Building capacity in **polar sciences**

Working with cyberinfrastructure in remote locations has offered **Dr Linda Hayden** the opportunity to support a wide range of students to develop research interests in Polar Regions

DR LINDA HAYDEN

How does your approach for remote sensing of ice sheets differ from previous studies?

The Polar Grid project deploys innovative technology to Greenland and Antarctica to aid polar science research on our changing planet. Our current cyberinfrastructure activities include support of field expeditions that build on previous Polar Grid work. There is increasing activity in the provision of offline data analysis, and initial progress is being made in preliminary Matlab processing, visualisation and presentation of data products from the Center for Remote Sensing of Ice Sheets (CReSIS) and related activities to support the interpretation of radar data. Cloud and advanced visualisation technologies are also being exploited in this work.

Field cyberinfrastructure consisted of field servers to process data in real-time and drivers to back up data collected during each mission. One seven-hour P-3 flight and two four-hour Twin Otter flights have generated close to two terabytes of data. This data is first copied onto the disc drives and verified. The copied data is processed with unfocused synthetic aperture radar (SAR) algorithms using a field server. The processed data is used to generate radar echograms. Data archival, processing and echogram generation is normally completed within 24 hours after completion of a mission; the data is then posted on the ftp server in order to check quality and re-plan any flight lines. During the 2010 field season, most of the data collected as a part of the NASA Operation Icebridge project over Antarctica was processed and posted on the website within 24 hours. We expect to follow a similar procedure during the spring deployment of the Twin Otter and P-3 aircraft in Greenland.

Could you describe some of the research training and professional activities that you provide?

We develop and deploy new or adapted courses that extend and reinforce students' knowledge of Polar science and their understanding of relevant fields, as well as support and supervise student research experiences. We also develop seminars and workshops for K-12 teachers to enhance their ability to teach Polar science. In addition, we believe it is important to provide graduate and undergraduate students with opportunities for field work so that they can acquire and practice research skills, work beside scientists and engineers from other institutions and apply their content knowledge in real-world contexts, for both graduate and undergraduate students.

Students are offered opportunities to attend workshops and seminars that enhance their content knowledge, to work with our international partners to provide opportunities for students to study and research abroad, as well as internship opportunities with industry, at national laboratories and internationally. Finally, we engage with K-12 students, parents and educators through a combination of informal education activities, classroom engagement events and a more broad public awareness campaign.

How has this initiative built on the successes of previous partnerships and projects?

Indiana University, Elizabeth City State University and the Association of Computer and Information Sciences and Engineering Departments at Minority Institutions (ADMI) have all collaborated on cyberinfrastructure and educational projects. This was prior to having Indiana University and ADMI join the CReSIS partnership during the second phase, which commenced in 2010. Dr Geoffrey Fox at Indiana University was a distinguished lecturer at Elizabeth City State University in 2006 and had worked with other ADMI institutions, specifically Jackson State University, in curriculum-related projects. In 2001, Charles Luther, former President of the Geoscience and Remote Sensing Society, introduced me to Dr Prasad Gogineni, now the Director of CReSIS, at the Institute of Electric and Electronics Engineers Geoscience and Remote Sensing Conference in Australia. At that time we agreed to join efforts and did so for the development of the CReSIS Science and Technology Center proposal.

What have been the greatest successes of your studies so far?

We have had many successes and points of pride for the CReSIS and Polar Grid projects within both the research and education arenas. Regarding research, we have developed technologies and techniques to sound ice in areas undergoing rapid changes, which is a major challenge in radio glaciology, and to both image the ice-bed interface to generate fine-resolution bed topography and determine basal conditions. CReSIS has successfully applied these techniques to sound three major glaciers in Greenland and produce the first and only bed topography maps for these glaciers. We have also demonstrated that fine-resolution 3D topography can be generated from data collected using SAR equipped with cross-track arrays. The scientific community has begun to use bed topography maps generated by CReSIS during the first phase and to produce results that can explain observed rapid changes. With regards to educational successes, hundreds of students have been engaged; and one team of students led by Dr Malcolm LeCompte (ECSU) and Dr Robert Bindschadler (NASA Goddard) produced results that were recognised in the recommendation and approval of the Advisory Committee on Antarctic Names (ACAN) to the US Board on Geographic Names to designate a bay in the West Antarctic as The Elizabeth City State University Bay.

DR LINDA HAYDEN

Linking real-time research data through Polar Grid

By using innovative cyber-based information systems, the **Center for Remote Sensing of Ice Sheets** is delivering technological solutions that connect data and people working in Antarctica and Greenland

THE TERM CYBERINFRASTRUCTURE has been used since the late 1990s to help describe a whole range of internet-based technologies that link research institutions, computers and data with the researchers themselves. It includes data tools such as storage, management, integration, visualisation and mining, as well as processing services. The benefit of cyberinstructure is that it supports research beyond the level that a single institution would generally be capable of, and often in sites that are remote and inherently difficult to access. One of the scientific fields that has most certainly benefited from the development of cyberinfrastructure is Polar research. In 2005, the National Science Foundation (NSF) helped to establish the Center for Remote Sensing of Ice Sheets (CReSIS) as one of their Science and Technology Centers. It was created with the purpose of developing novel technologies to support the measurement of sea level change and ice sheet movement in the Polar Regions. A partnership between Indiana University (IU) and the Center of Excellence in Remote Sensing Education and Research at Elizabeth City State University (ECSU), which was facilitated by Dr Geoffrey Fox at IU and Dr Linda Hayden at ECSU, has made it possible for the CReSIS team to focus on creating a range of cyberinfrastructure solutions that help to realise an improved knowledge of the mass balance of polar ice sheets.

BUILDING MUTUALLY BENEFICIAL ALLIANCES

One of the latest projects supported by the CReSIS collaboration is known as Polar Grid, which involves the construction of a large-scale distributed computing system that is specifically designed to assist with administering and managing any data that has been gathered by polar studies. Polar Grid is supported by a consortium of research institutes that are advancing these cyberinfrastructure tools. The lead institution of CReSIS is the University of Kansas, and they are collaborating with ECSU, IU, the University of Washington, The Pennsylvania State University, Los Alamos National Laboratory, and the Association of Computer and Information Science Engineering Departments at Minority Institutions (ADMI). They also work closely with a number of international partners, both academic and industrial.

Hayden, who is leading the ECSU's involvement in Polar Grid, explains that ECSU, through their E V Wilkins Academic Computing Center, is now housing a cluster with more than 600 nodes, which is also capable of acceptance into the national TeraGrid Project – the first historically black college/university to achieve this: "The Polar Grid laboratory will be the centre of all operations related to the use and support of that cluster and will grow as new projects, grants and individuals utilise the cluster through cyberinfrastructure". The collaborative approach that has been adopted by Polar Grid is absolutely integral to its success. It means that each of the partners can offer their own students, faculty and staff

the ability to engage with world leaders, in particular Polar science research field experts.

TRANSFERRING KNOWLEDGE

Cyberinfrastructure and its associated tools are become increasingly important for conducting research in the Polar Regions, and the Polar Grid group is at the cutting-edge of assisting scientists as they fully exploit research opportunities. One of the central processes involved in achieving this is CReSIS' Knowledge Transfer component, where two-way knowledge transfer that benefits the programme, scientific and academic communities, industry, and the wider public is undertaken. Apart from the traditional methods for sharing knowledge, such as preparing technical reports, publishing results and participating in conferences and workshops, the Polar Grid project is specifically involved in developing innovative knowledge transfer tools. This work is helping to take a significant amount of remotely-sensed ice sheet data and convert it into information and data that can then be easily shared.

This project has given policy makers access to real-time information about significant ice sheet changes and the effect that these changes will have on climate change through rising sea levels. Furthermore, the scope of this project offers the opportunity for further development at CReSIS in the near future, as Hayden describes: "Our work is assisting to stimulate regional and national economic growth, which has directly resulted from the marketable technologies and capabilities that have been developed through Polar Grid".

THE VALUE OF ANALYSING DATA ON SITE

In addition to a wide range of hardware and systems support tools, the collaboration has successfully developed Polar Grid Web tools. These included creating RSS feeds that are able to present time-ordered details of processed field data. They have also constructed a number of filter applications wrapped as Web services. "Following the Google Gadget and Open Social models, we developed composable user interfaces for these services, along with several supporting tools for social networking, and deployed these into the OGCE Gadget Container," recalls Hayden. They presented this work at the 5th Grid Computing Environments Workshop held in New York in 2009. More recently, Hayden, along with collaborators Jeff Wood and Raminder Singh, showcased the PHP client programmes they have produced, which can be integrated with non-Java portal environments, at the TeraGrid 2010 conference in Pittsburgh.

One of the challenges with research programmes that involve locational studies in the Polar Regions is the difficulty in ensuring data quality before leaving the site. The hope with Polar Grid is that it can promote the innovative and cost effective use of cyberinfrastructure, which Hayden believes should result in considerable cost savings for the expedition teams themselves: "The real savings provided by the Polar Grid cyberinfrastructure component of CReSIS have been in enabling field expedition personnel to overcome the disadvantages of low bandwidth and limited power availability". In the recent past, polar researchers were limited in their ability to analyse data and interpret results until they left the field. This meant that any inaccuracies in data, quality problems or additional information that was needed to support conclusions could not be garnered until they returned to the site.

Through the Polar Grid project, these scientists can now start to analyse data while on location. This is a significant step for polar researchers, as it means they can adjust experiments as needed and collect more data before leaving the field site. Testing equipment in the field, particularly in polar locations, is an important part of ensuring tools are research-ready. The Polar Grid equipment has now been used by CReSIS field teams in both Greenland and Antarctica on seven separate research projects. This equipment has proved to be invaluable in identifying faults with computers and measuring equipment that would otherwise have not been picked up and ensuring that the data being gathered is optimal.

PROVIDING EDUCATIONAL OPPORTUNITIES

An area that the Polar Grid partners see as being central to supporting future growth of this work is to provide training and practical experiences for students in the Polar environment. There are two key goals that CReSIS focuses on in this regard: To support the education of both undergraduate and graduate students in polar sciences and remote sensing topics; and to motivate younger students approaching tertiary study stages to choose these research subjects. Working in Polar Regions requires a whole range of different skill sets that the students need to be equipped with. This is achieved by creating opportunities for internships at the CReSIS partner sites, at industry partners and also at NASA research centres.

Through the project, these students are also offered opportunities for fieldwork where they have the opportunity to work alongside scientists and engineers working out in the field, meaning they can start to apply the knowledge they have learnt to real-life situations. The collaborators are also involved in the preparation and presentation of seminars and workshops, which are designed specifically for K-12 teachers to help enhance and improve their ability to teach polar sciences. By offering a combination of educational and classroom activities, the project team hopes to help encourage and inspire K-12 students to become involved in Polar research.

DIVERSIFYING POLAR SCIENCE RESEARCHERS

Making sciences more accessible to minority students is a key goal of ADMI, who became a full partner of CReSIS in 2010 and has since

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played an integral role in encouraging minority students in this particular sector. They have seen some outstanding results in this regard: "The Center has experienced significant success in minority graduate recruitment. Most notably, during year seven, the percentage of under-represented minority graduate students was at 30 per cent compared to just 7 per cent in year two," highlights Hayden. The advances they have made have resulted directly from the efforts put into mentoring minority students and helping them to use the summer internships that they take at CReSIS as a way to move onto graduate school, often at the same academic institution where they were hosted.

Encouraging female students to become involved in these research fields is another goal of CReSIS, and they have seen a steady rise in numbers over the past seven years; in fact over 60 per cent of summer research experience students are now female. The CReSIS External Education team is responsible for collecting and analysing the data available on students, and this team is currently progressing towards the creation of a broad database that has been designed to help track the progress of students' experiences and learning through Polar Grid. One component of this is the maintenance of a 'student mapping database', which identifies a range of factors, including which part of the project the student was working on, who their mentor was and when they graduated.

PLANNING FOR A SUSTAINABLE FUTURE

The current funding period for this project is set to expire in 2013. The researchers have already discussed what the future may hold and how the project will continue beyond that time. They anticipate that they will hold close to two petabytes of data when the project concludes. However, there is still much work to be done with regard to creating the algorithms that are needed to enable researchers to fully examine the basal conditions and bed maps with the required fine resolution. Hayden notes that they are likewise hoping to progress with improving the algorithms that will be used to model the fast-flowing glaciers.

They are also focused on ensuring the sustainability of the educational component of Polar Grid, which requires considerable efforts to produce materials and set out pathways for the future, as Hayden elaborates: "Within the education arena we are working to develop graduate programme bridges from the Master's level to the PhD, which require writing curriculum and programme development". In particular, she is keen to see that the scientific fields that are becoming increasingly crucial, such as data and Polar science, will be provided for. They are planning for the curriculum to be made available in a cloud resource, meaning that long-distance training can be appropriately supported.

The CReSIS partners are proud that they have been commended for the achievements that they have made in enhancing the education of both undergraduate and graduate students, as well as the way this education has been achieved and the diversity of students participating in this project. It is pleasing for the team to see the first group of students now studying for postgraduate qualifications, including PhDs, at collaborating institutions. "This is clearly a great success of the programme and will be a legacy that will live on once CReSIS is no longer active as an official NSF Science and Technology Center," comments Hayden. "It is clear that this is a model that works well, and the partner organisations have been leaders in making this happen." The Advisory Committee on Antarctic Names (ACAN) recommended the naming of a bay Elizabeth City State University Bay for approval at its meeting on 5 January 2012 to the US Board on Geographic Names who approved it on 17 April 2012. The CReSIS partnership has had a considerable impact that will be felt for a long time to come.

CRESIS-REU

CYBERINFRASTRUCTURE FOR REMOTE SENSING OF ICE SHEETS: REU SITE

OBJECTIVES

To provide summer educational opportunities for undergraduate students in the areas of cyberinfrastructure and polar science.

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