Solid Earth Response and influence on Cryospheric Evolution

http://www.scar.org/srp/serce

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Introduction

Rationale for the Programme

The Solid Earth Response and influence on Cryospheric Evolution (SERCE) scientific research programme aims to advance understanding of the interactions between the solid earth and the cryosphere to better constrain ice mass balance, ice dynamics and sea level change in a warming world. This overarching objective is being addressed through integrated analysis and incorporation of geological, geodetic and geophysical measurements into models of glacial isostatic adjustment (GIA) and ice sheet dynamics. The programme is designed to synthesize and integrate the extensive new geological and geophysical data sets obtained during and subsequent to the International Polar Year with modeling studies, in a timeframe to contribute to IPCC AR6. SERCE aims to provide the international collaborative framework and scientific leadership to investigate systems-scale solid earth – ice sheet interactions across Antarctica and relate these results to global earth system and geodynamic processes.

Overview of Programme Activities

SERCE has implemented a strategy to leverage the human and financial resources of the SRP by partnering with international groups with similar objectives to co-sponsor activities. This approach has been very productive, leading to a series of symposia, workshops and training schools of greater scope than could have been achieved by the SERCE SRP alone. Planning between contributing partners has inevitably led to changes in timing and/or revision of topic of some scheduled activities as summarized in the following table. A version of this table has been presented to the SCAR Executive Committee annually as SERCE’s implementation plan.

<table>
<thead>
<tr>
<th>YEAR</th>
<th>WORKSHOP/SYMPOSIA</th>
<th>THEME SESSION</th>
<th>TRAINING</th>
<th>OUTREACH</th>
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<tr>
<td>2012</td>
<td>Earth Structure/Modeling (SCAR OSC) ✔</td>
<td>Earth–Cryo Interactions SCAR OSC ✔</td>
<td>Logo ✔</td>
<td>Web site plan ✗</td>
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<td></td>
<td>Reconciling Observations and Models of Elastic and Viscoelastic Deformation due to Ice Mass Change (w/ IAG, Ilulissat, Greenland) ✔</td>
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<td>2013</td>
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<td>GIA Training School Postponed to 2015</td>
<td>Complete Web site ✗</td>
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<td></td>
<td>Ice load changes and Earth deformation ✔</td>
<td></td>
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<td>Data archiving &amp; exchange – ISAES ✗</td>
<td>Earth–Cryo Interactions EGU ✔ IUGG ✔ ISAES ✔</td>
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<td>2015</td>
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<td>Earth – Cryo. Interactions SCAR OSC ✔</td>
<td>• GIA Training School ✔ • Autonomous Systems-ISAES ✔</td>
<td>Training Videos on web ✔ Complete Web site ✗</td>
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✔ denotes completed. ✗ denotes delayed.
Deliverables and Milestones

The SERCE SRP has the following specific programme objectives:

• Convene thematic science symposia and workshops to bring together a cohort of investigators for knowledge exchange to propel the science of solid earth – cryosphere interactions beyond the current state of knowledge and contribute a body of new knowledge to the IPCC AR6 assessment.

• Convene a series of expert workshops to improve data-model integration and produce synthetic science products based on extensive new geophysical data sets for Antarctica.

• Carry out major efforts in capacity building, training and public outreach using complementary strategies to achieve technical capacity via information exchange, analytical capacity via training schools, engagement of new polar researchers via thematic science sessions, and public outreach via the world wide web.

See also Appendix III – SERCE Terms of Reference.

To meet these objectives, the SERCE SRP has carried out the activities summarized below during the 2012 – 2016 period.

A. Ten Science Symposia convened:

1. SCAR Open Science Conference, Portland, 2012: Thematic Symposium: Solid Earth Response and Cryosphere Evolution

2. AGU December 2012: T025: Interactions Between the Solid Earth and Cryosphere
   Convenors: Terry Wilson, Rick Aster, Douglas Wiens. Selected as a ‘Hot Topic’ by AGU program committee. 11/25 presentations by student/early-career researchers (44%).

3. IAG/SERCE Symposium: Reconciling observations and models of elastic & viscoelastic deformation due to ice mass change; Ilulissat, Greenland; 30 May - 2 June, 2013
   Convenors: Matt King, Abbas Khan
   This symposium attracted 60 scientists from across the globe, and gave the SERCE programme a significant profile beyond initial SCAR participants.
   Co-Sponsors of this symposium were: SCAR-SERGE SRP (provided the majority of travel funds ($25k) for students, early-career scientists, SCAR nation scientists); National Space Institute, Denmark (DTU Space); International Union of Geodesy and Geophysics (IUGG); International Lithosphere Program (ILP); Upper Mantle Dynamics and Quaternary Climate in Cratonic Areas (DynaQlim); EGU (student travel funds); NSF (travel funds for U.S. scientists)

   Convenor: Terry Wilson

5. EGU General Assembly, April 2015: GD6.2/CR2.5 Geodynamic evolution of the polar regions and interaction with the cryosphere
   Conveners: Douglas Wiens, Terry J. Wilson, Karsten Gohl, Pippa Whitehouse

Convenors: Jeff Freymueller, Abbas Khan, Michael Bentley, Pippa Whitehouse and Matt King

Sponsors: IAG sub-commission 3.2 “Cryospheric Deformation” and SCAR SERCE. SERCE funds supported travel expenses for early-career participants.

This symposium brought together those working on ice load reconstructions, modelling of (visco-)elastic processes and comparison to relative sea level and geodetic observations (e.g. GRACE, GPS, ICESat, CRYOSAT II) in order to further refine understanding of past-to-present ice-ocean load changes, and the characteristics of the solid Earth under time-varying loads, in order to advance our understanding of past ice sheet and sea level changes, of the structure and rheology of Earth, and of exactly what geodetic measurements are measuring.

7. **26th IUGG General Assembly**, June 22 – July 02, 2015: JG1 *Dynamics of the Cryosphere from Geometric and Gravimetric Observations*

Convenors: Mirko Scheinert (TU Dresden) (IAG), Pippa Whitehouse (University of Durham) (IACS), Matt King (University of Tasmania) (IAG), Erik Ivins (NASA/JPL) (IAG)

Session focus on advancing understanding of glacier, ice cap and ice sheet behaviour through a variety of synergistic combinations of geodetic methods with geological, geophysical and glaciological observation techniques, including the interdisciplinary use of a variety of observational techniques to understand the stability and evolution of the cryosphere and test numerical models.

8. **XII SCAR International Antarctic Symposium on Antarctic Earth Science**, Goa, India, 13-17th July 2015; Thematic Symposium: *Cryosphere – Solid Earth Interactions & Antarctic Geothermal Heat Flux, Subglacial Geology and Ice Dynamics*

Session Convenors: Terry Wilson, Ohio State University, USA; Samantha Hansen, Univ. of Alabama, USA; Wouter van der Wal, Univ. Delft, Netherlands; Chris Carson, Geoscience Australia; Sridhar Anandakrishnan, Penn State Univ., USA

Presentations addressed fundamental interactions between the Antarctic ice sheet and the underlying Antarctic crust and mantle. This session included discussions of the subglacial heat flow (both mantle and crustal sources of heat), and its heterogeneity, across the Antarctic continent, and explored the potential ramifications of the magnitude and variability of heat flow on the dynamics ice sheet behaviour.


Convenors: Catherine Ritz, France; Terry Wilson, USA; Nancy Bertler, New Zealand; Carlotta Escutia Dotti, Spain; Pippa Whitehouse, UK; Frank Pattyn, Belgium

The past behavior of the Antarctic ice sheet is the key to understanding its present evolution and to improving our ability to make projections under climatic change. This session will bring together the various communities interested in the past/present/future evolution of the ice sheet, via both data and modeling approaches and focuses on the interface between the topics of the following sessions: Past Antarctic Ice Sheet Dynamics, Solid Earth Responses and Influences on Cryospheric Evolution, Glaciers
and Ice Sheet mass balance and Evolution of the physical and biological environment of Antarctica and the Southern Ocean over the 21st and 22nd centuries.

10. SCAR Open Science Conference, Kuala Lumpur, Malaysia, *Future: August, 2016:  
**Thematic Session: Solid earth responses and influences on cryospheric evolution**  
Convenors: Thomas James, Canada; Terry Wilson, USA; Joachim Jacobs, Norway; Kristin Poinar, USA

This SERCE session will explore new data and modeling studies bearing on any aspect of the interaction between the solid earth and ice sheets. Topics are expected to include crust and mantle structure beneath the ice sheets, mapping of earth properties and their variations through seismological and other geophysical techniques, observations of solid earth deformation and feedbacks between solid earth deformation and ice sheet dynamics, new data and models for ice histories driving glacial isostatic adjustment (GIA) in Antarctica, incorporation of geological, geodetic and geophysical measurements into geodynamic modeling of the solid earth response to ice mass changes, and the assimilation of ground-based measurements with data from current space missions.

B. Two Expert Workshops convened:

1. SCAR OSC, Portland, USA, July, 2012: Assimilation of earth structure in GIA modelling  
Conveners: Douglas Wiens, Terry J. Wilson, Pippa Whitehouse

2. IAG/SERCÉ Workshop: Ice load changes and Earth deformation, University of Alaska, Fairbanks, USA, May 26-29, 2015  
Conveners: Giorgio Spada, Jeff Freymueller, Matt King

This 1-day workshop following the linked symposium provided an opportunity to gain hands on experience and tutoring on tools for computation of the high-resolution elastic response of Earth to surface load changes. The session explored the theory and practical application of two tools - REAR and SPOTL – as well as a summary of sources for obtaining observed or modeled ice loading changes and their treatments.

C. Two Capacity Building Workshops and Training Schools convened:

1. XII SCAR International Antarctic Symposium on Antarctic Earth Science, Goa, India, 12th July 2015: Autonomous GPS & Seismic Station Workshop  
Instructors: Sridhar Anandakrishnan (Penn State Univ.), Rick Aster (Colorado State Univ.), Paul Carpenter (PASSCAL), Audrey Huerta (Central Washington Univ), Joe Pettit (UNAVCO), Terry Wilson (Ohio State Univ.), Paul Winberry (Central Washington Univ.)

SERCE provided funds for the venue, and to allow participants from organizations across India to participate.

A 1-day workshop/training school was held with the aim of widely distributing information to the Antarctic community, particularly to countries where Antarctic research programmes are small. Invited speakers gave overviews of earth science research that can be done using autonomous remote systems, and then presented the design, installation, and operation of autonomous remote GPS and seismic systems, including the range of systems in use/under development.
2. **Glacial Isostatic Adjustment Training School**, Ohio State University Stone Laboratory, Gibraltar Island (Lake Erie), Ohio. September, 2015

Ten international instructors: Mike Bentley, Mike Bevis, Ian Dalziel, Erik Ivins, Giorgio Spada, Holger Steffen, Pippa Whitehouse, Wouter van der Wal, Doug Wiens, Terry Wilson

Funding for the Training School came from the SCAR-SERCE budget ($31k) and the NSF-POLENET project ($40k). Funding covered all participation costs for instructors and students on site, and partial travel support for the majority of participants.

The extensive organization for the training school was implemented by Wilson and POLENET project staff at Ohio State University.

A widely publicized call for applications yielded nearly 150 submissions. Through a selection process, **45 participants from 16 countries** were selected and invited; participants included 25 PhD students, 4 Postdocs and 12 Researchers/Faculty. Real time virtual participation was made available throughout the school – there were **31 ‘virtual participants’ from 8 additional countries**. The virtual participants were able to ask questions in real time.

Participants were given intensive training on GIA modeling and relevant processes, including ice mass change, solid-earth deformation, and sea-level and geoid variations. An introduction to the fundamentals of GIA modeling, including model inputs, methods, and current state of GIA models was discussed. Students learned about relevant data used to generate, tune, and constrain GIA models, including geologic/geomorphologic and ice core records, GPS, seismic, tide gauge, satellite gravity, and satellite altimetry. The program included both lectures and computer exercises utilizing freely available modeling software, and participants left with an understanding of the theory and development behind GIA modeling as well the practical ability to independently install and run GIA modeling software.

All lectures during the 13-19 September Training School were recorded. These recordings include the slides presented as well as audio from each lecturer. Links to view the lectures are at: [http://polenet.org/?page_id=2261](http://polenet.org/?page_id=2261)

Results of a survey of GIA Training School participants is provided in Appendix IV.

**D. SERCE Outreach**

**D1. Invited Lectures / Participation**

SCAR ‘Horizon Scan’ Retreat: A View beyond the Horizon: Future Directions in Antarctic Science, Arrowtown, New Zealand, April, 2014. [TJ Wilson, SRP Chief Officer, invited participant]

International Symposium on Contribution of Glaciers and Ice Sheets to Sea Level Change, International Glaciological Society, Chamonix, France, May, 2014. [TJ Wilson, SRP Chief Officer, invited plenary speaker]


**D2. Publications**

Only publications specifically linked with SERCE activities are listed here; publications indicative of SRP-related science scope are provided in the Appendix II – References.


15 articles


D3. SERCE Open Community / Business meetings convened:

• SCAR OSC, Portland, USA, July, 2012
• SCAR OSC, Auckland, New Zealand, August, 2014
• SCAR OSC, Kuala Lumpur, Malaysia, *Future*: August, 2016

SERCE Cross-Linkages

**SCAR Partners:**

• PAIS SRP – LGM ice sheet history; coupled models
• AntClim*SRP* – modern ice mass balance
• Ice Sheet Mass Balance and Sea Level (ISMASS) – ice dynamics & ice sheet modeling; modern ice mass balance
• GRAPE (GNSS Research and Application for Polar Environment)
• GIANT Geodetic Infrastructure in Antarctica

**Key International partners have included:**

• International Association of Geodesy sub-commission 3.2 “Cryospheric Deformation”
• International Union of Geodesy and Geophysics
• International Association of Cryospheric Sciences
• DYNAQLIM project of the International Lithosphere Programme (IUGS)
• U.S.-NSF-supported ANET/POLENET project.
SERCE SRP EXPENDITURES

NOTE: Through 2015, >99% of SERCE funding has been expended on support for student/early career participation in symposia, workshops, and training schools, for instructors for the training school, and for venue costs for these activities.

2013: Budget $20,000 + additional $5,000 allocation
1. $25,000 spent on travel support for the Ilulissat symposium (payment to DTU, Denmark)
2. $220 spent for logo design for SERCE web site

2014: Original budget of $20,000.
2. $19,780 Carried Forward to 2015 for GIA Training School

2015: Budget Allocation of $20,000, plus $19,780 carried forward.
1. $6,515 for support of GIA Modeling workshop, Fairbanks, Alaska, USA
2. $1,763 for support of ‘Autonomous Remote Instrumentation’ workshop, ISAES-Goa, India.
3. $31,000 for support of GIA Training School, Gibraltar Island, USA, September, 2015

2016: Budget Allocation of $21,000, plus $500 carry forward
Will request carry forward of these funds for the re-scheduled Cryoseismology Training School

2017: Anticipated Budget Allocation of $20,000, plus $21,500 carry forward
1. $15,000 for early-career participant support - IAG/SERCE workshop - Separation of elastic and viscoelastic GIA signals (w/ IAG, Reykjavik, Iceland); costs will be shared with multiple partners
2. $26,500 for participant and instructor support for Cryoseismology Training School (costs will be shared with NSF-POLENET project)

Future Plans

A. Developing Transdisciplinary Science toward SCAR Horizon Scan Objectives

The SERCE SRP plans to pursue symposia and workshops with partners within SCAR and other international science organizations to map new cross-disciplinary approaches to several relevant SCAR Horizon Scan top questions:

#37 What is the crust and mantle structure of Antarctica and the Southern Ocean, and how do they affect surface motions due to glacial isostatic adjustment?

#41 Will increased deformation and volcanism characterize Antarctica when ice mass is reduced in a warmer world, and if so, how will glacial- and ecosystems be affected?
#24 How does small-scale morphology in subglacial and continental shelf bathymetry affect Antarctic Ice Sheet response to changing environmental conditions? [and how will changes in the bed due to glacial isostatic adjustment influence ice sheet dynamical response?]

#26 How does subglacial hydrology affect ice sheet dynamics, and how important is it?

#27 How do the characteristics of the ice sheet bed, such as geothermal heat flux and sediment distribution, affect ice flow and ice sheet stability?

**B. Symposia and Training School Plans**

- A joint workshop with Intl Association of Geodesy Subcommission 3.4 – Cryospheric Deformation is being planned for 2017. The focus of the workshop will be on establishing robust methods to separate components of crustal motions measured by geodetic methods due to various drivers, including elastic rebound due to modern ice mass change, viscoelastic rebound due to ancient ice mass change, and tectonics.

- **Cryo-Seismology Training School**, Colorado, USA, 2017: A ‘training school’ (short courses) for graduate students and early-career researchers is planned, with the overarching goal of developing a new cadre of polar scientists trained in integrated geodetic and ‘cryoseismology’ techniques to study ice dynamics. This 5-day short course will a) provide intensive training, including lectures and hands-on exercises b) provide students access to scientific leaders in multiple disciplines, and c) through the opportunity to network with other students, form the basis for future multidisciplinary, international collaboration. The Cryoseismology Training School will be co-funded by the U.S. NSF as part of the outreach program of the POLENET-ANET project. We expect that 20 U.S. (funded by NSF) and 20 additional students (funded by SCAR and, perhaps, additional partners) from a large number of nations will attend the course, and we will provide broader access via ‘live’ participation of off-site students using videocom and by recording and posting the school content on the POLENET and SERCE web sites. A venue for the course is being explored at the campus of Colorado State University, USA.

**C. Outreach**

The SERCE website (http://www.scar.org/srp/serce) has not been developed yet, due to limitations on time/personnel available. The Ohio State University has just agreed to provide a small budget to hire an individual part-time to work with Wilson (current SERCE Chief Officer) to develop and post material on the web site. Work will commence in April, 2016.

**D. Rotation of SERCE Chief Officers and Steering Committee Members**

SEE Appendix 1 – Membership

The initial Steering Committee established in 2012 consisted of 7 individuals and 2 ‘liaison’ personnel to related programs. Three additional people were added based on community input in 2014. T. Wilson has served as Chief Officer for the 2012-16 period. New Co-Chief Officers of the group are proposed beginning in 2016: Dr. Matt King (Australia) and Dr. Pippa Whitehouse (U.K.). The current Steering Committee is discussing rotation of members and expects to make new appointments at the SERCE business/community meeting at SCAR OSC 2016.
## Appendix I - Membership

### Steering Committee

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<tr>
<th>Last Name, First Name</th>
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<td>Wilson, Terry</td>
<td>Ohio State Univ.</td>
<td>USA</td>
<td><a href="mailto:Wilson.43@osu.edu">Wilson.43@osu.edu</a></td>
<td>F</td>
<td>2012-</td>
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<td>Bentley, Mike</td>
<td>Durham Univ.</td>
<td>UK</td>
<td><a href="mailto:m.j.bentley@durham.ac.uk">m.j.bentley@durham.ac.uk</a></td>
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<td>2014</td>
<td>Member; liason PAIS</td>
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<tr>
<td>Danesi, Stefania</td>
<td>INGV-Bologna</td>
<td>Italy</td>
<td><a href="mailto:stefania.danesi@ingv.it">stefania.danesi@ingv.it</a></td>
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<td>Hansen, Samantha</td>
<td>Univ Alabama</td>
<td>USA</td>
<td><a href="mailto:shansen@ua.edu">shansen@ua.edu</a></td>
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<td>2014</td>
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<td>Kanao, Masaki</td>
<td>NIPR</td>
<td>Japan</td>
<td><a href="mailto:kanao@npr.ac.jp">kanao@npr.ac.jp</a></td>
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<td><a href="mailto:matt.king@utas.edu.au">matt.king@utas.edu.au</a></td>
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<td><a href="mailto:francisco.navarro@upm.es">francisco.navarro@upm.es</a></td>
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<td>Member, liaison ISMASS &amp; IASC</td>
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<td>Poutanen, Markku</td>
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<td>Rogister, Yves</td>
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<td>Germany</td>
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</table>

### Members

SERCE does not have formal ‘membership’. Wilson currently has an email list of participants interested in SERCE activities of approximately 100 individuals.
Appendix II - References

The articles and topics listed here are representative of science results that were presented at SERCE-sponsored thematic sessions or symposia:

A. Discovery of active subglacial magmatism in West Antarctica

Clustered seismic events beneath the ice are spatially coincident with the subglacial extension of the Executive Committee Range chain of volcanoes and the long periods and frequency contents of the events are characteristic of subsurface magma movement, in some cases signaling pending eruptive activity. High heat flux associated with active magmatism may impact the behaviour of the overlying ice sheet.


Examples of science news coverage:

- Scientists find Volcano Simmering beneath Western Antarctica: http://www.natureworldnews.com/articles/4956/20131118/scientists-find-volcano-simmering-beneath-western-antarctica.htm

B. Improved models of Glacial Isostatic Adjustment (GIA) in Antarctica

Glacial isostatic adjustment, the response of the solid earth to the changing mass of overlying ice, produces displacements of the crust measureable by modern geodetic techniques. Much effort is focused on improving the ice history model and earth rheology model components of GIA models, as well as obtaining new geodetic measurements to test these models. Examples are:


C. Improved estimates of modern ice mass balance in Antarctica

Improving estimates of how Antarctic ice mass change has contributed to global sea level rise requires an accurate model for glacial isostatic adjustment (GIA), used to ‘correct’ mass estimates derived from time-varying gravity measurements. Increased recognition of the importance of the GIA factor has led to renewed efforts to improve both observational constraints and modeling methods. Two examples of many articles published on this topic are:


D. Demonstration of importance of deep earth structure in elastic and viscoelastic GIA response in Antarctica

Modern ice mass loss can produce an immediate elastic crustal motion response, superimposed on the steady viscoelastic GIA motions induced by ice loss since the Last Glacial Maximum. Although well-documented in Greenland, rapid uplift due to modern ice mass change is now reported for the Amundsen Embayment and Antarctic Peninsula regions. In addition, a viscoelastic response to young ice mass loss can occur where the mantle has low viscosity. Recent examples of these discoveries are:


E. Triggering of Antarctic ice sheet deformation by distant tectonic earthquakes

Triggering of earthquakes in active tectonic zones due to transient energy perturbations is well known, but a newly recognized phenomenon is the triggering of icequakes, due to induced basal slip or internal fracturing of ice, as reported in the following articles:


F. Laterally Varying Earth Models

Development of a new generation of ‘earth models’, one fundamental element of glacial isostatic adjustment (GIA) models, is essential to capture the solid earth response to ice mass change in Antarctica. Progress in model development is reported in:

G. GIA-driven bedrock uplift – influence on future ice sheet dynamics

The first exploration of how uplift and subsidence of the earth’s surface due to glacial isostatic adjustment will modify the configuration of the bedrock surface underlying the ice sheets, and thus impact ice dynamics, is reported in:


H. Revised Ice History scenarios – improvement of GIA-model-predicted and GPS-measured bedrock uplift

Mismatch between vertical uplift of the earth’s surface measured by GPS and the rates of uplift predicted by GIA models are being identified, and new ice history models are being developed to reconcile the discrepancies:

The proposed SERCE SRP will:
1. Coordinate key disciplinary studies aimed at advancing understanding of the interactions between the solid earth and the cryosphere and implement expert workshops to bring researchers in these studies together to facilitate interdisciplinary outcomes.
2. Communicate and coordinate with other international groups investigating solid earth – ice sheet interactions.
3. Work with SCAR action/expert groups and research programmes to promote interdisciplinary science on ice sheet mass balance and sea level change, and new, interdisciplinary applications of geophysical data.
4. Use the SCAR-IASC international framework to improve access to polar geodetic and geophysical data, and to provide an international framework for maintaining, and potentially augmenting, the remote autonomous observational infrastructure established by the POLENET consortium.
5. Increase capacity through provision of technological ‘best practices’, open data access, and research training relevant to SERCE science.

Scientific objectives of the SERCE SRP include:
1. Integrate and synthesize geodetic observations obtained from the multinational POLENET geophysical network during IPY to obtain a crustal velocity field (vertical and horizontal) across the Antarctic continent.
2. Integrate and synthesize seismological data obtained from the POLENET geophysical network together with airborne and *in situ* geophysical data to map Antarctic lithospheric and upper mantle structure and rheological properties and to model heat flux from the solid earth to the base of the ice sheets.
3. Combine GPS vertical velocity fields with information on ice sheet histories from geological and glaciological information, to improve understanding of Antarctic ice sheet evolution from the Last Glacial Maximum (LGM) to the present – an outcome to be obtained through collaboration with the SCAR/IASC Ice Sheet Mass Balance (ISMASS) expert group.
4. Foster GIA modeling capabilities to incorporate lateral heterogeneity in earth rheology.
5. Develop improved models of glacial isostatic adjustment constrained by vertical crustal motion observations (objective 1), improved earth structure (objective 2), improved ice sheet history (objective 3), and next-generation models (objective 4).
6. Improve the estimates of present-day ice mass balance obtained from satellite observations. Provision of improved constraints on the rates of gravitational change and crustal uplift due to GIA will remove one of the largest uncertainties in analysis of satellite data for present-day change.
7. Document ice sheet boundary conditions and subglacial processes from geophysical and glacial surface motion observations.
8. Determine seismicity levels in Antarctica and link to cryospheric and tectonic processes.
9. Better understand neotectonic processes through analysis of improved earthquake catalogues and horizontal crustal motion observations.
10. Improve the understanding of ionospheric and tropospheric processes through analysis of new POLENET space-geodetic observations – an objective driven through collaboration with the SCAR GNSS Research and Application for Polar Environment expert group.
Appendix IV – Participant Survey Results - SERCE GIA Training School

SURVEY OF COURSE PARTICIPANTS: GIA TRAINING SCHOOL, SEPT. 2015

SCALE: Strongly Agree = 5; Agree = 4; Neutral = 3; Disagree = 2; Agree = 1

RESPONSE RATE: 18 of 43 course participants

Q1: Lecture material was presented clearly and concisely.

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Q2: Lectures were an appropriate length.

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Q3: The field trip helped to reinforce material presented in the lectures.

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Q4: Instructors were able to answer questions during and after lectures.

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Q5: I would recommend this course to my colleagues or fellow students.

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Note to reviewers:
When reviewing an SRP’s capabilities, activities and outputs, please keep in mind that SRPs are managed by volunteers from the SCAR community and that they receive between 20,000 to 25,000 USD per year to facilitate/coordinate the activities that will allow them to fulfil their goals. Please also be aware that your reviews will be shared with the SRP chairs and the SCAR Delegates, and be made public on the SCAR website after September 2016. Your name will be kept confidential, unless you specify otherwise.
Science quality. Recognising that the national/international science on which the research was based has already been peer-reviewed, do the scientific highlights and published papers indicate that the internationally collaborative research stimulated by the programme has produced science that is excellent, good, or fair? (please provide a brief justification for your choice).

The quality of the scientific highlights and of the science produced by this SRP is very good. This is well documented by the number and quality of published papers on international journals, by technical reports and by the amount of international collaborative activities developed.

Science importance/relevance/timeliness. Has the work advanced scientific understanding and been in accordance with the SCAR Strategic Plan (http://www.scar.org/about/futureplans/)? (Yes or no; please provide a brief explanation for your choice). Are there important gaps currently not considered by the SRP? (If yes, please provide a brief description)

Yes. The work has advanced scientific understanding and it has been fully in accordance with the SCAR Strategic Plan. I see no significant gaps.

Data archival and access. Is the programme adequately addressing the issues of data archiving and data access, and are its data accessible to the wider community? (Yes or no; please provide a brief explanation of your choice).

From the Report I cannot assess which kind of policy has been adopted for the geophysical data archiving and, in general, for data access. I presume that data are available to the community under request.

Communication activities. Are the communication activities of the SRP contributing to the promotion of SCAR and its mission? (Yes or no; please provide a brief explanation of your choice).

Yes. The communication activities within the SRP have been developed at an excellent level, in particular regarding the training schools organised. The communication and coordination with international groups that are investigating the interaction between the solid Earth and the cryosphere have been greatly facilitated by these activities. The same holds for the sea-level community.

Education. Is the work contributing to education about Antarctic science? (Yes or no; please provide a brief explanation of your choice).

Yes, at an high level, by means of a significant number symposia/workshops funded and convened, open to the whole geophysical community, and by the publication of significant results on scientific papers and reports.

Building capacity across all SCAR Member countries. Has the programme contributed to building the capacity of countries with less well developed Antarctic programmes and/or early career scientists a lot, modestly, little, or not at all? Keeping in mind that there are various difficulties in this area, e.g. depending on the current interest of science topics in certain countries, please provide a brief explanation of your choice.

Yes, a lot. The training schools have been organised with the primary target of "widely distributing information to the Antarctic community, particularly to countries where Antarctic research programmes are small". As far as I know, this goal has been successfully met.
**Value for Money.** Considering that SCAR is only able to invest ~20,000-25,000 USD per year in each SRP, do the results indicate excellent/good/fair/poor value for money (please provide a brief justification for your choice)?

The results show excellent value for money. The relatively low amount of money invested has generated an excellent quality of science and has greatly facilitated the international exchanges and collaborations.

**Terms of Reference.** To what extent do you feel the SRP has met the Terms of Reference (provided on the following page).

*The SRP is meeting the Terms of Reference to a large extent.*
Science quality. Recognising that the national/international science on which the research was based has already been peer-reviewed, do the scientific highlights and published papers indicate that the internationally collaborative research stimulated by the programme has produced science that is excellent, good, or fair? (please provide a brief justification for your choice).

Excellent. First, one has to note that SERCE aims to provide the international collaborative framework and scientific leadership so that cutting edge science can be developed and addressed by experts of various scientific fields. SERCE’s performance is outstanding here by convening dedicated workshops and sessions at all the major geoscientific conferences as well as having organized the well-received GIA Training School. Such opportunities for discussion trigger such major achievements as listed in Appendix II. Under the umbrella of SERCE among other things subglacial magmatism in West Antarctica has been detected and improved GIA models were developed (addressing all components including ice history and underlying earth structure). The latter helped in defining improved estimates of modern ice mass balance (see e.g., the IMBIE project) and in the separation of elastic and viscoelastic effects in recent geodetic observations. All these achievements and discoveries were published in high-ranked international journals and partly received attention in news and media. I took the liberty analyzing the performance of the articles in terms of citation etc. In view of the partly short time span since their publication, the performance is clearly outstanding. A small suggestion from my side would be that in future the SERCE SRP should be acknowledged in the Acknowledgment section of scientific papers where capacity building within SERCE set the ground for. This would make the SRP more visible to a broader community.

Science importance/relevance/timeliness. Has the work advanced scientific understanding and been in accordance with the SCAR Strategic Plan (http://www.scar.org/about/futureplans/)? (Yes or no; please provide a brief explanation for your choice). Are there important gaps currently not considered by the SRP? (If yes, please provide a brief description)

Yes. SCAR’s mission “is to advance and promote scientific knowledge, understanding and education on any aspect of the Antarctic region, on the role of the Antarctic region in the Earth system and on the effect of global change on the Antarctic region.” SERCE has strongly contributed with its activities, i.e. organizing capacity building events, to bring leading experts together that jointly advanced our scientific understanding of the basement structure of Antarctica or the dynamics of the ice sheet, e.g., due to the underlying earth structure or distant earthquakes. The application of improved GIA models in other geoscientific fields also helps in answering climatic questions and identifying the overarching role of Antarctica in the Earth’s system. Despite all these positive results, I wonder a bit to what extent SERCE has so far contributed to or fulfilled its own scientific objectives in Appendix III. This has not been clearly addressed in the report.
Data archival and access. Is the programme adequately addressing the issues of data archiving and data access, and are its data accessible to the wider community? (Yes or no; please provide a brief explanation of your choice).

Yes. However, this has not been addressed in the report. I strongly ask the authors to briefly comment on this. I know that e.g., new ice history models are shared and several geodetic data can be downloaded, but to which extent SERCE helped here or if the seismic results have already been forwarded to SDLS remains unclear.

Communication activities. Are the communication activities of the SRP contributing to the promotion of SCAR and its mission? (Yes or no; please provide a brief explanation of your choice).

Yes. SERCE has contributed to several outreach activities in form of lectures, dedicated publications in EOS, and a special issue of Polar Science as well as an important comment in Nature on the six priorities for Antarctic Science. On another note, I must strongly encourage the SERCE steering committee to complete the SRP website. The website development is delayed now for 4 years. Although I understand the issue with time/personnel limitation (i.e. when committed to many other activities as faculty member), a website and information distribution via social media are nowadays of major importance as many news channels set the link.

Education. Is the work contributing to education about Antarctic science? (Yes or no; please provide a brief explanation of your choice).

Yes. SERCE organized the GIA Training School in 2015, which according to the survey must have been really great. I strongly acknowledge that real time virtual participation was enabled. Training videos are available online allowing more interested people (not only researchers) to get a thorough overview of GIA and related processes. Another Training School on Cryoseismology is planned for 2017.

Building capacity across all SCAR Member countries. Has the programme contributed to building the capacity of countries with less well developed Antarctic programmes and/or early career scientists a lot, modestly, little, or not at all? Keeping in mind that there are various difficulties in this area, e.g. depending on the current interest of science topics in certain countries, please provide a brief explanation of your choice.

Modestly. However, focusing on early career scientists only, SERCE has to due to the Trainings Schools as well as the percentage of early career conference presentations contributed a lot. In turn, capacity building with researchers from countries with less well developed Antarctic programmes is only mentioned in part C of the Deliverables. A workshop in India was held aiming to widen the capacity, but it is not further mentioned in e.g., the analysis of participants in the GIA Training School. The authors should briefly comment on this and e.g., difficulties that further capacity building is currently not possible due to missing interest from such countries. Then I can clearly value SERCE’s overall contribution “a lot”.

**Value for Money.** Considering that SCAR is only able to invest ~20,000-25,000 USD per year in each SRP, do the results indicate excellent/good/fair/poor value for money (please provide a brief justification for your choice)?

**Excellent.** More than 99% of the money has been spent for training and conference participation of i.e. early career scientists. Nothing is better than promoting the next generation of scientist!

**Terms of Reference.** To what extent do you feel the SRP has met the Terms of Reference (provided on the following page).

The specific programme objectives listed in the Deliverables are currently all met by SERCE. Planned programme activities have been completed and were adjusted accordingly if needed. The missing activity of complete web site will be addressed this year. I only miss a note on the delay of the Data archiving workshop. Programme activities have been annually presented to the SCAR Executive Committee, thus this interaction is given. Cutting edge research has been published by members/participants of SERCE. Dedicated programme-related publications were released as well. Though not mentioned explicitly in the report, data between participants have been shared (otherwise many publications would not have been possible). The Steering Committee has liaison members from another SRP and two expert groups, which is very good. 50% of the Committee members (not counting the liaison) are female, and the Chief Officer is female. Members are from different countries and have different scientific background. In view of the above, I feel that SERCE has met the SCAR Terms of Reference to a large extent, although I miss the discussion of the fulfilment of SERCE’s scientific objectives in the report.
Name of SRP: _SERCE (Solid Earth Response and influence on Cryosphere Evolution)_

Science quality. Recognising that the national/international science on which the research was based has already been peer-reviewed, do the scientific highlights and published papers indicate that the internationally collaborative research stimulated by the programme has produced science that is excellent, good, or fair? (please provide a brief justification for your choice).

The scientific highlights and published papers indicate that the science is excellent for a number of reasons:
- The articles have been published in high impact journals such as Nature and Nature Geoscience and in a wide range of journals.
- The articles cover a wide range of topics such as the improvement of models for glacial isostatic adjustment, (ice and earth component), the use of those models to correct models of ice mass change, the relation between earthquakes and icequakes.
- Some of the articles have been picked up by international media such as the paper on subglacial magma.

Science importance/relevance/timeliness. Has the work advanced scientific understanding and been in accordance with the SCAR Strategic Plan (http://www.scar.org/about/futureplans/)? (Yes or no; please provide a brief explanation for your choice). Are there important gaps currently not considered by the SRP? (If yes, please provide a brief description)

Yes, advanced understanding. in GIA modelling community much of the attention has focused on glacial loading on century time scales and this is not in the least thanks to the papers published in the context of SERCE and workshops such as the 2013 workshop in Ilulissat that brought together specialists on the mantle and cryosphere. As such the SRP is leading the earth science community on the topic of interaction between cryosphere and solid earth.
The SRP is in accordance with SCAR strategic plan, contributing to the ‘leadership in Antarctic Science’ and the ‘Capacity building, Education and Training’. Specifically the SRP has been successful in the following items from the summary of the SCAR strategic plan:
- scanning the horizon to identify evolving issues and emerging frontiers in Antarctic science’, such as the importance of century scale glacial loading.
- ‘affiliating with organizations with complementary interests to address regional and global issues’ and ‘providing venues for presentation of the latest research results’, as clear from the long list of symposia, expert and capacity building workshops.
- ‘developing the capacity of students and early career scientists’, by means of the very successful 2015 GIA training school in Ohio.
The fora organized by the SRP were also important for generating new ideas for proposals to national science foundations.
I am not sure if gaps refers to gaps in the science or gaps in the contribution to the SCAR strategic plan. It is not clear to me how much the SRP was able to give advice, but this could be because such advice was not asked for. Concerning gaps in the scientific areas, I could identify the importance of heatflow, subglacial hydrology in driving ice flow, but these are addressed in the future plans of the external review report and will be the topic of future meetings.

Data archival and access. Is the programme adequately addressing the issues of data archiving and data access, and are its data accessible to the wider community? (Yes or no; please provide a brief explanation of your choice).

The Overview of Programme activities notes that Data archiving & exchange – ISAES is delayed. I don’t think the objective of the SRP was to produce data, but it has been very successful in fostering cooperation for studying the data that is produced by other programmes such as POLENET and the SERCE meetings have been a breeding ground for proposals that will fund data collection in
Antarctica. Furthermore, the SRP has greatly benefited the scientific community by distributing software for loading calculations and providing hands-on experience on instrumentation.

**Communication activities.** Are the communication activities of the SRP contributing to the promotion of SCAR and its mission? (Yes or no; please provide a brief explanation of your choice).

The communication activities certainly contribute to the promotion of SCAR. As examples can be mentioned the invited presentations and the articles in EOS, which is widely read by earth scientists. SCAR officers contributed to the science paper on priorities for Antarctica in Nature. The development of the SERCE website is a point of attention, the report notes that it will be developed from April this year.

**Education.** Is the work contributing to education about Antarctic science? (Yes or no; please provide a brief explanation of your choice).

The SRP has been very successful in contributing to education about Antarctic science. The 2015 GIA training school has reached participants from many different countries and received very positive feedback. Both the IAG/SERCE workshop ‘Ice load changes and Earth deformation’ and the GIA training school focused on teaching how to use software. Software is indispensable for simulation but teaching how to use software is not addressed in conferences. Thus, SERCE has filled an important gap in the education of young scientists. I also note that another training school, on Cryoseismology, has been planned.

**Building capacity across all SCAR Member countries.** Has the programme contributed to building the capacity of countries with less well developed Antarctic programmes and/or early career scientists a lot, modestly, little, or not at all? Keeping in mind that there are various difficulties in this area, e.g. depending on the current interest of science topics in certain countries, please provide a brief explanation of your choice.

With almost all of the funding available to the SRP going to fund young scientists for attending workshops and meetings, the SRP could not have contributed more to building the capacity of early career scientists. Furthermore, the GIA training school in Ohio had participants from 16 countries, and the funds for the Autonomous GPS & Seismic Station Workshop at the symposium in Goa benefited scientists from India. In the symposia organised, the SRP has clearly given priority to presentations by early career scientists, for example in the SERCE session at the AGU meeting in 2012.

**Value for Money.** Considering that SCAR is only able to invest ~20,000-25,000 USD per year in each SRP, do the results indicate excellent/good/fair/poor value for money (please provide a brief justification for your choice)?

The results indicate excellent value for money. By partnering with international groups the SRP has been able to significantly leverage its funding and organize an impressive number of symposia and workshops.

**Terms of Reference.** To what extent do you feel the SRP has met the Terms of Reference (provided on the following page).

- **to actively seek support of the programme’s implementation through national and international mechanism**
  The SRP has been very successful in partnering up with national and international bodies
- **to ensure the delivery of agreed/approved scientific outcomes, including synthesis activities and public/policy outreach,**
  The publications in a wide range of journals, and more popular outlets such as EOS show that the
SRP is dedicated to disseminating results
- request for advice
I cannot judge on whether this has taken place
- to ensure appropriate exchange and archiving of data generated as a result of the programme,
I think it was not the goal of the SRP to produce its own data, but as stated before lectures and software have been made available.
- to establish scientific liaison and logistical cooperation with other Antarctic activities as appropriate,
The SRP established cooperation with Antarctic partners such as GRAPE and GIANT, and cooperation with international partners such as IAG, IUGG and POLENET.
- to advise the SCAR Executive Committee and Delegates on progress and on the use of funds.
I cannot judge on whether this has taken place.
**Name of SRP:**  Solid Earth Response and influence on Cryospheric Evolution (SERCE)

Name of Reviewer (optional): _______________________________________

**Science quality.** Recognising that the national/international science on which the research was based has already been peer-reviewed, do the scientific highlights and published papers indicate that the internationally collaborative research stimulated by the programme has produced science that is excellent, good, or fair? (please provide a brief justification for your choice).

The science stimulated by the SERCE programme is excellent, resulting in publications published in high impact journals, new and widely used compilations and analyses of geodetic datasets, important advancements in GIA, Earth structure and ice modeling in Antarctica, and further constraints on modern and future ice mass balance.

**Science importance/relevance/timeliness.** Has the work advanced scientific understanding and been in accordance with the SCAR Strategic Plan (http://www.scar.org/about/futureplans/)? (Yes or no; please provide a brief explanation for your choice). Are there important gaps currently not considered by the SRP? (If yes, please provide a brief description)

Yes. The research discussed above has rapidly advanced scientific understanding of the role of the solid Earth in past, present, and future cryospheric evolution. These advances are very timely in that there has recently been a wealth of newly available and relevant data from the Antarctic region that can shed new light on this problem. It is clear that the solid Earth response in Antarctica plays an important role in interpreting geophysical datasets, influencing ice sheet evolution, and ultimately constraining the contribution from Antarctica to future sea-level rise. In accordance with the SCAR Strategic Plan, the science contributions of the SERCE programme will aid in informing and advising policy makers of emerging climate change and sea-level rise–related issues.

**Data archival and access.** Is the programme adequately addressing the issues of data archiving and data access, and are its data accessible to the wider community? (Yes or no; please provide a brief explanation of your choice).

SERCE has included a workshop/symposium on ‘data archiving and exchange’ and the construction of a website (which presumably could link to available datasets) in its planned activities. In the programme overview table, the latter has been listed as postponed to being completed in the next two years, and the former did not happen in 2015 as proposed, and does not appear on the schedule in future years. A symposium on data exchange, and a website with centralized information on relevant data and modeling tools and outreach material could both be very useful to the community. However, I believe that the new datasets and modeling results that have come out of the science associated with SERCE (i.e. in the references included in Appendix II) have, for the most part, been made available. One area for
improvement in this regard, particularly considering the cross-disciplinary nature of this field, could be to make (high resolution) ice history models (e.g. ICE6G, W12, etc.) available for use in GIA modeling.

With respect to data, since there are a number of other groups that already undertake activities related to archiving and access of the relevant geophysical datasets (e.g. UNAVCO, Polenet), it is unclear that there is a need for the data archiving to be happening through SERCE. The SERCE programme is meeting its main objectives as listed on page 2 of the report (e.g. there have been many excellent meetings organized already by the SRP on reconciling data and modeling work), but these objectives do not directly include data archival and access.

**Communication activities.** Are the communication activities of the SRP contributing to the promotion of SCAR and its mission? (Yes or no; please provide a brief explanation of your choice).

Yes. My impression is that the communication activities listed in the report are very much in line with the SCAR mission.

**Education.** Is the work contributing to education about Antarctic science? (Yes or no; please provide a brief explanation of your choice).

Yes. The GIA training workshop was an impressive contribution to education in the field, and the future planned training workshop will be similarly very helpful in providing opportunities for networking, training and collaboration for new scientists in the field. I would recommend further promoting the availability of video lectures and summaries that emerged from the training school. (I was not aware that such material was available until I read this report, and having such resources available for future graduate students and new scientists in the field could be an easy way to strongly increase the impact of the workshops.)

**Building capacity across all SCAR Member countries.** Has the programme contributed to building the capacity of countries with less well developed Antarctic programmes and/or early career scientists a lot, modestly, little, or not at all? Keeping in mind that there are various difficulties in this area, e.g. depending on the current interest of science topics in certain countries, please provide a brief explanation of your choice.

I am not very familiar with the Antarctic programmes of various countries, but I would say that this programme strongly supports an international presence at meetings and early career scientist involvement. The conferences, symposia, etc. listed in the report were available to the international community and had support for early career scientists. The GIA training workshop was (impressively!) fully funded for all participants, making it very accessible to all, including presumably those countries with less well developed Antarctic programmes.

**Value for Money.** Considering that SCAR is only able to invest ~20,000-25,000 USD per year in each SRP, do the results indicate excellent/good/fair/poor value for money (please provide a brief justification for your choice)?

The SERCE programme has leveraged available funding to get excellent value through collaborating and co-organizing meetings and workshops with other related efforts/groups (as listed under the SCAR Partners section of the report). Some other groups with similar goals to consider forming cross-linkages to in future include
Terms of Reference. To what extent do you feel the SRP has met the Terms of Reference (provided on the following page).

To the best of my knowledge, I feel that the SRP has met the Terms of Reference. The SERCE programme has aided in facilitating rapid progress of science addressing the role of the solid Earth in cryosphere systems, training new scientists in the field, and promoting international collaborations and connections within the various related subdisciplines. These activities are contributing to meeting the overall goals of SCAR, and future proposed plans suggest that the programme will continue to contribute in this way.
Solid Earth Response and influence on Cryosphere Evolution (SERCE)

SERCE aims to provide the international collaborative framework and scientific leadership so that cutting edge science can be developed and addressed by experts of various scientific fields. SERCE’s performance is outstanding here by convening dedicated workshops and sessions at all the major geoscientific conferences as well as having organised the well-received GIA Training School.

The quality of the scientific highlights and of the science produced by this SRP is very good. The articles cover a wide range of topics such as the improvement of models for glacial isostatic adjustment (ice and earth component), the use of those models to correct models of ice mass change, the relation between earthquakes and icequakes. This is well documented by the number and quality of published papers on international journals, by technical reports and by the amount of international collaborative activities developed. The application of improved GIA models in other geoscientific fields also helps in answering climatic questions and identifying the overarching role of Antarctica in the Earth’s system.

Concerning gaps in the scientific areas, the importance of heat flow, subglacial hydrology in driving ice flow have not yet been included, but these are addressed in the future plans of the external review report and will be the topic of future meetings.

The communication activities within the SRP have been excellent regarding the training schools organised. The communication and coordination with international groups that are investigating the interaction between the solid Earth and the cryosphere have been greatly facilitated by these activities. The same holds for the sea-level community.

The training schools have been organised with the primary target of “widely distributing information to the Antarctic community, particularly to countries where Antarctic research programmes are small”. The ability for people to participate remotely and the archiving of the presentations after the workshop is commendable. SERCE has filled an important gap in the education of young scientists by providing training on how to use software for simulations - something not often taught in classes or learned at conferences.

The objective of the SRP was not to produce data, but it has been very successful in fostering cooperation for studying the data that are made available by other programmes such as POLENET, and the SERCE meetings have been a breeding ground for proposals that will fund data collection in Antarctica. Furthermore, the SRP has greatly benefited the scientific community by distributing software for loading calculations and providing hands-on experience on instrumentation.

NOTE: One reviewer made a strong point about the website being empty - this has now been changed and it is almost complete.

SERCE Recommendations:

• SERCE needs to finish its implementation plan - it is 4 years overdue.

• SERCE should specifically address to what extent it has fulfilled its own scientific objectives (from Appendix III).

• SERCE needs to better detail their data archiving activities, particularly in defining what data have been made available and where and how SERCE efforts have influenced them.
• SERCE should complete their website by including information on data and all the publications, including press articles, that have resulted. In addition, links to relevant data and modeling tools and outreach material could both be very useful to the community.

• It should be recommended to members to mention in their publications that the paper is a contribution to the SCAR SERCE SRP.

• SERCE should briefly comment on the outcomes of their efforts to engage scientists from countries with smaller Antarctic programmes. This is briefly mentioned in the report, but more concrete results would be good to include.

• SERCE may want to consider making (high resolution) ice history models (e.g. ICE6G, W12, etc.) available for use in GIA modeling.

• SERCE should move forward on its plans for a workshop/symposium on ‘data archiving and exchange’.

• SERCE should consider further promoting the availability of video lectures and summaries that emerged from the training school.

• SERCE may want to consider engaging with the PALSEA2 community and the WCRP Grand Challenges Sea Level Science group. If they are already, this should be noted in the report.
Recommendations for all SRPs and/or SCAR

The following are recommendations arising from the 2016 SRP External Review Process that apply to all SRPs and/or SCAR as a whole:

• Given that SRPs are intended to be finite in duration, it would be useful to identify some key outputs that can be put forward to summarize progress achieved, for example “We now have sufficient information on x to support robust conservation and management of this component of the Antarctic ecosystem. Document y assembles all the relevant information. SCAR can now focus on other priorities”. Along this line, all SRPs should consider putting an emphasis on synthesis of the information collected thus far and have such a paper/product result in the completion of their programme.

• All SRPs should consider assessing the impact of their research by having some additional summary statistics, such as a list of paper citations, or impact factors of the journals where publications have been accepted which could be a useful metric to assess science quality in future reviews.

• All the SRPs should recommend to their members to mention in their publications that the paper is a contribution to the SCAR xxxxx SRP.

• All SRPs should somehow document which of their achievements are directly resulting from the SRP and would not have happened otherwise.

• All SRPs should improve their engagement with scientists from less well-developed Antarctic programmes. Collaborations in Asia, Scandinavia, Africa and South American are particularly important to increase. To help assess current engagement, SRPs should create a graph of the distribution of people involved from various SCAR member countries.

• It is recognized that the SRPs establishment was prior to the SCAR Science Horizon Scan. However, SRPs might want to consider mapping their activities to Horizon Scan questions and including this information on their websites and make sure it is included in all Horizon Scan follow-ups/accomplishment reports.

• Support for early career scientists should involve some kind of ‘feed-back’ to their home countries, the larger early career and science community and/or other ‘outreach’ efforts. This could include a presentation to their home department when they return, a report to their National Committee, a webinar, or another activity to share their experience with the wider community

• The SRPs are encouraged to contribute to reinforce the linkages of SCAR with the IPCC and the future Special Reports.

• The SCAR Social Sciences groups could potentially consider doing case studies detailing how the science community was coordinated through the SRPs, if goals were met, what lessons might be learned, and detail examples of management/policy outcomes that were based on work arising from the SRP.

• SCAR should do better at showcasing the results of the SRPs and recognizing the amazing voluntary efforts of their many participants and the amount of in-kind contributions from participating institutions.

• SCAR as a whole, should have a real communication strategy for major publications and scientific outputs, including the outputs of the SRPs. This includes a more standardized format for the SRPs
that meet the needs of the programmes and help to showcase their efforts. Including metrics of hits for various programmes on webpages and social media channels would be useful to assessing reach of content.

- All SCAR groups, including the SRPs, should be reminded that acknowledging SCAR in publications is important. SCAR may wish to develop a standard statement that groups could use to help showcase publications that would not be possible without SCAR support. In a similar vein, when groups report publications they should highlight how papers advance the objectives of the programme, or listing them under the objectives to which they are targeted may also be useful for tracking progress.

- SCAR needs to define how publications can be attributed to a SCAR SRP, and which publications would have not been possible without SCAR involvement/endorsement. In the same vein, SCAR should set up a reference collection ‘facility’ to showcase all publications attributed to SCAR activities. This should also include non-technical publications.

- SCAR may wish to have a more detailed list of where all its data are stored and a contingency plan for maintaining the data in case current funding decisions are reversed.

- There is great value in SCAR’s small contribution to these SRPs, which can often provide incentive funds to bring scientists together and it is essential that this be continued. SCAR Members are asked to continue to advocate for the support of SCAR efforts, particularly because few national funding sources allow for international collaborations such as those offered through SCAR activities.
Scientific Research Programmes
Antarctic data management evaluation

General comments

The Antarctic Treaty System offers a clear statement on data. “Scientific observations and results from Antarctica shall be exchanged and made freely available (Art. III).”
Even at the level of ICSU the need for free and open access is becoming increasingly recognized. See “Open data in a big Data world”. SCAR through the Standing Committee on Antarctic Data management has developed the SCAR Data and Information Management Strategy (DIMS). A principal component of this is the Antarctic Data Management System (ADMS) which is composed of The Antarctic Master Directory (AMD) and The National Antarctic Data Centres (NADCs). The Antarctic Master Directory is part of NASA’s GCMD.

While overall the different research programs show good intent on making data and metadata available (through the AMD), this is not achieved in a consistent manner. Showing ample room from improvement.
It is clear all SRP’s could be more aware of the SCADM and the ADMS. In regards to the overall reporting on data activities It would be good to have a more detailed description of how data feeds into the AMD as well as an overview of the records that belong to a specific SRP. This is a task that needs to be addressed by the SRP’s and SCADM in collaboration.

For this purpose it would be good if all SRP could interact with SCADM during the upcoming SCAR OSC conference in Kuala Lumpur.
The SCADM joint meeting takes place on the 19th and 20th August. SRP’s are invited to participate in this meeting (the 20th is probably of most interest). The meeting is open but notification of who will participate is mandatory. For this the SCADM Chief Officer can be contacte (avandeputte@naturalsciences.be or antonarctica@gmail.com). We believe that participation to this meeting would held SRP’s better understand SCAR DIMS and how to use it for improving the visibility of the research and data of their SRP.

Evaluation of the individual reports.

SERCE (score: B)
No section on data management, no mention of the AMD. Nevertheless Data archiving & exchange is mentioned for instance in a 2015 workshop.
PAIS (score: A)

PAIS has a section on data management and they provide an overview of a number of domain specific data repositories. Metadata is not always put into the AMD directly by these repositories (Pangaea, IODP). But for instance IPEV IMAGES is part of GCMD and will as such feed into the GCMD. No concrete overview of which metadata was made available and national repositories are just briefly mentioned.

AntarcticClimate21 (score: A)

AntClim21 has a section on data management. It seems metadata and data is not yet made available but would be in future. No Mention of the AMD specifically but they would be using SOCCOM. SOCCOM contributes to SOOS (which is a SCAR data product), and as such this also to the AMD.

AntEco (score: A)

AntEco has a section on data and metadata, no mention of the AMD specifically, but data is fed into the biodiversity.aq, a SCAR data product that feeds into the AMD. However there is no outlined protocol. Some specific contributions are listed.

AnT-ERA (score: A)

AnT-ERA has a section on data management and they provide an overview of a number of domain specific data repositories. Not all of these feed into the AMD though.

Kind Regards

Dr Anton P. Van de Putte On behalf of SCADM
Response to the SERCE specific recommendations:

SERCE needs to finish its implementation plan - it is 4 years overdue.

The outline of an implementation plan for the SERCE program was presented in the original SERCE proposal, approved by the Delegates in 2012. Each year SERCE has provided an update on the activities that the SRP has completed, together with revised plans for activities in future years, in the annual reports to EXCOM and/or the Delegates. These annual updates provide the most pertinent record of the SERCE SRP objectives, their implementation and modifications made as the programme evolves. This information will be copied into a formal ‘implementation plan’ document, to be completed in July, 2016. We note, however, that the objectives will continue to evolve through ongoing discussions amongst the SRP leadership and the community, and the changes in plans resulting from discussion and input will continue to be provided in the annual SRP reports.

SERCE should specifically address to what extent it has fulfilled its own scientific objectives (from Appendix III).

The science objectives listed in Appendix III of the SERCE report are all major, ongoing efforts. Significant progress has been achieved on these objectives, as specifically discussed in the topic list giving selected publications (Reference list provided in the report).

SERCE needs to better detail their data archiving activities, particularly in defining what data have been made available and where and how SERCE efforts have influenced them.

The principal objectives of SERCE entail nurturing and facilitating development of the scientific framework for integrated interpretation of data acquired by a multitude of research programs. As such, the SRP provides overarching science rationale for collection of new data by projects which are funded by national Antarctic programmes, including internationally coordinated projects. Data collected by these nationally-funded research programmes follow data archiving protocols established by their national funding agencies – this does not fall under the purview of the SERCE SRP.

Recognizing that the pan-Antarctic and global science questions that the SERCE programme addresses require integrated data sets from across the continent (and beyond), the SRP has an objective to facilitate the exchange of data between individual projects and nations. Discussion of plans for improving data exchange are on the agenda for the SERCE business meeting in Kuala Lumpur.

The SERCE leadership and community will discuss the value of, and the available resources to support, a virtual archive of existing data. Individual projects and SCAR nations will be encouraged to provide metadata contact information for persons responsible for relevant data sets. In addition, SERCE will consider providing a virtual archive of products derived from integrated data sets.
SERCE should complete their website by including information on data and all the publications, including press articles, that have resulted. In addition, links to relevant data and modeling tools and outreach material could both be very useful to the community.

The SERCE website has been substantially updated in 2016. The recommendation to provide a resource on data and data products is discussed in the previous response. Provision of information about modeling tools and outreach material is an excellent one, and the SRP will prioritize the improvement of these components on the website.

It should be recommended to members to mention in their publications that the paper is a contribution to the SCAR SERCE SRP.

The framework for requesting this action of the community associated with SCAR-SERCE is under discussion by SERCE leadership and will also be discussed by the broader community at the SRP business meeting in Kuala Lumpur. At issue is establishing criteria for a ‘contribution’, when the research published is directly supported by national funding agencies, and the less tangible scientific framework is supported by the SRP. Publication authors can only be requested to acknowledge SCAR SERCE on a voluntary basis. If agreed, a statement to this effect will be provided on the SERCE website and the email list will be used to request authors to include it in the acknowledgements section of their publications.

SERCE should briefly comment on the outcomes of their efforts to engage scientists from countries with smaller Antarctic programmes. This is briefly mentioned in the report, but more concrete results would be good to include.

SERCE has made a special effort to engage scientists from all SCAR nations, including those from countries with smaller Antarctic research programmes:

• The workshop organized by SERCE, in collaboration with the U.S. POLENET project, in conjunction with the SCAR International Antarctic Earth Sciences Symposium in Goa, India, was explicitly targeted for participants from the region, as well as earth scientists from the wide range of nations that participate in the ISAES.

• The ‘GIA Training School’ organized by SERCE was very widely advertised and had nearly 150 applicants for 45 student slots. There were explicit criteria for selection of participants from the applicant pool for individuals from SCAR nations, and from nations with smaller Antarctic programmes. This resulted in participants from 16 countries in the training school.

SERCE may want to consider making (high resolution) ice history models (e.g. ICE6G, W12, etc.) available for use in GIA modeling.

Ice history models are an essential component of GIA models. Researchers who have published these models typically either make them available on their own research website, or via direct request. SERCE will contact the authors of these models and request their permission to post statements on ‘how to access ice history models’ on the SERCE website.
We note that the provision of other critical GIA input data/models, such as crust/lithosphere thickness models, seismic wave velocity models, mantle viscosity models, etc., is also under discussion, and we anticipate providing information on how/where to access and use these models on the SERCE website.

**SERCE should move forward on its plans for a workshop/symposium on ‘data archiving and exchange’**.

Discussion of this proposed workshop is an agenda item for the SERCE business meeting in Kuala Lumpur. We note that the most likely scenario is to append such a workshop to a science-themed symposium, to increase the breadth of the community who will attend.

**SERCE should consider further promoting the availability of video lectures and summaries that emerged from the training school.**

Excellent suggestion. We will use community listserves and email lists to make a larger number aware of the availability of the lectures, and also post this item more prominently on the SERCE website.

**SERCE may want to consider engaging with the PALSEA2 community and the WCRP Grand Challenges Sea Level Science group. If they are already, this should be noted in the report.**

Pippa Whitehouse, current SERCE steering committee member and future co-Chief Officer of SERCE, is engaged with the PALSEA2 group and has volunteered to serve as the SERCE liaison. Whitehouse has also initiated discussions with Mark Tamisiea and Natalya Gomez, who lead the relevant component of WCRP, about a jointly-supported meeting on GIA-ice dynamic feedbacks. We anticipate finalizing this plan during discussions leading to the Kuala Lumpur meeting.

**Response to Antarctic data management evaluation**

(score: B)

No section on data management, no mention of the AMD. Nevertheless Data archiving & exchange is mentioned for instance in a 2015 workshop.

Antarctic geophysical and geodetic data is, in general, archived under well-established protocols followed by the global science community. Metadata are, for many nations, provided in the Antarctic Master Directory. SERCE provides a science framework for both modeling of existing data and acquisition of new data by independent, nationally-funded projects, and so does not have any direct role in data archiving. As mentioned above, it is essential to have continent-wide data available to meet science objectives, and so SERCE plans ongoing facilitation – including a workshop discussion – on data availability and exchange.

**Response to the Recommendations for all SRPs and/or SCAR:**

*Key outputs to summarize progress achieved*
SERCE leadership will discuss review summaries and other means to encapsulate the diverse outcomes achieved by the SRP. An overview of activities (past and planned for the future) and science objectives will be presented at the OSC in Kuala Lumpur.

**Assessing the impact of their research by having some additional summary statistics**

This recommendation, while important, is difficult to implement consistently and with true relevancy to the achievements of the SRPs. Typically, publications that advance SRP science are the direct result of research projects supported by national funding agencies. The role of the SRP is to help establish the key science questions and overarching rationale for these research efforts, and to facilitate interdisciplinary and international collaborations. This type of role is very important, but difficult to quantify by statistics derived from metrics like citations and journal impact factors. Perhaps the SRPs and SCAR disciplinary groups can jointly establish criteria for including publications as contributions resulting from the SCAR SRP activities. Community input on this topic is needed. Voluntarily acknowledging a ‘contribution from SCAR SRP’ in a publication can be encouraged, and volunteering the publication for the SRP output list can be requested.

**Acknowledge SRP in their publications**

See comments above and in the specific SERCE recommendation responses.

**Document which of their achievements are directly resulting from the SRP and would not have happened otherwise**

Again, see previous comments on quantifying SRP outcomes. Clearly some achievements, such as symposia and education/outreach activities can be directly attributed to the ‘would not have happened otherwise’ category. Research projects and publications may be greatly facilitated by the SRP framework, but it would in general be difficult to establish that these would not have gone forward under the leadership of individual investigators. Discussion on how to evaluate this are needed.

**Improve engagement with scientists from less well-developed Antarctic programmes**

There is no list of “less well-developed” Antarctic programmes, so this target is a bit murky. That said, I think all of the SRPs are completely open to scientists from all SCAR nations and endeavor to engage them in SRP activities. Commonly a barrier (perhaps ‘the’ barrier) is availability of funding – the SRPs can and do provide support for participation in meetings and workshops; SERCE explicitly targeted this sector for the ‘GIA Training School’ (as noted in previous response). However, it is beyond the scope and budget of SRPs to provide funding for research projects. Perhaps more ‘information papers’ to national programmes and funding agencies of SCAR member nations could help in promoting financial support of projects contributing to SRP science objectives.

**Map activities to Horizon Scan questions**
SERCE leadership participated in the SCAR Horizon Scan and in the ARC Roadmap Challenge workshop looking at requirements to carry out science advocated by the Horizon Scan questions. Many questions map directly to SERCE science objectives and the SRP will continue to discuss and develop contributions to these questions, as well as look for opportunities to work with other SCAR groups to contribute to interdisciplinary science problems. As one example, SERCE joined with PAIS, AntClim21 and ISMASS, to organize an interdisciplinary mini-symposium and discussion session at the OSC in Kuala Lumpur.

There are several relevant SCAR Horizon Scan top questions:

#37 What is the crust and mantle structure of Antarctica and the Southern Ocean, and how do they affect surface motions due to glacial isostatic adjustment?

#41 Will increased deformation and volcanism characterize Antarctica when ice mass is reduced in a warmer world, and if so, how will glacial- and ecosystems be affected?

#24 How does small-scale morphology in subglacial and continental shelf bathymetry affect Antarctic Ice Sheet response to changing environmental conditions? [and how will changes in the bed due to glacial isostatic adjustment influence ice sheet dynamical response?]  

#26 How does subglacial hydrology affect ice sheet dynamics, and how important is it? 

#27 How do the characteristics of the ice sheet bed, such as geothermal heat flux and sediment distribution, affect ice flow and ice sheet.

‘Feed-back’ by supported early-career scientists to their home countries, the larger early career and science community and/or other ‘outreach’ efforts

This is an interesting recommendation – in principle, a very good idea; in practice, there are some challenges in implementation. All scientists, including early-career scientists, should be requested to both acknowledge the support of SCAR SRP funding and ‘pay it forward’ by communicating about their experience via various forms of outreach activities. This can only be ‘requested’ and ‘encouraged’, because it requires extra time and effort on the part of the individual, and there may be no source of support for these additional activities.

Reinforce the linkages of SCAR with the IPCC

Outcomes of SERCE-related research bears directly on the mass budget of the polar ice sheets and their contribution to sea level change. These results will figure prominently in the next IPCC assessment.

Case studies of SRPs by SCAR Social Sciences groups

The SRPs are evaluated primarily on their science outcomes, and this should be maintained. It could be useful to have documentation and assessment of effective practices in science
leadership, community engagement and education/outreach – as long as such studies do not divert the Social Sciences group from their own established priorities.

**SCAR should do better at showcasing the results of the SRPs.....**

This is an important objective and SERCE leadership will be glad to participate in discussions regarding ways to achieve this.

**Communication strategy for major publications and scientific outputs, including the outputs of the SRPs**

Currently SCAR communicates to the science community through reports, newsletters, website and social media. All these modes are important. Perhaps more science results could be highlighted on social media, but time constraints limit this. The suggestion for overview papers summarizing SCAR-sponsored research programmes is a good way to achieve broader recognition beyond the Antarctic community.

**Acknowledgment of SCAR in publications**

As previously stated, this should be encouraged, where appropriate, and will be promoted to SERCE participants. Emphasizing the importance of this can, with time, lead to a cultural shift such that this becomes standard practice.

**Define how publications can be attributed to a SCAR SRP, and which publications would have not been possible without SCAR involvement/endorsement**

As per previous comments, this is a challenging task. The science symposia and related discussions, together with the coordination and facilitation roles of SCAR SRPs, are all important in shaping the future directions of Antarctic research. Since national Antarctic programmes from member countries have very different processes for setting their science agendas – some with defined programmes including explicit endorsement of SCAR-endorsed science priorities, but many with an open call for science. Even for the latter case, SCAR-endorsed science priorities remain influential, but it would not be possible to assess whether funded research projects would have happened independent of SCAR endorsement. Criteria to ‘attribute’ a publication to a particular SCAR SRP need to be broadly discussed and endorsed by the research community. Voluntary attribution can also be promoted, as per the recommendation above.

**Set up a reference collection ‘facility’ to showcase all publications attributed to SCAR activities**

This could be a time-consuming task – perhaps a strategy could be establishing a set of ‘key words’ to be used in SCAR-related publications that would effectively yield publication lists in search engines already in wide use for research.

**[Create] detailed list of where all its data are stored and a contingency plan for maintaining the data**
Perhaps a list of archives for Antarctic data would be useful for the community, particularly scientists new to Antarctic research. SCAR should be careful not to duplicate existing data archiving efforts.

*SCAR Members are asked to continue to advocate for the support of SCAR efforts*

Perhaps the best way to do this, given the wide range in funding mechanisms in different nations, is to widely disseminate the objectives and achievements of SCAR SRPs and other science groups to national program agencies in SCAR nations.