

**SCAR Subglacial Antarctic Lake Environments (SALE)
Scientific Research Program
Four-Year Cumulative Progress Report
Renewal Application - 2008**

I. Outputs/Deliverables

(a) Key achievements – The SCAR SALE program is a facilitator of partnerships and cooperation and as such does not produce scientific outputs per se. However, members of SALE funded through their national programs conduct the science of SALE. In this sense the achievements of SALE research over the first 4 years of the program have been a collaborative and interrelated set of advances by a cohort of national efforts. Major new understanding and recognition of phenomena related to subglacial aquatic environments are advancing our understanding of Antarctica now and in the past on a number of fronts. This was demonstrated by presentations at a workshop in 2006 and articles that have appeared in leading scientific journals over the past 4 years. These new insights are the key scientific achievements of the SALE program and could only be achieved by the funding and support of individual national programs. Since these environments have yet to be penetrated and sampled in a rigorous manner, SALE science and discovery is at the very beginning of what will be many years of research. We have chosen to express the program's achievements as scientific and programmatic, with one advancing scientific understanding of these environments and the second facilitating and developing an international SALE community, both are important missions for a SCAR Scientific Research Program.

Scientific Achievement #1 - *Subglacial accumulations of water are common features beneath thick ice sheets*

In 2005, the second inventory of Antarctic subglacial lakes and aquatic environments was published, containing details (location, size, ice thickness) of 145 lakes, 68 more lakes than the previous inventory of 1996 (Siegert et al. 2005). Since this publication, several new lakes have been identified, bringing the total identified features to over 160. A third inventory is planned for 2010. It is expected that as aerial coverage by various types of survey techniques planned during the IPY improves, the number of recognized subglacial features will dramatically increase.

Scientific Achievement #2 - *Outburst discharges of subglacial water have repeatedly occurred over geologic time and are an on-going process that influences the dynamics of the overlying ice.*

Satellite altimetry of the ice sheet surface has shown that a portion of the central East Antarctic ice sheet lowered by 2-3 m between 1996 and 1997, at the same time the ice sheet was elevated 1-2 m some 250 km away. The only feasible explanation for this observation is the rapid loss of 1.8 km³ of water from a subglacial lake, which flowed along the base of the ice sheet and into a series of other lakes (Wingham et al., 2006). Similar observations have been made near the margins of West Antarctica (Gray et al., 2005, Fricker et al., 2006). Significant fluxes of water are flowing beneath the Antarctic ice sheet producing an interconnected system of subglacial lakes. The consequences for subglacial lakes as habitable environments and for modifications to large-scale ice flow conditions are considerable. The expected pathways of subglacial

water drainage have been calculated, revealing a coherent network of channel systems, feeding water from large upstream catchments into several large outlets. Through these hydrological systems it is plausible that subglacial water can flow from the interior of ice-sheets to the ocean (Siegert et al., 2007). The land forms created by paleo-outbursts have been documented suggesting that these processes have been an important agent of morphologic change over geologic history (Marchant, et al 1993).

Scientific Achievement #3 - *A Spectrum of Subglacial Aquatic Environments Exists*

Subglacial aquatic environments occur in a range of geological settings suggesting that individual lakes may have differing origins and evolutions. Subglacial aquatic environments are not randomly distributed across the Antarctic continent, occurring in preferred locations. This suggests that the limnological conditions, the age, the source of founder microbes, the time of isolation and the extant microbiological inhabitants will vary from location-to-location. More than one classification system has been proposed. The recognition of a spectrum of subglacial lake types provides a framework for comparing and contrasting lake environments across the Antarctic continent greatly enhancing our ability to test fundamental hypotheses about the origins, evolution, and significance of subglacial aquatic environments to the evolution of the Antarctic continent, its ice sheets and microbiota.

Programmatic Achievement #1 – *Building of a SALE community through workshops, meetings, and sessions at scientific meetings*

Programmatic Achievement #2 - *Identification of major scientific and technological goals for SALE research and exploration through active engagement of the community*

Programmatic Achievement #3 – *Provision of the framework for the US National Academies report on environmental stewardship of subglacial aquatic environments*

Programmatic Achievement #4 – *Regular meetings that serve as forums for the discussion of science and technology amongst national programs*

Programmatic Achievement #5 – *Education of the public through extensive and sustained coverage of SALE science in the lay and scientific press*

(b) Contributions to IPY programs

- SALE is a recognized IPY Program as SALE – the Unified International Team for Exploration and Discovery (SALE-UNITED). It is IPY Project-42. http://www.ipy.org/index.php?ipy/detail/sale_united/
- Antarctica's Gamburtzsev Province Exploration program includes subglacial lake characterization.
- Subglacial aquatic environments are a target for exploration by the US-Norway Traverse 08-09.
- SCAR SALE adheres to and abides by all IPY data policies.
- SCAR SALE participates in IPY education and public outreach activities (SALE UNITED was a featured program in the IPY Program Office Ice Sheet day in 2007).

- German SALE-UNITED activities are highlighted on the German IPY homepage (in German and English).
<http://www.polarjahr.de/SALE-UNITED.343+M52087573abo.o.html>

(c) List of publications in peer reviewed literature – Most SALE related publications are the result of national SALE programs in various countries that are members of SALE. The number of SALE related publications in peer-reviewed journals is increasing each year and this can be seen as an extrinsic metric of SALE performance in facilitating SALE science. However, SALE does not take credit for, nor is it credited in, such publications.

- Lists of publications by year are maintained at the SCAR SALE web site <http://scarsale.tamu.edu/selected-publications>.
- The SALE Workshop organizers (Kennicutt and Petit) published an EOS front page article in 2007. EOS Transactions Vol. 88, No. 11, 13 March 2007, Pages 129, 131.
- Many important articles have been published in Science and Nature on various aspects of SALE science authored by SALE participants and collaborators.

(d) List of other publications

- The 2006 workshop produced a workshop report that can be viewed at the workshop web site. <http://salepo.tamu.edu/saleworkshop2006>
- Other SALE related workshop and meeting reports are archived at the SALE web site <http://scarsale.tamu.edu/archives>

(e) Lists of brochures, posters, press/media articles and similar PR material

- SALE has garnered significant popular press attention over the years and selected instances are chronicled at the web site - <http://scarsale.tamu.edu/press>
- A 3-fold glossy brochure of the 2006 workshop recommendations was produced and widely circulated.

(f) Details of the SRP web site and number of hits per web site

- The SALE web site was restructured and relocated in 2007. Web site statistics were not collected on the old website and the new website has not been “live” long enough to establish utilization. <http://scarsale.tamu.edu/>
- A German Lake Vostok project web suite has been established (<http://www.geo.uni-bremen.de/geomod/staff/grosfeld//LV.html>) and for the geodetic project (http://www.tu-dresden.de/ipg/ipy_saleunited.html).

(g) Information on SRP database(s), and amount of use of database(s)

- The SALE data policies are outlined at the SALE web site <http://scarsale.tamu.edu/data-portal>. SALE does not attempt to archive data or monitor access to data other than acting as a portal to existing data repositories and archives.

(h) Number and type of education/training and other capacity building activities

- SALE sponsors workshops and encourages the formation of SALE sessions at major scientific meetings world-wide – i.e., AGU, EGU sessions are regularly held. There was a SALE Union Session at the Fall, 2007 AGU National Meeting that was attended by about 125 people.

- During each SALE meeting local students and experts in relevant fields are invited to be observers and to present their latest research findings.

(i) Notes on new technology/model developments

- SALE workshops and sessions always include a discussion of the latest technological developments.
- SALE stays abreast of developments in the ice coring, sediment coring and scientific drilling communities by inviting speakers to meetings and maintaining liaisons with these groups.
- A 3D numerical Ocean circulation model was further developed for the investigation of subglacial lake circulation and the interaction between ice sheet and subglacial water bodies: ROMBAX. Coupling with a numerical ice sheet model is envisaged (C Mayer and F. Pattyn).

II. Inputs

(a) Number, gender and country of participating scientists other than those on the steering committee

- The original SALE membership included 10 members from 6 countries - France, Germany, Italy, Russia, United Kingdom, and United States.
- SALE membership has been expanded to 14 members from 9 countries (Belgium, Japan and China).
- SALE currently includes 13 male and 1 female members.
- At SALE Meeting #2 (April, 2006) SALE recommended an expansion of its membership to 14 which increased the number of countries participating to 9 (Belgium, China and Japan) and improved disciplinary balance.
- The latest details about SALE membership can be found at the web site; <http://scarsale.tamu.edu/About/membership/membership.html>
- A plan for rotation of SALE membership in 2009 is provided in Appendix 1 that increases female participation from 1 to 3 (of 14 total) and increases the number of participating countries by 40% in comparison to SALEGoS membership (4 years ago).

(b) Title, place and type of meetings/workshops, and numbers, genders and countries represented in their attendees

- SALE has annual meetings and minutes are posted on the web site. Presentations are posted as well <http://scarsale.tamu.edu/meetings>. These meetings are attended by the SALE members and augmented by local observers as noted in the meeting minutes (gender, country of origin, and numbers can be ascertained from the meeting minutes):
 - SALE Meeting #1, Vienna, Austria, April 2005
<http://scarsale.tamu.edu/meetings/sale-meeting-1-april-2005>
 - SALE Meeting #2 - Grenoble, France, April 2006
<http://scarsale.tamu.edu/meetings/meeting-2-april-2006>
 - SALE Meeting #3 – Big Sky, Montana, June 2007
<http://scarsale.tamu.edu/meetings/meeting-3-june-2007>
- SALE co-sponsored a major international workshop in April, 2006 in Grenoble, France, entitled: “SALE in the IPY: Advanced Science and Technology Planning”,

There were 84 attendees from 11 countries. Fourteen (14) women attended the workshop. For details go to the workshop web site.

<http://salepo.tamu.edu/saleworkshop2006>

(c) Links to other SCAR SRPs or SCAR Action or Expert Groups

- SALE is most closely linked SCAR SRPs ACE and EBA and has formal liaisons with these SCAR SRPs.
- Two SALE members are active ACE members (M Siegert and R Powell).
- One SALE member is an active EBA member (J Priscu).
- SALE representatives attended ACE (M Kennicutt) and EBA (J Priscu) planning meetings in 2005 and 2006.
- SALE will liaise with the Expert Group on drilling once established.

(d) Links to other ICSU bodies or to other scientific groups

- SALE has explored links with COSPAR but no beneficial relationships have evolved.

(e) Development and staffing of a project office or other administrative support

- The SCAR SALE Program is housed at Texas A&M University under the supervision of M Kennicutt. The web site was recently restructured and relocated to <http://scarsale.tamu.edu/>
- Administrative and computer support is provided by the Office of the Vice President for Research at Texas A&M University for SCAR SALE.

(f) Sources and amounts of SCAR and external income (or in kind contribution) for project activities

- A workshop proposal for \$75,000 was funded by the US National Science Foundation Office of Polar Program - 7/19/05. Additional funds (Euros 15,000) were provided to the workshop by CNRS-INSU, University Joseph Fourier Grenoble, Ministere de l'Ecologie et Developpement Durable and Rhone Alpes region
- Hosts of SALE annual meetings provide local facilities at no cost to the program.
- The office of the Vice President for Research at Texas A&M University provides in-kind support for the SCAR SALE web site.

(g) Expenditures on project activities

- SCAR provides between \$21,000 and \$23,000/year and most funds are spent on travel expenses for SALE members to attend the yearly SALE meetings.

III. Future Plans

- 1) Membership** – It is essential that SALE membership is renewed on a regular basis to allow for broad participation, refreshing of ideas and perspective, and to ensure proper disciplinary balance. A SCAR membership rotation plan is provided in Appendix 1.
- 2) Revised Meeting Organization** – At each meeting a major aspect of SALE science will be the focus and a program of invited speakers will be developed for the

chosen topic. The outcome from these meetings will be a white paper published in a journal summarizing the state-of-the-art and recommending next steps. To increase participation, the responsibility for organizing these focused meetings will reside with the SALE members who are the most expert in the topic to be discussed. This does not preclude a brief update of all aspects of SALE science and technology at each annual meeting.

- 3) Major Workshops - Advancing SALE Science and Technology** – On a regular basis, when advances warrant it, major workshops will be convened to exchange new information and knowledge with a larger audience. Events of this type require external funding and will be developed and organized as the need arises. Preliminary application for an AGU Chapman Conference entitled “EXPLORATION AND STUDY OF ANTARCTIC SUBGLACIAL AQUATIC ENVIRONMENTS” has been made by M Siegert and M Kennicutt. If approved, the conference will be held in the US in 2010 and produce an AGU monograph. The Conference will provide a forum for presentation of the latest information developed during the International Polar Year 2007-2008.
- 4) Organize SALE Sessions at Science Conventions** – A regular meeting agenda item will be assignment of responsibilities for proposing and organizing SALE sessions at all major earth and polar science meetings and venues. Volunteers will be assigned to specific meetings and the theme will be agreed.

5) National Programs

- **Subglacial Lake Ellsworth, West Antarctica (UK, US, BEL, GER, NZ, CHILE)** – A multidisciplinary, international team has been assembled to plan the direct measurement and sampling of Subglacial Lake Ellsworth (Siegert et al., 2004; www.geos.ed.ac.uk/ellsworth). The project will be conducted in three stages. The planning stage has been completed, and an outline of what needs to be achieved has been published (Lake Ellsworth consortium, 2007). The geophysical survey stage is being undertaken in 2007-8, in which a full array of seismic and radar measurements will quantify the shape and depth of the lake, and the surrounding topography and hydrology. Based on the outcome of the geophysics results, the third stage is to explore and access the lake. This will require the construction of a probe to measure and sample the lake water and sediment, a hot-water drill to access the lake, and a gravity core to extract a sediment sequence from the lake floor. The access experiment, using hot-water drilling, will preserve the pristine environment of the lake, and will follow advice as laid out in the 2007 NAS report on subglacial lake access and stewardship. Samples extracted from Lake Ellsworth will be analyzed in a number of laboratories to identify life and the conditions in which it survives, the chemistry of the lake water, and the records of climate change held in the sediment. If funded the access experiment could take place as early as the 2012/13 season.
- **Subglacial Lake Vostok, East Antarctica (RUS)** – The multidisciplinary national project entitled “Water Sampling from the Surface Layer of Lake Vostok” will be implemented by Russian research teams representing the Federal Service for Hydrometeorology and Environmental Monitoring, the Ministry of Education and Science and the Russian Academy of Science in the framework of the 3rd stage (2009-2012) of the subprogram “Exploration and Investigation of Antarctica” of the Federal Program “Global Ocean”.

During Antarctic seasons 2008-09 and 2009-2010 the Russian Antarctic Expedition will continue the ice drilling in the borehole 5G-1 at Vostok station at the depth range of 3668 – 3720 m by means of an electrical mechanical drill. At the final stage of the season 2009-2010 this drill will be exchanged for the thermal drill which will be used for the penetration to the water layer of Lake Vostok. The draft CEE for this type of activity was presented by Russia at ATCM XXV in 2002 in Warsaw, Poland. The revised draft CEE for penetration to the lake with the purpose of (surface) water sampling was submitted by the Delegation of Russia at ATCM XXVI in 2003 in Madrid, Spain. Russia will present the final CEE at ATCM XXXII in 2009 in Washington, USA just before starting the Antarctic season 2009-2010. The first water samples from the surface layer of the lake are expected to be collected in early January 2010. The drilling of the newly formed ice core from the frozen water, originating from the surface layer of Lake Vostok water that will enter (rise up into) the borehole, will be carried out during the season 2010-2011. These samples provide a first approximation in assessing both the geochemical and microbiological composition of the surface water of Lake Vostok.

For investigating the water column and bottom sediments of the subglacial Lake Vostok another national interagency project entitled “Complex biophysical-metagenomic exploration of the subglacial Lake Vostok (water and sediments) in Antarctica as the only Earthly analogue of extraterrestrial icy environments” will be realized. At present time this project is submitted for endorsement to the Presidium of the Russian Academy of Science. The project is led by the St. Petersburg Nuclear Physics Institution, RAS and envisages the development, construction and testing of a special set of biophysical instruments to be deployed in the borehole aboard vehicles (ROV or AUV like) designed to detect life *in situ* in the water column and in lake sediments. Technologies and protocols for the bio-decontamination of the vehicle-based instruments and their transportation (by means of a special module) through the overlying column of drilling fluid will be developed.

The development of ROV/AUV-based sensors and relevant instruments along with a module to transfer them through the drilling fluid column is planned for 2009-2010. The prototypes will be constructed in 2011-2012 and field trials will be conducted during the season 2012-2013. Simultaneously with the ‘hydrocryobot’ development in 2010, a draft CEE for this type of activity will be prepared. The document may be presented to CEP at ATCM XXXIV or ATCM XXXV.

- **Dynamics of Subglacial Lake Environments (GER, BEL, UK, US)** - In the coming years a German/Belgium research team, in cooperation with colleagues from different countries, aims on providing answers to several of the major issues connected with the interaction between subglacial water bodies, the overlying ice and drainage at the ice sheet bottom and across the ice sheet's boundaries. The approach contains the coupling of already existing numerical models of high-resolution ice dynamics and subglacial lake circulation. This will be completed by developing means for the implementation of drainage mechanisms into the coupled model. A considerable effort is taken in order to evaluate the model's reliability for the best known ice-lake system of subglacial Lake Vostok. With a working numerical model system at hand a number of very important questions will be tackled which are crucial for evaluating the recent and future physical/dynamical condition of the Antarctic Ice Sheet. Namely, the relevance of subglacial water bodies for the dynamic

situation of the ice sheet will be investigated, starting from large subglacial lakes and reaching down to local drainage systems. Also the significance of lake existence for the onset of ice streams and the influence of major subglacial water bursts on the adjacent oceanic circulation will be investigated within this project. A synthesis of the investigated mechanisms and their impacts will provide new ideas about the dynamic status and the sensitivity of large parts of the Antarctic Ice Sheet.

APPENDIX 1 Proposed SALE Membership – 2009 -2010

SALE members had a robust and thoughtful discussion about how best to configure SALE membership on entering its second 4-year term. SCAR procedures for Scientific Research Programs were devised to ensure that science programs remain vibrant, stay abreast of the state-of-the-art, aspire to the highest quality science, and have a finite duration. It was also an objective to ensure broad participation and representation of the best that the SCAR scientific community has to offer. SALE membership agreed that these objectives could be obtained and that the 4-year rotations could be used to invigorate the program for the coming years.

SALE is entering a critical period in its development and major advances and programs will occur in the next 4 years. Solid leadership and continuity is essential to ensure that the progress and success to date continues unabated. Some rotation of membership was seen as being necessary to broaden SALE participation and infuse new ideas. Current SALE members Ross Powell, Jean Robert Petit, and Cynan Ellis-Evans agreed not to seek reappointment and their years of service to SALE were recognized. Based on preferences from a vote of the SALE membership - 3 proposed new SALE members are J Wadham, H Fricker, and P Doran. The proposed SALE Membership is:

1. J Priscu (US, limnologist) - 2012
2. C Kennicutt (US, oceanographer/ geochemist) - 2012
3. R Bell (US, geophysics/geology) - 2012
4. P Doran (US, limnology, geochemistry) - 2012
5. H Fricker (US, satellite remote sensing) - 2012
6. S Bulat (RUS, genomicist) - 2012
7. V Lukin (RUS, glaciologist) - 2012
8. F Pattyn (BEL, glaciologist) - 2012
9. C Mayer (GER, glaciologist) - 2010
10. C Barbante (ITAL, geochemist) - 2010
11. S Imura (JPN, microbiologist) - 2010
12. Y Li (CHINA, glaciologist) - 2010
13. J Wadham (UK, microbiologist) - 2012
14. M Siegert (UK, geology) - 2012

This membership rotation:

- (a) maintains continuity through the reappointment of 6 members,
- (b) provides representation for all major SALE programs,
- (c) increases female membership from 1 to 3,
- (d) maintains balance among disciplines,
- (e) ensures the participation of 8 countries,
- (f) provides a ~60% change in membership (n=8) since SALEGOS (4 years ago),
- (g) increases by ~40% the number of countries participating and
- (h) allows for ~30% of the membership terms to end in 2 years allowing for a secondary membership rotation.