Agenda Item: 2.4.8

Person Responsible: A Capra

EXCOM/COs Meeting 2011

Edinburgh, 16,18,19th July 2011

SCAR Programme Planning Group on

Solid Earth Response and Cryosphere Evolution

(SERCE)

Executive Summary

Title: Solid Earth response and Cryosphere Evolution (SERCE)

Authors: Terry Wilson, A.Capra

Relevant URLs or references to other reports:

Introduction/ Background:

Important Issues or Factors: verify at ISAES 2011 the scientific interdisciplinary collaboration io order to become a SRP

Recommendations/Actions and Justification: EXCOM has to evaluate the feasability of SERCE as SRP

Expected Benefits/Outcomes: a new SRP on interdisciplinary approach for geological, geodetical and galciological study of erath and ice interactions in polar regions

Partners: POLENET,ICEMASS, GOOS, SSG PS

Budget Implications:

Title

SCAR PROGRAMME on Solid Earth Response and Cryosphere Evolution (SERCE)

Delegates at XXX SCAR approved the formation of SERCE as a planning group to develop a full proposal for consideration at SCAR in 2012. The programme planning group will:
1. Identify and develop key disciplinary and interdisciplinary science components of a science programme aimed at advancing understanding of the interactions between the solid earth and the cryosphere, including glacial isostatic adjustment (GIA) and ice mass change and the influence of solid earth parameters (heat flow, disposition of sediments) on ice sheet dynamics. The programme will be designed to synthesize and interpret extensive new data sets obtained during IPY, including those from the major international *Polar Earth Observing Network* (POLENET) geophysical sensor deployment and recent/planned data from glacial geology and ice sheet modeling studies.
2. Communicate and coordinate with other international groups investigating ice mass change, ice sheet contributions to global sea level rise, glacial isostatic adjustment models of Greenland and other ice caps, and other pertinent research efforts.
3. Work with SCAR action/expert groups and research programmes to promote interdisciplinary science using POLENET data.
4. Provide an international framework for maintaining, and potentially augmenting, the remote autonomous POLENET infrastructure as the International Polar Year (IPY) ends.

If approved as a Scientific Research Programme, SERCE aims to improve understanding of the solid Earth response to cryospheric and tectonic forcing by:
1. Integrating and synthesizing geodetic observations obtained from the multinational POLENET geophysical network during IPY to obtain a velocity field (vertical and horizontal) across the Antarctic continent.
2. Integrating and synthesizing seismological data obtained from the POLENET geophysical network during IPY to map Antarctic lithospheric and upper mantle structure and rheological properties.
3. Synthesizing available observations and carrying out glaciological modelling to obtain an improved understanding of Antarctic Ice Sheet (AIS) evolution since Last Glacial Maximum (LGM).
4. Developing improved models of glacial isostatic adjustment constrained by vertical crustal motion observations (objective 1), improved earth structure (objective 2), and improved ice sheet history (objective 3).
5. Improving 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.
6. Documenting ice sheet boundary conditions and subglacial processes from seismological and glacial surface motion observations.
7. Determining seismicity levels in Antarctica and linking them to cryospheric and tectonic processes.
8. Improving understanding of neotectonic processes through analysis of improved earthquake catalogues and horizontal crustal motion observations.
9. Improving understanding of ionospheric and tropospheric processes through analysis of new POLENET space-geodetic observations.

Programmatic and outreach/educational objectives will include:

10. Providing a coordination body for ongoing maintenance and augmentation of the POLENET geophysical network established during IPY.
11. Providing a forum for exchange of metdata and data, and for sharing of technical information and improvements essential to establishing and maintaining autonomous remote geophysical observatories.
12. Providing educational and outreach materials on Antarctic crustal motions and seismicity, solid-Earth and cryospheric evolution, and present-day ice sheet mass balance.

Scientific background
The polar regions have unique geodynamic environments where the solid earth, the cryosphere, the oceans, the atmosphere and the global climate system are intimately linked. Understanding polar environmental change is of global interest, particularly with regard to predicting the contributions of polar ice sheets to global sea level rise. A scientific expert group of SCAR focused on Antarctic NeoTECtonics (ANTEC) was convened to promote and coordinate multidisciplinary, multinational research aimed at improving understanding of the unique neotectonic regime of the Antarctic plate. In particular, ANTEC's charter included encouraging and coordinating deployment of remote geodetic and seismic stations across the continent, encouraging installation of permanent instruments and regional networks of instruments (GPS, tide gauge, gravity, seismic), and coordinating sharing of instrumentation, logistics, and data. The ANTEC group convened a series of workshops and thematic science sessions to identify promising research directions and to develop an implementation plan for geophysical deployments across the Antarctic continent.

Neotectonic motion across Antarctica is expected to occur due to displacements on active structures, deformation associated with active volcanism, and due to glacio-isostatic adjustment (GIA) of the Earth in response to changes in ice mass load. Predicted vertical motions due to GIA exceed 4 mm/year over large areas of the continent and range up to 20 mm/year - rates that can be measured with precision GPS. Discovering modern structural displacements (for example across the West Antarctic rift system) and testing different GIA models requires a distributed array of GPS stations across the continental interior. In addition to promoting broader acquisition of GPS measurements, ANTEC recognized the importance of many interdisciplinary goals, including the integration of geodetic results with geological records, the incorporation of GPS measurements into GIA and other geodynamic modeling, the development of new comprehensive ice history models, the resolution of rheological properties of the crust and mantle that influence crustal motion patterns and rates, and the assimilation of ground-based measurements with data from current space missions.

Glacio-isostatic adjustment (GIA) is the response of the Earth to past and present-day changes in ice sheets and glaciers. In Antarctica GIA is an important, and in most regions, the predominant, process causing neotectonic crustal motions. GIA models combine an ice sheet history with an assumed Earth rheology to predict past and present crustal motion, sea-level change, and changes to the Earth's gravitational field. Current GIA models give different spatial patterns of uplift and also differ by about a factor of two in the peak predicted uplift rate, owing to the very different ice sheet histories that were assumed. Earth rheology is poorly known in the region, and this also contributes to the variability in GIA model predictions.
The history of the Antarctic ice sheet during and since the Last Glacial Maximum (LGM) is an essential component of GIA models. Although data constraining the magnitude and timing of ice mass change since the LGM are accumulating from glacial geological and related studies at individual locations, ongoing efforts to compile these data into continent-wide ice models are required. In addition, there is ongoing active research into the role of plate configuration, vertical tectonics, and
paleotopography in the inception of the Antarctic ice sheets.

Seismological studies of the structure of the crust and mantle beneath Antarctica are essential for deciphering the geological evolution of the continent, but also have important bearing on the interactions between the solid earth and the cryosphere that rests upon it. To obtain more accurate earth models for GIA predictions, we need to know how the physical properties and thermal structure vary laterally and with depth in the East and West Antarctic crust and mantle. Existing seismic stations allow resolution of the structure beneath the continent at a horizontal scale of ~1000 km – sufficient to detect fundamental differences in the lithosphere beneath East and West Antarctica, but not to clearly define the structure within each sector. Seismological mapping of earth properties provides a proxy for mantle temperature, which can be used to predict heat flux to the base of the ice sheets, a fundamental control on ice sheet dynamics. In addition, our knowledge of the seismicity of the Antarctic continent is limited by the sparse distribution of seismic stations and the detection level for earthquakes remains inadequate for full evaluation of seismotectonic activity. New instrumentation to monitor seismicity can address the geodynamic paradox between active neotectonic processes vs. the low level of seismicity in Antarctica. Importantly, it can also contribute to understanding 'glacial earthquake'
processes, which may be related to changing basal conditions of the ice sheets due to a warming environment.

The efforts of the ANTEC group culminated in the *Polar Earth Observing Network* (POLENET) International Polar Year core activity, in which 28 nations are collaborating in the Arctic and the Antarctic to obtain data from geophysical observatories. POLENET is acquiring systems-scale observational data in the Earth's polar regions and aims to provide a legacy in observational infrastructure and technological capability in autonomous monitoring in extreme environments. The science programme of POLENET was assembled from the individual projects of the consortium, and includes investigating polar geodynamics, the earth's magnetic field, crust, mantle and core structure and dynamics, and systems-scale interactions of the solid earth, the cryosphere, the oceans and the atmosphere. Bipolar field activities are focused on deployment of autonomous observatories at remote sites on the continents, coordinated with measurements made at permanent station observatories and by
satellite campaigns.

Geodetic studies from POLENET, including GPS measurements of crustal motion, tide-gauge measurements of relative sea-level change, and gravity measurements of mass change, constitute essential elements in developing an understanding of the stability and mass balance of the cryosphere and of ongoing sea-level change. There is a critical need to understand the contribution to sea-level change due to changes in mass balance of the major ice sheets of the world, most importantly the Antarctic and Greenland ice sheets. Accurate measurement of millimeter-scale vertical and horizontal crustal motions is possible in only 2-5 years if continuous GPS trackers are deployed. Deployment of C-GPS stations in optimal positions with respect to historical and modern ice mass changes, and at sufficiently high spatial resolution, provides robust constraints on ice models, improving our ability to predict sea-level change. Deployment of C-GPS stations across tectonic blocks and boundaries allows
crustal motions due to global plate motion and intraplate neotectonic deformation to be measured and velocity fields to be mapped and modeled.

Seismological data from the observatories will provide the first relatively high-resolution data on the Earth beneath the polar seas and ice sheets. Advanced techniques to image the Earth's deep interior, such as seismic tomography, will be used to place constraints on the planet's internal processes. Seismic imaging of the crust and mantle will assess causes for anomalously high elevations in East
Antarctica, linked with ice sheet development, will provide information on heat flow and mantle viscosity that are key factors controlling ice sheet dynamics and the Earth's response to ice mass

change.

Program rationale and methodologies
Owing to its remoteness and hostile environment, knowledge of Antarctic crustal motions, seismicity, and ice sheet evolution has remained poorly constrained relative to the northern hemisphere. By the middle of the next decade many new data sets will have been collected that will serve to advance our understanding of GIA. These include those from glacial geology (e.g., new and planned cosmogenic dating studies), marine geophysical surveys of ice sheet extent and retreat timing and direct observations of GIA using GPS. During the IPY, an unprecedented new GPS data set is being acquired through the deployment of the POLENET geophysical network across the entire Antarctic continent. POLENET data are being acquired by a large number of nations in individual projects.

Complementary data are being acquired in the Arctic, particularly in Greenland, during the IPY. It is essential that an internationally coordinated approach to data analysis and synthesis be established in order to optimize the science outcomes of these new data sets. The proposed SERCE scientific research programme will provide the international 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.

As the results of satellite missions aimed at detecting and monitoring changes in ice mass in the earth's polar regions are emerging, it has become increasingly clear how important it is to advance our knowledge of systems-scale GIA patterns. Because the spaceborne platforms measure an integrated signal that includes a GIA component, accurately removing this component is essential to deriving ice mass balance. Many recent authors have shown that the so-called "PGR [post-glacial rebound] correction" applied to remove the GIA component is the largest source of error in ice mass balance estimates derived from the time-varying gravity measurements from the GRACE mission. Ongoing studies of rapid change of outlet glaciers have shown that ice dynamical responses resulting in increased evacuation of ice, at least in part related to changes in basal conditions of the glaciers and ice sheets, are important controls on ice mass change. It is clear that *in situ* constraints and ongoing synthesis and modeling efforts evaluating GIA and other processes and feedbacks between the
cryosphere and the solid earth system are now more urgent than ever.
SCAR has the opportunity to take a leading role in advancing in this aspect of Antarctic environmental change. Strengthened scientific ties between a variety of SCAR groups will accelerate this. The proposed SERCE programme would aim to promote integrative efforts such as:
• Improving ice sheet models, working with the ISMASS group, by combining GPS-derived uplift rates, knowledge of ice sheet substrate and basal heat flux derived from seismological observations, and ice sheet histories synthesized from glacial geology, marine geophysics and glaciological modeling.
• The GPS, seismic and meteorological data being collected by POLENET will be used by a global community that extends beyond the traditional polar community. The proposed SERCE group will help to ensure that the POLENET data from the polar regions are incorporated in global studies of environmental change, including studies of tropospheric water vapour and space weather, through working with the AGCS and ICESTAR programmes, as well as the proposed GPS-Weather cross-SSG group.
• Working with the PantOS group to provide a forum for remote station network information exchange and to help coordinate the use of remote networks such as POLENET as a platform for deployment of additional sensors (e.g., weather stations).

Program management

An international steering committee will be established for SERCE. A wide range of disciplinary experts to guide the developing science program, as well as representatives from the many nations contributing to acquiring POLENET data, will be assembled. The SC will interact with IRIS, UNAVCO, SCAR, IASC, and national polar operators to promote participation of the widest possible array of nations and researchers, to ensure coordination of technologies and logistics, and to establish
open data archiving and access. The SC will plan annual workshops to review, assess and exchange results, and to promote integrated interpretation and modelling efforts. Thematic symposia will be planned at international meetings, with resultant publications.

Initial Implementation Plan for SERCE SP Planning Group, 2008-2010

1. Encourage and coordinate ongoing field deployments during IPY and beyond
2. Convene an multidisciplinary workshop to establish priority research themes and groups for the SERCE program- ISAES 2011
3. Convene a workshop aimed at establishing integrated data processing schemes for continent-wide POLENET data compilations - ISAES 2011
4. POLENET special session at ISAES 2011
4. Work with other international programmes with common goals to ensure appropriate integration of activities, e.g. the COST (European Cooperation in the field of Scientific and Technical Research) Action ES071 on *Improved Constraints on Models of Glacial Isostatic Adjustment* (Matt King, Chair).
6. Proposal for Scientific Research Programme: SCAR – 2012 (IPY ends).