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CASEE sponsored papers:

HIGH LATITUDE OCEANOGRAPHY USING THE AUTOSUB UNDERWATER VEHICLE

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We use a combination of measurements using Autosub, an autonomous underwater vehicle (AUV), and those from ship-based instruments to describe the oceanographic conditions beneath Fimbul ice shelf, Antarctica. The data show an intricate oceanographic regime that is suggestive of variability at seasonal or longer time scales. The snapshot survey data complement those obtained from instruments moored beneath the ice shelf. These also show substantial temporal variability including events where the potential temperature beneath the ice shelf increased by as much as 0.2 degrees. We contrast the two techniques and discuss how one might optimise observation strategies in future campaigns. An Autosub campaign in an East Greenland fjord is used to highlight other observational constraints and opportunities, looking at the meltwater from a tidewater glacier.

AUTOSUB-UNDER-ICE: COMBINED SCIENCE USE AND TECHNICAL DEVELOPMENT IN A POLAR PROGRAMME

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The United Kingdom's Autosub-Under-Ice(AUI) programme (2000-2007) brought together scientists and technologists

to build a special polar-capable autonomous underwater vehicle (AUV) and use it for scientific research on three dedicated cruises of the research icebreaker, J.C. Ross, in both the Arctic and Antarctic. The Autosub AUV was specifically funded to investigate the ice shelf cavities and under sea ice environment in both polar regions. We discuss the merits and challenges of the approach used whose ultimate aim was to use the vehicle simultaneously on a number of highly disparate programs; from mapping using swath bathymetry, water sampling and CTD while underway, measuring ocean currents using ADCP, and digital photography of the benthic life. Technical challenges included developing autonomous precision navigation, obstacle avoidance systems and a water sampler. Science advice and support proved vital in identifying difficult operating conditions and in building cruises to maximize Autosub and vessel utilization. A current challenge is to work internationally, at present highly encumbered because of the structure of national research programmes where suitable working vessels are in different nations than the UK. Developing international cooperation is therefore crucial to allow this new polar capability to be maximized for scientific gain.

DEVELOPING A LONG TERM STRATEGY FOR USING AUVS IN POLAR RESEARCH

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Three international workshops have reviewed the use of Autonomous Underwater Vehicles (AUVs) in polar and extreme environments:

(1) Acoustic Navigation and Communications for High-latitude Research, Seattle, Feb.06

<http://anchor.apl.washington.edu/index.html>

(2) Masterclass in AUV Technology for Polar Science, NOCS, Mar. 06

<http://www.noc.soton.ac.uk/CASEE/CASEE2/Introduction.html>

(3) AUV Science in Extreme Environments, SPRI, Apr. 07

<http://www.noc.soton.ac.uk/CASEE/CASEE2/pages/Science.html>

The proceedings for the latter two have been published and case studies are being presented within Session 3.4 of this meeting. AUV technology is well developed and can answer a range of scientific questions beyond the capabilities of other technologies. The third workshop identified that there was a need for strategic planning for the incorporation of AUVs into polar research, especially given the long term legacy objectives of IPY specifically:

- A collective multinational programme drawing upon national assets and resolving the institutional barriers to implementing this.

- A move from short expeditions to long term effort, (sufficiently resourced to withstand occasional setbacks) for example: routinely launching and recovering AUV from bases around the Antarctic, Lagrangian drifters and acoustic navigation networks (ANCHOR).

- The need for interoperability, standardisation of equipment and support infrastructure.

AUTONOMOUS UNDERWATER VEHICLES IN POLAR EXPLORATION: QUANTIFYING RISKS FROM SEA ICE

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Autonomous Underwater Vehicles (AUVs) are becoming highly capable platforms for multi-disciplinary science investigations in the polar oceans. However, their operation under ice does involve a significant degree of risk of losing

the vehicle. A risk assessment and management process (RMP-AUV) has been devised that balances the risk appetite of

the responsible owner with the reliability of the vehicle and the probability of loss. This last step involves expert judgement, and is sensitive to the type of ice cover. In contrast to the simple, high risk, case of operation under an ice shelf, sea ice offers a more complex risk environment. However, the risk is further modified by the characteristics of the

support vessel, including its ice-breaking capability. We explore how the ASPeCt sea ice characterisation protocol can be used within RMP-AUV to quantify risk under different conditions on ships of differing ice capabilities, and how experts have scored the relative risk of operations of the Autosub AUV under shelf and under sea ice.

COLLABORATIVE AUTOSUB SCIENCE IN EXTREME ENVIRONMENTS PROGRAMME SUMMARY

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This programme has reviewed the use of Autonomous Underwater Vehicle (AUVs) technology and science in polar environments through two international workshops:

Masterclass in AUV Technology for Polar Science, NOCS, Mar. 06.

<http://www.noc.soton.ac.uk/CASEE/CASEE2/Introduction.html>

AUV Science in Extreme Environments, SPRI, Apr. 07

<http://www.noc.soton.ac.uk/CASEE/CASEE2/pages/Science.html>

The proceedings of both have been published reviewing the achievements of Autosub and other AUVs. Autosub uniquely has ventured beneath the Fimbul ice shelf. AUVs have measured ice thickness, undertaken sidescan surveys of

the seabed and the underside of ice, used ADCPs and CTDs data to determine flows and thus calculate heat fluxes beneath ice masses, collected water samples for isotopic analysis, photographed seabed features with associated

megafauna and mapped krill distribution. This poster illustrates the results of these studies and summarises the range of programme outreach activities including web broadcasts and young research bursaries to promote international collaboration.

AUTONOMOUS UNDERWATER VEHICLE MEASUREMENTS OF SURFACE WAVE PROPERTIES IN THE MARGINAL SEA ICE ZONE

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The Autosub AUV (autonomous underwater vehicle) of the National Oceanography Centre (UK) carried out several missions under sea ice in March 2003 in the western Bellingshausen Sea. Data from the upward-looking Acoustic Doppler Current Profiler (ADCP) indicate a strongly-oscillating horizontal velocity of the ice due to ocean swell. The nature of the swell depends on distance from the ice edge, evident from the three missions in which the vehicle traveled

from the ice edge to the interior of the ice pack. Swell period, height, direction, and directional spread have been computed every 800 m from the ice edge to 10 km inward for these missions. Exponential, period-dependent attenuation of waves propagating through sea ice was observed. Mean period increased with distance from the ice edge.

The wave field was refracted during propagation through the ice cover. The directional wave spread does not seem to relate to distance from the ice edge, although higher frequencies tended to be more spread. An ordinary ADCP suitably deployed from an autonomous or fixed platform may be used with this technique to study both scalar and directional properties of waves in open or ice-covered water.

UNDER-ICE TURBULENCE MEASUREMENTS IN THE ARCTIC SUMMER MADE BY AN AUTONOMOUS UNDERWATER VEHICLE

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Horizontal profiles of ice-ocean boundary layer fluxes in summer were obtained using data collected by an Autonomous

Underwater Vehicle (AUV) during the Surface Heat Balance of the Arctic Ocean (SHEBA) experiment of 1998. Scalars and their fluxes, as well as vertical stability, varied in the horizontal direction with correspondence to the changes in the overlying surface. A highly-stable fresh layer of ice and snow melt was formed in leads and grew in thickness over June and July. Subsequently, a storm removed this layer via shear-generated turbulence, supercritical hydraulic flow speeds, and ice divergence. Strong fluxes were observed under and downstream of rough, ridged ice, and properties changed rapidly with distance downstream of leads. The location and signs of the fluxes suggest that fresh surface water was forced under more dense salty water downstream of leads and/or ridges. Simulations from a 2-D unsteady model suggest that both mechanical forcing from ice topography and a dynamic instability near downstream

lead edges may enhance vertical mixing, particularly when ice velocity is large. The horizontal variability in interfacial fluxes observed at SHEBA may explain the difference between the observed melt rates and those calculated using a bulk relationship.

PHOTOGRAPHIC ASSESSMENT OF POLAR BENTHIC COMMUNITIES USING AN AUTONOMOUS UNDERWATER VEHICLE

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We outline the development, integration and use of a digital stills camera system for the Autosub Autonomous Underwater Vehicle and describe its use in polar benthic community assessment. The operational limitations of Autosub, particularly the safe flying altitude of 10m required solutions for effective photography. A high-sensitivity

Starlight SXV-H9 monochrome CCD camera system and Minolta 3600HS zoom flash were integrated into Autosub; the system was small enough to fit into the limited scientific payload space and had low power consumption. The camera required autonomy in operation and links to the onboard computer systems on Autosub. The system successfully carried out science missions in East Greenland (September 2004) and the Weddell Sea, Antarctica (Feb 2005). Autosub photographs were suitable for biological and geological analysis and allowed comparable assessment of faunal density and diversity with those obtained with a towed camera platform (WASP), they covered a comparable area and were more consistent but had a slightly lower resolution and lacked colour information. While the expense of AUVs is a consideration in their imaging potential, their autonomous nature allows use in remote polar environments where community assessment is impossible with existing technology.

FRESHWATER TRANSPORT AT FIMBULISEN, ANTARCTICA

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The intricate near-circumpolar system of fronts and currents surrounding Antarctica isolates much of Earth's freshwater from the saline oceans immediately north. The Antarctic Slope Front sustains bathymetrically-steered flow at the shelf break whereas the shallow Coastal Current travels rapidly alongside the ice front. A hydrographic survey of the northeastern Weddell Sea finds these two features to have merged near the narrow (<40 km wide) continental shelf at Fimbulisen. On the prime meridian, its Trolltunga ice tongue overshoots the shelf break into this slope current. Observations either side of this feature demonstrate its retarding effect on the westward-flowing waters it overhangs and its contribution to the freshwater budget. From oxygen isotope ratio measurements and referenced geostrophic shears, we find the combined glacial meltwater and sea ice melt transport to account for 1.2% of the total 1.6 ± 0.2 Sv westward transport ($Sv = 10^6 \text{ m}^3 \text{ s}^{-1}$). Downstream from Trolltunga at 3°W , we find this figure to ultimately increase to 0.9% of 2.8 ± 0.4 Sv. This highlights the disproportionately large role Fimbulisen plays in preconditioning shelf waters before they reach broad continental shelves in the southwestern Weddell Sea where their transformation to bottom waters helps drive the shallow and deep limbs of the meridional overturning circulation.