasons, bait types, as well as an interaction of both factors, independently whether only presence-absence or whole community data were used. The method proved to be successful to investigate scavengers feeding preferences, and their interspecific interactions at bait.

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Progress in Optically-powered Ice Penetrators

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Stone Aerospace has continued work on an optically-powered ice penetrator. The ARCHIMEDES cryobot uses patented Direct Laser Probe (DLP) technology wherein laser light from a surface-based laser travels to a probe via a fiber optic tether that is spooled onboard the vehicle and is paid out as the probe descends. The laser emission travels through a series of lenses in the probe nose before exiting the probe and being absorbed into the ice, where it induces melting and the probe descends under its own weight.

Originally developed under NASA funding for outer planet robotics, DLP can be adapted for use in terrestrial glaciated environments as a clean-access tool to investigate thick ice sheets, ice shelves, and subglacial water bodies. The approach can potentially be scaled to work through more than 4000 meters of ice. Initial calculations indicate that at high power, a 5 cm diameter DLP probe could be used to reach 4000 m penetration in 16 hours in Antarctic ice temperature profiles with 60 kW of power reaching the probe. The compact and simple design means that the probe can be sterilized prior to deployment to satisfy clean access protocols without complex on-site sterilization procedures.

Here we present recent laboratory test results of DLP technology operating in ultra-cold temperatures and show designs for an ultra-low-footprint, 4000 meter capable Distributed Temperature Sensing instrument field installation system.

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Fully Autonomous Behavior-Based Exploration of Restricted Access Sub-surface Environments

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In August 2019 the autonomous underwater vehicle SUNFISH completed the first robotic exploration of previously unmapped caverns. Three sites of increasing topological complexity were explored: Lake Guinas, Harasib Shaft, and Dragon's Breath Cave, all in northern Namibia. In each, a subterranean water body of unknown extent existed at varying depths below the surface. These sites provide an analog for advanced sub-glacial and sub-ice shell missions both in terms of providing a completely unknown environment as well as restricted access whereby the vehicle must absolutely return to at the conclusion of a mission or be lost. This represents the identical problem presented by drilled shaft access beneath the Ross Ice Shelf, e.g., or access to any of the interior deep sub-glacial lakes. In each of these GPS-denied situations the rover is entirely dependent on its own internal navigation system.

SUNFISH uses a multi-stage navigation system to create 3D maps as it proceeds into unknown spaces while registering its position and orientation within that map. The vehicle is a six degree of freedom hover-capable platform. It rotates, sweeping 120-degree fan-like multi-beam sonar to build complete spherical knowledge of the world about it within a 120 m radius. Behavioral routines then react in real time to real world data while the vehicle is moving forward. Alternative science behaviors can be superimposed onto the basic exploration behavior.

Here we present results from the cave exploration work and describe how this technology could be used for advanced subglacial lake and sub-ice shelf autonomous science.

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Glider-derived Determinations of Vertical Flux and Iron Limitation in the Ross Sea

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Gliders have become increasingly used in oceanographic studies in the Southern Ocean, largely due to their ability to sample small spatial scales and over long time periods, providing information that ship-board investigations cannot obtain. However, gliders are also limited in terms of what they can routinely measure, as sensors for biogeochemical studies are limited. We describe procedures that use glider data to investigate the temporal variations in both vertical flux and iron limitation in the Ross Sea. Glider observations were collected from Nov. 29 through Jan. 15 in a spatially restricted region in the southern Ross Sea during the annual phytoplankton bloom. Surface chlorophyll concentrations indicated that there were three stages: the first in which phytoplankton growth was large, resulting in a rapid accumulation of biomass; the second in which biomass remained relatively constant; and the third in which biomass in the surface layer decreased. Changes in particulate organic carbon in the water column were quantified, and the flux of carbon below 50 m assessed by mass balance. Fluxes were near zero initially, but increased through time, and were greatest during the last portion of the experiment. Iron limitation was determined using the recently developed fluorescence inhibition technique. It was determined that iron limitation became strong during the second and third portions of the study, and that it increased passive sinking rates considerably. Hence, the flux of organic matter and surface iron limitation are intimately connected and need to be considered within biogeochemical models of the Ross Sea.

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