

ABSTRACTS

Overview Talk 1 **Why polar marine science is important**

Peter Wadhams

When we look from space, one of the most clearly visible changes occurring in the appearance of the Earth is the year-to-year shrinkage of the Arctic sea ice cover, especially in summer. This process is set to lead to an ice-free Arctic Ocean some time this century, a massive change in the nature of our planet with incalculable consequences for ecology, regional climate and human affairs. The nature of the forces that are bringing this about, whether they be atmospheric or oceanic (changes in currents and water masses) need to be understood both in the Arctic and the Antarctic, and makes polar marine science one of the most important fields of climate change research.

Overview Talk 2:

Political/Economic Drivers: Potential for AUV technologies in UNCLOS

Lindsay Parson and Rosemary Edwards

The United Nations Convention on the Law of the Sea (UNCLOS) provides a framework of governance for the world's oceans with respect to the rights and responsibilities of coastal states and other users of maritime space. The rate of acquisition of marine geological and geophysical data to support entitlement to territorial sovereignty – especially that concerned with extending continental shelf areas beyond 200 nautical miles under Article 76 of UNCLOS - has been steadily increasing in recent years in response to approaching deadlines enshrined in the Convention. The expense and logistical difficulties associated with data collection in problematic shelf/margin settings (such as, for example, ice-affected ocean basins) invites the application of AUV technology to secure cost-effective and accurate datasets. Single-beam and multibeam bathymetric echo-sounder data for the determination of key Article 76 criteria such as 'foot of continental slope' and the 2500m isobath; and/or high resolution seismic profiler (3.5 kHz or equivalent) to confirm sediment sequence continuity are all capabilities already embraced by AUVs of a range of types. Seismic reflection profiling, perhaps in a mode combined with surface seismic source, now presents the next challenge for the use of AUVs in difficult or frontier areas.

Overview Talk 3 **Research and Development, Past, Present, and Future AUV Technologies**

Ikuo Yamamoto

The past, present, and future AUV (Autonomous Underwater Vehicle) technologies developed by the authors are described in the paper. Firstly, a deep and long-distance cruising AUV EURASHIMA powered by fuel cell is mentioned. This has specifications of 10 m length, 2.5 m width, 2.4 m height, 10 tons weight, 300 km cruising distance, 3500 m depth diving at 3 kt speed autonomously in the ocean, and used for survey of sea bottom earthquake area and research of global warming phenomena. Secondly, a marine robot designed for works in the ocean, such as tracking planktons, installing and retrieving observation equipment, and measuring sea data autonomously by quick diving up to 4200 m. Thirdly, bio-manoeuvring type autonomous underwater vehicles are described, which are real fish-like swimming robots used for various purpose in scientific area. Finally, the ideal method for developing the next generation AUV is proposed and applications are mentioned.

A1- **Navigation, homing & docking**

Bill Stone

This discussion will focus on the issues of navigation, homing, and docking in "overhead" environments in the context of autonomous underwater vehicle behavior. Ocean going AUVs (as well as UGVs and UAVs) have the benefit of the possibility of periodic external

navigation corrections to purely proprioceptive (dead reckoned) position and velocity vector estimates. The classic example is the airborne commercial navigation system that blends GPS and inertial guidance in a single package that employs Kalman filtering for deriving the best navigation update. Sub-ice (as well as subterranean) environments preclude such external aiding unless extraordinary efforts are undertaken to provide a down-hole equivalent of GPS in the form of a USBL or SBL array. And even then, one would find, due to the limited range of such systems, that they would only be useful in the context of proximity operations - assuming that multipath interference issues (range and heading spoofing due to signal bounce) could be dealt with. In general, for truly autonomous navigation over long baseline distances one cannot assume that such aids will exist or that their validity will only exist within refined zones of operation. One approach that is being undertaken for the NASA Europa lander third stage AUV is that of 3D SLAM (simultaneous localization and mapping) as the primary navigation driver. We will discuss this method, the exploration context in which it is being currently tested, and the potential generic utility of this approach to under-ice operations. Proximity operations (proxops) will also be discussed along with some recent related research in which real-time lidar is being used for auto-docking and component placement. The algorithms being developed for lidar-based-docking are directly applicable to sonar-based-docking of AUVs. Hopefully, this will set the stage for an animated breakout discussion of the merits of these and several other approaches (machine vision, video mosaics, magnetic low frequency beacons etc) that can be brought to bear on the problem of sub-ice autonomy.

B1- Sensors & instrument requirements

Dan Hayes

First of all, selection of sensors for AUVs used in polar science is widely variable depending on the goals of each particular study. However, a sensor suite is usually necessary to provide the background setting. Moreover, especially for polar science, serendipity plays an important role. Using a reliable, robust, redundant instrument or set of instruments improves the potential for pleasant surprises during post-experiment analysis. It also decreases the risk of coming home empty-handed.

I consider the basic necessities to be the following: conductivity probe, temperature probe, pressure sensor, upward/downward looking altimeter, upward/downward looking current profiler, inertial motion package, velocimeter, and GPS. The required specifications or best design of each sensor is a matter of application and debate. However, there are many versions of each sensor which are well-tested, reliable, and readily available. Besides instruments that provide direct information about water or ice, I have also included instruments that provide information on vehicle motion. Typically, these are thought of as only necessary for the navigation systems and not for the scientific goals. Vehicle motion is critical to many AUV studies because it allows the accurate determination of the location and time. In other words, we need to know platform position and motion when analyzing our data. More than that, in some cases, platform motion or position IS the variable of interest. In some cases, it is also critical that the control system algorithm is available and easily expressed (hopefully linearly).

C1- Communications U/W & RF

Dick Blidberg

Underwater acoustic communications are a limiting factor in the utilization of Autonomous Underwater Vehicle Systems (AUVs). The environment limits the effective range of communications and introduces significant noise constraints. The end result is a communication channel with very limited bandwidth. To understand this problem, it is advantageous to recognize that communications is composed of three components:

i. The Pipe

To implement communications, we must first consider the communication channel and the environment in which the channel is established. Understanding that environment and its

impact on communication is the primary issue. This understanding provides constraints that must be overcome by any modem that operates in that environment. Transmission schemes, modulation techniques, and receiver strategies must be implemented. RF communications simplify establishment of a communication channel, however, introduce other issues that must be considered

ii. The Network of Pipes

More importantly, multiple agent systems require the ability to communicate over a network environment where any vehicle can talk directly to any other vehicle or talk to all of the vehicles in the group using a broadcast mode. This requires a network protocol that functions efficiently in the underwater environment with its noisy communication channel with limited bandwidth. To provide a network environment where mobile and non-mobile nodes can communicate over an underwater network with reasonable bandwidth and high reliability is a lofty goal.

iii. The Information in the Pipe

Clearly whatever bandwidth is available in an underwater or terrestrial communications channel, the amount of information that needs to be moved through that channel will exceed its capacity. Methods must be developed to abstract information and data to optimize the number of bits to be transmitted across a communication channel.

Overview Talk 3: **Autosub Operations in the Arctic and Antarctic**

Stephen McPhail

Autosub is a 3600 kg, 6.7m long AUV, with a 1600m operating depth and range of 400 km. Between 2001 and 2005, as part of NERC funded scientific cruises, we took Autosub on five expeditions; three in the Antarctic, two in the Arctic. Autosub executed a wide variety of missions, including assessment of krill populations underneath Antarctic sea ice, the measurement of sea-ice thickness and ice-berg drafts, oceanographic measurements under sea ice, and finally, measurements of oceanography, biology and glaciology under an Antarctic ice shelf. There were a wide variety of technical problems to overcome: Most missions required good navigation accuracy, whereas compasses and gyros are compromised by high latitudes. Shifting sea-ice meant that we needed to develop a homing system to shepherd Autosub back to a safe recovery position, and the cold conditions were found to cause problems with the sealing of some types of underwater connectors. Launch and recovery, as ever, was a problem, exacerbated by ice covered waters and, at times, rough sea states. This talk will describe the scientific achievements, the technical difficulties and the solutions we adopted to solving them, and some of the near (and ultimately actual) disasters which befell the AUV.

Overview Talk 4: **Theseus on Ice operations**

David Hopkin

Commencing in 1988, joint CAN/US ICESHELF experiments were executed in the Lincoln Sea, north of Ellesmere Island, NWT, Canada. These experiments were designed to resolve various aspects of underwater system design and installation in ice-covered waters. This was followed in 1992 by a joint CAN/US undertaking, sponsored by the US Department of Defense and the Canadian Department of National Defence, to install a bottom-mounted research system and associated cable to shore, based on design concepts and lessons learned from the previous work.

To support this project, the autonomous underwater vehicle (AUV) Theseus was developed. Built from 1992 to 1996 by International Submarine Engineering Research and Defence Research & Development Canada, the Theseus vehicle is one of the worlds largest AUVs. The vehicle was designed to lay up to 220 km of fibre-optic cable in ice-covered waters of between 50 m depth at the launch site to between 500 and 700 m at the array site.

This paper will provide an overview of the joint CAN/US project, review the Theseus vehicle development and highlight key technical challenges, and provide an overview of the Arctic logistics required to support the mission.

Overview Talk 5: **MBARI's AUV experience**

Hans Thomas

Beginning in 1999, MBARI began developing unmanned and untethered vehicles, called AUVs (Autonomous Underwater Vehicles) as increase the quality and resolution of existing ocean survey programs, while at the same time reducing the associated costs of these operations. Knowing that there would be demand for diverse payloads, MBARI engineers created a fundamentally modular vehicle that can be quickly reconfigured to host a number of payloads without modifying basic units such as the propulsion, navigation, power, control, and emergency location systems. The Dorado class AUV is 21' in diameter and can be as short as 8' or as long as 21', depending on the mission. The first Dorado was operated in late 2001 to measure the inflow of water into the Arctic basin through the Fram Straits, and provides the basic template for MBARI Dorado-class AUVs.

Since then, variants of the basic vehicle design have been constructed for three basic missions. The first system to come on-line incorporates a variety of physical, bio-optical, and chemical sensors into a platform with 20 hour endurance and Iridium satellite telemetry.

MBARI operates this vehicle as an unattended midwater survey platform, performing regular transects as part of a time series monitoring program. We are currently developing an in-situ water sampler to return pristine seawater samples to shore for laboratory analysis.

The second vehicle constructed is a 6000m geophysical mapping vehicle, equipped with a multibeam echosounder, sub-bottom profiler, and sidescan sonar. The vehicle is capable of performing precision navigation using a Doppler aided inertial navigation system, and can communicate with the surface via a low frequency acoustic modem. The data collected so far has demonstrated the ability to map the seafloor to better than 30cm resolution.

Our current development work focuses on constructing an AUV docking system, allowing a Dorado vehicle to connect to seafloor observatories. The system utilizes a 4000m rated USBL system to home into the dock, and an inductive charging system to transfer power. Initial testing of the homing system has demonstrated a high degree of repeatability.

In this talk, I will present an overview of our vehicle program and provide detail regarding our vehicle systems. I will also discuss some of the recent scientific results of our arctic, CTD and mapping efforts. In closing, I will discuss some of the lessons learned from the various operations.

Overview Talk 6: **Operational feedbacks and innovations for the Asterx AUV and Victor 6000 ROV**

Vincent Rigaud

This presentation will settle the status of the operational ROV "Victor 6000" and 3000m depth AUV "ASTERx" operated by Ifremer.

"Victor 6000" is part of a global system integrating, "scientific module", winch and cable, dead weight and umbilical, positioning sub-system through acoustic ultra short base line (USBL) techniques, and all the exploitation software for the data and dives management. In 2005 the system have been equipped with a second module dedicated to high resolution mapping of the sea bottom, with acoustical and optical devices. Recent key missions on margins, Ridges and for the installation of the ANTARES Neutrinos Telescope would illustrated the feedbacks.

The first Ifremer's AUV named AsterX is 4.5 meters in length with a diameter of 0.69 meters. Depending on the payload its weight is between 600 and 800 kg in air, with a diving depth of 3000 meters. Its cruising speed is between 0.5 to 2.5 meters per second. The AUV is capable of carrying various payloads in its payload sections for wide spectrum of applications. The vehicle can cruise up to 100km range. For coastal applications this vehicle is operated by a

limited crew team possibly from small non-specialized or opportunity vessels. The vehicle have made numerous cruises in Mediterranean sea and in the Atlantic on board IFREMER ships in 2004. Numerous requests to use it on German ships (Missions on the R/V Meteor in 2006 and on the AWI R/V Heincke in 2005) and more than 200 days at sea are requested in 2006. A second vehicle will be design and build in 2005. Cross cooperation with AWI , St Johns university in Canada, and Mississippi University will be active in 2005 and 2006. The second vehicle , optimised from ASTERX design in term of maintenance cost, named IDEFx is under building . Results with multibeam sounder mapping slopes instabilities in Med Sea, with EK60 fishery sounders in North Sea, and with physical sensors sets in Atlantic will illustrate the missions feedbacks with scientific results, and a specific analysis of the operational cost would be presented.

A2 - Future technologies & requirements

Nils Storkersen

I suggest that this group initially take a top-down approach to future ocean science missions and from this break down to isolate the major technology drivers for enabling these future missions. I would imagine that this would lead to requirements for more endurance, better sustainability, more sophisticated autonomy, more precise navigation with less options for external aiding, operations in deeper waters and under ice and requirements to exploit multi-system operations (multiple AUVs and coupling between AUVs and stationary installations on the sea floor). Also new sensors for specific scientific purposes could be required in future missions. I foresee that the group will overlap with most of the other groups in our recommendations, however in addition we will try to capture new ideas in future scientific scenarios.

B2 - Needs of new users

Neil Bose

This section will describe briefly the purchase of an International Submarine Engineering Ltd., British Columbia, Canada, Explorer Class AUV (Autonomous Underwater Vehicle) and outline the needs of the underwater vehicle research laboratory of Memorial University of Newfoundland in setting up the operational infrastructure for the AUV operations. The section will present the results of a discussion from a workshop held at the Masterclass workshop that will consider aspects that include: personnel, funding, insurance and safety. Personnel issues include recruitment, skills and education, training and management. Funding is required for capital, operating, maintenance and repairs. Insurance is a large cost item and is hampered by the very small numbers of users. Safety issues include safety of the vehicle itself and safety of others due to operations of the vehicle: loss and recovery, damage during launch, collisions, operating protocols, regulations, operating personnel and support vessels.

C2 - Deployment & recovery

Peter Stevenson

Autosub, hosted at the NOC and funded by the Natural Environment Research Council (NERC) has been launched and recovered from a variety of ships between 20 and 100m in length. The mobilisation, learning curve and the experience using our bespoke gantry tends to be different of each occasion. Other methods include crane style of cheery picker (e.g. Geosub), stern ramp (e.g. Hugin), or if the AUV is small enough, manually handling it over the side. If working conditions allow, launching a small boat in the water gives a very flexible and simple way of working. However, for open ocean work, this is not an option. The paper will describe the experience gained throughout the history of Autosub and look at methods that others have adopted.

The interface of an AUV launch, location and recovery system with the ship is a significant mobilisation exercise involving equipment deck loadings, significant power supplies, shelter for vehicle and operators, vehicle to ship communications and people communications at

almost every level on the ship. Once these systems are in place the operating issues are not restricted to the physical lifting to and from the sea, the vehicle is not 'launched' until it has started its mission. Similarly, recovery begins by locating the vehicle. These two operations can take more time and create more risk to the success of the mission than what is normally viewed as launch and recovery. Factors that help and events that can go wrong will be described and discussed.

D2 - Autonomy and Collision Avoidance

Miles Pebody

The degree of Autonomy exhibited by AUVs that are operational today is relatively low and varied. Many vehicles are constantly escorted by and in constant communication with a support ship while only a few are operated in a truly autonomous "over the horizon" scenario. The autonomy of all these vehicles tends to consist of a simplistic event driven waypoint following behaviour. The reasons for this are practical rather than technological. An AUV that is relatively straight forward to operate and does more or less exactly what it was told is generally more likely to be ready and in a working state at the prescribed time and place for deployment. However, the use of AUVs is becoming more widespread and the environments in which they operate and the tasks they perform becoming more challenging. Consequently an increase in autonomy is inevitable.

One area where enhanced autonomy is being utilised is that of collision avoidance. AUVs such as the NOCS Autosub have been equipped with reactive control behaviours that use sensed information of the local environment to avoid collisions and obstacles within the course of their scripted waypoint tracking. In addition to the collision avoidance behaviour that is fundamental to furthering the mission capabilities of AUVs, other autonomous control behaviours are being developed such the automated nested survey system that is operational in the Woods Hole Abe vehicle. Other more advanced and higher level forms of Autonomy such as autonomous mission planning are yet to appear in a sufficiently robust and tested form for them to be adopted by the ocean science and offshore survey communities.

This talk will set the scene for the Autonomy and Collision Avoidance break out group discussion. A few questions will be posed, however it is hoped that the contents of the talk will stimulate more.

A3 - When things go horribly wrong

James Ferguson

The motivating influences for the development of AUVs have been, and continue to lie in the reduction of cost and risk attendant with subsea survey. AUVs were developed to acquire data more cost effectively than manned systems and to go to places where it was unsafe to send humans. Implicit with this rationale is the probability that some vehicles are going to be lost. In open water, a loss is not necessarily catastrophic as the vehicle will often return to the surface, or signal its presence from the seabed. Under-ice, things can get horrible as the title suggests. It is time consuming to find a vehicle that is either floating under the ice or bottomed. In some instances, weather, ice conditions and the environment come together to make the loss irretrievable with only one thing left to do – call the insurance underwriter or tell your funding sponsor to order another vehicle.

Consequently, we should expect to lose AUVs. It should be an event that is planned for – just as one plans for other breakdowns or malfunctions. The planning starts with some consideration as to how expensive a system should be if it is going to be expendable and continue to encompass a spare vehicle to complete the operations. Planning can also provide for localization and reactivation operations to find a lost vehicle and put it back to work. Planning against the possibility that a vehicle may be lost is equally important. This aspect of planning starts in the design and takes into account how reliable the vehicle should be, and how much that reliability should cost. This aspect of AUV development is covered separately in the workshop.

Planning also extends into real time with the use of tools such as mission planners, fault-response software and obstacle avoidance systems. Tools such as these have served us well in open water, but perhaps are they are good enough for under-ice operations. Can decisions continue to be based on simple look-up tables? This topic was hotly debated at an IARP Workshop in 1994, and it may be time to have this discussion again.

These notes are intended to set the stage for a breakout group that will be asked to consider issues such as

- a. what to do when you think you've lost your AUV
- b. what could have been done to reduce the chance of a loss
- c. which is better – insurance or redundancy (spares)
- d. is there technology which could help to prevent a loss – and what's the risk of it not working
- e. are we doing a good enough job in educating our funding sponsors about expendability and the value of the data we are getting

B3 - Risk, Reliability and Mitigation for Polar AUV Missions

Gwyn Griffiths

On 22 August 1931, to the north of Svalbard, a submersible attempted to perform a science mission under polar sea ice for the very first time. The mission failed. Nautilus could not dive. Inspection showed her dive planes were no longer present. The exact reason remains unknown. Sabotage was suspected. Nevertheless, H U Sverdrup and others brought back exciting new information on seabed topography and ocean circulation in the Arctic.

On 16 February 2005, at Fimbulisen on the edge of the Antarctic ice cap, an autonomous underwater vehicle set out on a science mission under the ice shelf. The vehicle did not return. Autosub2 was lost, under 200 m of ice, some 17 km from the face of the ice shelf. The exact reason remains unknown. Connectors were suspected. The earlier successful mission has brought back startling and unexpected information on the roughness of the under side of the ice shelf.

It is quite possible that the real causes for these two failures had nothing to do with the polar environment itself, and yet the environment was a major factor, through fear in the Nautilus and through precluding recovery of Autosub.

What is clear is that the reliability of AUVs needs to be improved. There is a severe lack of data and analysis in the open literature on AUV reliability. What there is gives rise to concern. Published results for Autosub2 (NOCS) and Dorado (MBARI) suggest that for both vehicles the probability of completing a 24-hour mission without a fault was below 61%. Experience with the C-Surveyor AUV showed that the initial reliability was low, but that extensive use over 12 months and more brought the availability in any one month up to over 90%. Without human intervention, might the Theseus AUV still be lying beneath sea ice north of Ellesmere Island?

There are attendees at the Masterclass that are uniquely placed to:

- a) contribute to the debate on AUV reliability;
- b) make a significant contribution in the move from anecdote to quantitative assessment of AUV risk and reliability for several vehicles
- c) embark on a transition from 'revealed reliability' to 'targeted reliability', including increasing our visibility with sub-system manufacturers
- d) share information that may help others in their quest to improve the reliability of AUV missions through technology and through mitigation.

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C3 - Future campaigns & missions

Jeremy Wilkinson

The polar oceans are an ideal home for AUV technology as the almost continuous covering of sea ice prevents the use of most autonomous oceanographic platforms. At present under-ice investigations have been limited to submarine operations. Since the end of the Cold War the deployment of submarines in the Arctic has become more sporadic and their use in the Antarctic is prohibited. AUVs offer scientists the flexibility to determine the location as well as timing from which scientifically controlled and directed missions can occur. The AUV has many advantages over submarines, notably the high resolution which is possible by sailing close to the ice bottom or in areas of shallow bathymetry. More importantly the AUV can be viewed as a multidisciplinary tool and therefore it enhances partnership between scientists from different disciplines. Whilst my interest is purely scientific, to many AUVs have a more, dare I say, practical usage. With oil exploration already occurring in ice covered seas and predicted to accelerate there is an urgent need to determine the sea ice and oceanographic properties at these sites, the AUV offers many challenges and opportunities in this field. It is unlikely that a one size fits all approach to AUV design will fulfil all our aspirations, however this workshop should unlock many of the doors that have remained closed to polar oceanography and with a little imagination anything is possible...

Future Opportunities for Polar AUVs and Workshop Roundup

James Ferguson

This is the first convention of AUV users that has focused solely on Arctic operations. It is fitting that such a convention should occur as researchers are starting to plan their IPY activities. It is also fitting that this occur at a time when evidence of polar warming is pointing towards the possibility that polar sea resources may shortly become more accessible than they have been for the past .

This Masterclass brings together past, current and future users of AUVs with polar applications. Perhaps the smallest group is the past user - those who come with under-ice AUV experience. This group provides some grounding on what can and what cannot currently be done, and how to do it. Of greater significance however, are the current and future user groups that come with new requirements and applications necessary to develop the economic resources as they become accessible in the coming decades. The accomplishment of the Masterclass is in bringing these groups together for 3 days and to work together in defining how these new requirements can be met.

Providing a roundup for the Masterclass is not simply a matter of tabling the new opportunities for AUVs that become apparent during the three days. It is also important to understand the technology and infrastructure that exists as well as what might be required to enable these new applications.

In rounding up the Masterclass, a synopsis of current and new applications will be distributed along with an outline of the supporting technology required. The roundup will then proceed interactively to “fill” out this synopsis, resulting in a number polar AUV research and development. Finally, an effort will be made to find within the convention body volunteers who are willing to follow up and report on the progress of these activities.

AUVs in the context of global climate change

Colin Summerhayes

Even if man had no impact on the climate, it would still be changing. As climate affects everything we do, and will affect progressively more people as population grows and resources diminish, there is an increasing need to observe climate change now as the basis for forecasting the rates and magnitudes of future change. Those forecasts are essential to underpin global sustainable development, and will be useful to forestry, agriculture, fisheries, energy supply, water supply, and the transportation, construction, and recreation industries. The added effect of emissions of greenhouse gases merely exacerbates an underlying problem. More emissions will make the problem worse.

The oceans play a crucial role in governing the climate, through the ocean's tremendous heat capacity (as much heat can be stored in the top metre of the ocean as in the whole of the atmosphere), and the tendency of ocean currents to move that heat around, northwest Europe being a prime beneficiary. Accurate climate forecasts depend therefore on an abundant supply of ocean data. Although the ocean's surface is now well sampled by sensors on satellites, they cannot 'see' the ocean beneath the surface. There we rely on data from fixed moorings, profiling floats (Argo), ships of opportunity deploying disposable bathythermographs, repeat hydrographic sections, and the activities of underwater vehicles such as Autosubs or gliders. Provided that Autosubs and gliders can be manufactured in large enough numbers and at low enough cost they may replace ships to a large extent as a major source of subsurface ocean data. AUVs are unlikely to be able to compete with the high data returns and low costs of drifting (Argo type) profiling floats, but fill a different niche because they can be directed. One of the key elements in the ocean's transport of heat and freshwater is the Antarctic Circumpolar Current, whose remoteness makes it costly to investigate. AUVs may have an important role to play in monitoring the behaviour of this complex and powerful part of the climate system, where sinking surface waters form Intermediate and Mode Waters that ventilate the upper ocean globally. The Southern Ocean close to Antarctica plays a different but equally key role in the climate system, as this is where North Atlantic Deep Water wells up from below, releasing CO₂, and where Antarctic Bottom Water sinks. Observing these key processes is made doubly difficult by the combination of geographical remoteness, and a winter cover of sea-ice that doubles the size of Antarctica. AUVs provide a practical (though not yet entirely reliable) means of gathering climate-relevant data from beneath this icy cap. AUVs have an equally important role in monitoring ocean behaviour in relation to climate change beneath the ever-shrinking Arctic sea-ice. With the creation of the Global Earth Observing System of Systems (GEOSS), of which the Global Ocean Observing System (GOOS) and the Global Climate Observing System (GCOS) are integral parts, governments are demonstrating that they have woken up to the need to observe the Earth's environment. As the polar oceans are heating up faster than other parts of the ocean system, they are the harbingers of change elsewhere, and governments would do well to use the GEOSS to pay them much more attention. Now is the time to press the case for under-ice observations of the oceans by AUVs.