Development of Educational Partnerships Dedicated to Remote Sensing of Ice Sheets Cyberinfrastructure

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***Abstract*- The Center for Remote Sensing of Ice Sheets (CReSIS) is a Science and Technology Center with the mission of developing new technologies and computer models to measure and predict the response sea level change to the mass balance of ice sheets in Greenland and Antarctica. The data processing and computer modeling requirements of CReSIS demand a distributed cyberinfrastructure. Real-time processing and data analysis infrastructure are being developed for field use and for use at partner institutions for both education and research.**

I. INTRODUCTION

The Center for Remote Sensing of Ice Sheets (CReSIS) is a Science and Technology Center established by the National Science Foundation (NSF) in 2005, with the mission of developing new technologies and computer models to measure and predict the response sea level change to the mass balance of ice sheets in Greenland and Antarctica. With regards to research, CReSIS is developing new technologies to perform 3-D characterization of ice sheets to understand the physics of rapid changes, and develop models to explain observed changes and predict future behavior. CReSIS research activities require a distributed Cyberinfrastructure to gather and process data, and to assimilate these data into large ice sheet simulations. In past years, most of the data collected in the polar regions were not processed in real time. Instead, data were shipped to computing facilities in the continental US and analyzed well after collection. Real-time processing and data analysis are urgently needed, both in the field and at supporting computing centers, to adjust collection strategies in response to new information contained in the data.

CReSIS is comprised of six partner universities, with the headquarters located at the lead institution, the University of Kansas (KU). The other universities are The Center of Excellence in Remote Sensing Education and Research (CERSER) at Elizabeth City State University (ECSU), Haskell Indian Nations University (Haskell), The Ohio State University (OSU, The Pennsylvania State University (PSU), and the University of Maine (UM). In addition to this core group, CReSIS collaborates with several international institutions and industry partners. Participating in field activities have been KU, ECSU, PSU, UM and OSU faculty and students.

CReSIS has an education component which has a goal of preparing future generations of highly trained scientists and engineers who can carry on this work into the future. These future leaders in polar science and engineering should more closely mirror the diversity in our world. This paper details the work of CReSIS and the expanding educational partnerships constructed to not only develop sophisticated sensors and platforms, but also to build and implement a cyberinfrastructure to support related education outreach and field operations. The developing partnerships, which include Indiana University (IU), TeraGrid, The Association of Computer and Information Science/Engineering Departments at Minority Institutions (ADMI) and Minority-Serving Institution Cyber-infrastructure Empowerment Coalition MSI C(I)^2, provide a strong base to build the Cyberinfrastructure required for polar science research, education and outreach efforts.

II. CReSIS ICE SHEET REMOTE SENSING

Satellite observations have shown that some regions of the polar ice sheets are undergoing rapid changes. All of the existing ice sheet models, including those assessed by the Intergovernmental Panel on Climate Change (IPCC)[2], cannot explain the rapid changes being observed. These recent rapid changes include the disintegration of ice shelves in West Antarctica and speedup of several glaciers in Greenland [3][4][5] This trend is especially alarming because the impact of even very modest sea level rise on humanity is substantial. A 1 meter increase in sea level would directly impact about 108 million people worldwide [6]. Ice sheet models are stymied by the lack of information on conditions at the base of the ice, shear margins, and the grounding line, and closing this knowledge gap is an important goal for CReSIS.

CReSIS is developing several new technologies to better understand the rapid changes ice sheets are undergoing. These

technologies have sufficient sensitivity and spatial resolution to provide ice sheet models with the necessary 3-D boundary conditions to simulate rapid ice sheet change, and hence, improve predictions of future global sea level rise. One sensor in particular, a Synthetic Aperture Radar (SAR), has the potential to revolutionize our understanding of ice sheet processes. CReSIS has demonstrated that a SAR system can image the ice-bed interface through a 3-km thick ice sheet. In 2005, the ice-bed interface at Summit Camp, Greenland (72.58°N, 38.46°W) was mapped over approximately a 30 km by 6 km area with this system. This was the first time ever that an ice bed this deep had been imaged. Understanding the ice-bed interface through such deep ice sheets is critical to understanding rapid glacial change.

We have also used a similar radar that operates over a narrower bandwidth from a Twin Otter aircraft in 2006. We successfully obtained InSAR images of the ice bed and accomplished the first-ever radar sounding of the Jacobshavn channel in western Greenland.

III. Cyberinfrastructure Center for Polar Science (CICPS)

In past years, most of the data collected in the polar regions were not processed in real time. Instead, data were collected and shipped to computing facilities in the continental US and analyzed well after collection. Real-time processing and data analysis in the field are needed to adjust collection strategies before a field season ends. To address this need, CReSIS is in the process of developing a state-of-the-art computing infrastructure to process the large volumes of data to be collected by several experiments conducted as a part of the International Polar Year (IPY) activities (2007-2009), and to support large-scale ice-sheet models. This infrastructure will include high performance computing capability, tens of terabytes of storage to accommodate both archival storage and staging of aggregated sensor data, and a field deployable computer network.

We have formed the Cyberinfrastructure Center for Polar Science (CICPS) with experts in Polar Science, Remote Sensing and Cyberinfrastructure. CICPS involve several projects and will support development of a sophisticated Cyberinfrastructure instrument that will both enable the crucial ice-sheet science and educate and train a diverse workforce in both Polar Science and Cyberinfrastructure. This center includes the University of Kansas (KU), the lead CReSIS institution; Indiana University (IU), which is internationally known for its broad expertise in research and infrastructure for eScience; and Elizabeth City State University (ECSU), a founding member of CReSIS with a center of excellence in remote sensing.

CICPS is founded with the vision that Cyberinfrastructure will have a profound impact on polar science. We will realize this vision through a set of projects that are of the highest quality in all dimensions: Polar Science, Computer Science, Cyberinfrastructure, and EOT (education, outreach and training). Two CICPS projects are the NSF CI-TEAM Cyberinfrastructure for Remote Sensing of Ice Sheets and the proposed PolarGrid: Cyberinfrastructure for Polar Science.

NSF CI-TEAM Cyberinfrastructure for Remote Sensing of Ice Sheets

The first of these projects is an NSF CI-TEAM project (PI: Hayden, Co-PIs: Fox and Gogineni), "Cyberinfrastructure for Remote Sensing of Ice Sheets," which establishes a CReSIS Science Gateway for TeraGrid working with ADMI, IU, CReSIS, MSI C(I)^2, and TeraGrid. The project demonstrates a compelling vision to provide a model for the development of MSI capacity to prepare students for a future in CI-enabled science, the knowledge-based economy, and the scientific professoriate.

With regards to interdisciplinary research, the implementation of the GRID technologies across the academic community will enable routine interactions among investigators from CReSIS and others at dispersed locations to improve in frequency and productivity, and generalize the current education and research collaborations. The existing suite of collaborations offers a strong base to build on and establish a new class of coordinated educational activities. ECSU is in the process of creating a virtual classroom (VC) and a TeraGrid gateway for remote sensing applications to ice-sheet research and education. In addition, aggressive efforts to engage computer science and engineering students from Minority-Serving Institutions in the GRID, remote sensing, and CReSIS training, seminars, workshops and classes are underway through the ADMI institutions.

ADMI was established as a national organization dedicated to exploring and providing remedies to the educational issues in computer/information science and computer engineering that confront minority institutions of higher learning. ADMI's role in the proposed GRID project organization. will be to establish capability within their institutions to allow students and faculty to participate in the virtual workshops, training and courses. In addition, students from the ADMI institutions will participate in a summer GRID technology research training program to be conducted at ECSU.

The CI-TEAM Management Team is composed of the Dr. Linda Hayden-PI, Dr. Geoffrey Fox and Dr. Prasad Gogineni-

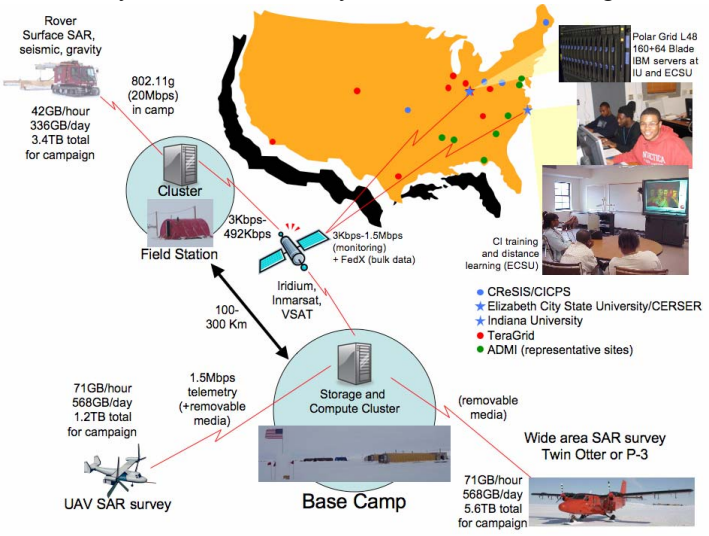

Figure 1. PolarGrid

Co-PIs, a Science team, a Technology team, and an Education and Outreach team. Members of the Science, Technology and Education/Outreach teams are representatives from the partner institutions and organizations with the necessary expertise in their fields to ensure the success of this project. The Management Team is responsible for the on-going coordination of project activities and associated tasks. Responsibilities of the Science, Education and Technology teams are listed below with the affiliations for all team members.

Technology Team: Responsible for installation and maintenance of virtual classroom and GRID. Team members include ECSU, MSI C(I)^2 and KU representatives.

Science Team: Responsible for GRID sensor and satellite data content. Team members include CReSIS representatives.

Education Team: Responsible for virtual classroom content. Team members include ECSU, CReSIS, IU, SDSC, and ADMI representatives.

Partner	VC Role	GRID Computing Role
ECSU	* Establish and maintain the VC * Initiate remote sensing courses * Education Team * Operate summer and AY research training for undergraduates	*Establish and maintain a 32-compute node GRID *Provide satellite data from CERSER to GRID *Users of student and research portals *Science Team *Technology Team
CReSIS Institutions	* Initiate glacier, radar and modeling courses * Education Team	*Provide SAR and other sensor data to GRID *Science Team Member *Technology Team *Users of student and research portals
ADMI	* Desktop VC * Education Team * Participate in classes and training * Summer student research projects * Faculty research	*Users of student and research portals
MSI C(I)^2	* GRID / GIS courses * Education team	*Technology Team
IU	* Faculty research collaborations * Education Team	* Provide support for GRID set-up and administration * Co-PI and Administration Team

PolarGrid: Cyberinfrastructure for Polar Science

The second project (proposed and is currently pending) will deploy a Cyberinfrastructure, called PolarGrid, needed to support polar science computing needs at home and in the field. The major components, including the field camp, base camp, and core systems, are depicted in figure 1. The infrastructure for PolarGrid will have its central component at Indiana University with distributed capabilities spread among the CReSIS sites at KU, OSU, PSU and ECSU. The Indiana University installation will be fully integrated with TeraGrid and the Open Science Grid as well as the distributed CReSIS systems. The PolarGrid implementation and development will focus on the following key areas sketched in Figure 1.

a) Field data collection systems to be taken with Polar Science researchers as they collect data.
b) A base camp 64-core cluster, allowing near real-time analysis of radar data by the polar field teams.
c) A large 17 Teraflops cluster, to be integrated with the NSF-funded TeraGrid, to serve the polar research community in final processing of data and supporting simulations. This is split between IU and ECSU to support research and education/training respectively.
d) The implementation of new improvements to the speed and capabilities of ice sheet models, and implementation of web portals to make the data, data products, and resources easily accessible to the polar research community.
e) An educational videoconferencing Grid to support educational activities.

The major part of this part of PolarGrid is the 5 Teraflop ECSU Grid and Laboratory system. This is augmented by client PC's for student laboratories and scientific analysis software IDL, Matlab and ArcGIS. Also included is video conferencing hardware to support distance education. This configuration will support the powerful Education, Outreach and Training (EOT) component led by ECSU.

The EOT goals are designed to foster the integration of polar science research and education through use of the virtual classroom environment and on-site training laboratories which are equipped with Cyberinfrastructure especially configured for the training environment. The EOT goal will be to make a wide range of CI training resources available including on-site training, on-line tutorials and courses, virtual presentations from workshops and seminars, software tools, and other resources for education, outreach and training. ECSU will assume primary responsibility for the training and outreach activities associated with the PolarGrid Infrastructure project. "Educational settings, audiences, and goals are too important to be adequately addressed as afterthoughts or add-ons to CyberInfrastructure projects, and instead must be treated as high priorities integrated in a project's overall design" [7]. To that end the PolarGrid project includes support for training activities associated with the new partnerships across academia, government agencies, the private sector and polar scientists targeted as users of the PolarGrid. The targeted audience will first be the CReSIS community of scientists and the minority serving institutions associated with the current CI-TEAM project. The audience will later be extended to include the larger polar science community.

Crucial to the effective use of CI are trained personnel and interdisciplinary education [8]. The EOT objectives are structured to maximize the training and preparation of the targeted audiences to effectively use the PolarGrid as a research and education tool.

- Objective 1: ECSU will enhance its Master's in Applied Mathematics with a concentration in remote sensing.
- Objective 2: IU will pilot new computational science and Informatics application modules, while TeraGrid will ensure that its training materials are appropriate for broader participation.
- Objective 3: CReSIS scientists and students will develop understanding of how to use the PolarGrid capabilities to address ice-sheet and other polar science problems.
- Objective 4: ADMI will be provided with access to curriculum, including CyberInfrastructure, remote sensing, modeling and polar-science-specific components which are outside of their current capabilities.
- Objective 5: Code writers, users and experts on high performance computing performance and the larger polar science community will be brought together through parallelization activities.

To achieve these objectives, the project proposes extension of the virtual classroom capabilities and the on-site training laboratories to include CI to be used for training purposes. ECSU has allocated total usage of the E.V. Wilkins building to house the proposed training facility associated with PolarGrid. The facility will support a vigorous schedule of virtual and onsite training on Grid technology, PolarGrid data access, and remote sensing data usage. Each organization will contribute its expertise; ECSU provides remote sensing, Haskell GIS, Kansas and Maine aspects of ice-sheet science, the TeraGrid team covers core CI and IU Grid workflow, data systems and sensors. We will meld VC, on-site training, workshops, academic year and summer CI research opportunities, the Cyberinfrastructure concept from TeraGrid and MSI $C(I)^2$, online tutorials, parallelization activities, middle school outreach and of course an excellent project web portal.

The EOT management team will establish a regular schedule of seminars and summer programs and talks that will be made available via the virtual classroom. This will involve interactive broadcasting to all partners and archiving the content for future viewing. The CReSIS educational program already involves synergy between the different CReSIS partners, by re-using material between institutions while each retains its own curriculum. The PolarGrid EOT program will follow a similar model. A schedule of courses will be developed and advertised, allowing all partners to directly enroll students or to embed the content in their individual home institution course offerings [1].

CONCLUSION

There are several interesting synergies here with the same nodes supporting both research and education and a uniform architecture extending to grid components supporting the ECSU student laboratories. This will support our goal of training ECSU and other MSI students to be familiar with the very latest Cyberinfrastructure and polar science.

The PolarGrid project represents the first attempt by the Grid and glaciological communities to establish a comprehensive data analysis and distribution center and to make data available to the scientific community in a timely manner. While other data centers exist, such as the National Snow and Ice Data Center (NSIDC) and the World Data Center (WDC), these are not well-equipped to handle the large quantities of data now becoming available. Further, the proposed Cyberinfrastructure will allow data from various remote-sensing platforms and other sources to be linked and visualized in a logical and consistent manner. This will provide an invaluable service to the international polar science community. The innovative architecture of PolarGrid with intermittently disconnected components has applications to other power- and bandwidth-challenged applications.

The education, training and outreach illustrate our major commitment to familiarize students with the proposed grid and to bring polar science to undergraduates, graduate students and to an alliance of over 335 Minority Serving Institutions.

ACKNOWLEDGMENT

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