Award 0833450 - Final Project Report

Cover

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Accomplishments

*** What are the major goals of the project?**

This report details activities that took place under the five-year core-funding award “Unidata 2013: A Transformative Community Facility for the Atmospheric and Related Sciences” (NSF 0833450). The proposal for that funding award

grouped the Unidata program's activities into the following six thematic focus areas:

1. Broadening participation and expanding community services
2. Advancing data services
3. Developing and deploying useful tools
4. Enhancing user support services
5. Providing leadership in cyberinfrastructure
6. Promoting diversity by expanding opportunities

Unidata significantly increased the reliability, volume, and variety of data provided to the community, extended the functionalities of its software, developed and deployed new tools and services, and actively engaged its growing user community. The program's contributions and accomplishments have had a demonstrable and sustained impact on the geosciences community, empowering faculty, students, and researchers to be more productive and enhancing their ability to advance science and learning.

The following sections detail the program's activities and results during the proposal period.

*** What was accomplished under these goals (you must provide information for at least one of the 4 categories below)?**

Major Activities: The following list highlights, in no particular order, Unidata's most significant accomplishments during the proposal period.

- **Data Delivery.** The volume of data input to Unidata's IDD cluster has more than tripled since 2008, now averaging over 13 GB/hr; data output averages more than 540 GB/hr. Numerous new datasets were added to the IDD system, including higher resolution WSR-88D products (February 2010), Global Lightning Network (GLN) and North American Precision Lightning Network (NAPLN) (April 2011), Fire Weather products (September 2011), and Rapid Refresh (RAP) grids (replacing RUC grids April 2012).
- **OGC Standards.** In 2011, the netCDF Classic data model was accepted as an OGC core standard. The binary encoding for the classic data model was established as the first extension to the netCDF core standard, followed by the enhanced data model and the CF (Climate and Forecast) conventions extension in 2012 and 2013. These advancements encourage broader international use and greater interoperability among clients and servers interchanging data in netCDF format and will make the large collections of environmental netCDF data more readily accessible and usable.
- **NetCDF.** Unidata released netCDF-4 in late 2008, incorporating an expanded data model, compression, parallel I/O, multiple unlimited dimensions, user-defined data types, and other features supported by the HDF5 format. The NOAA GOES-R project will make all L2 and L2+ products available in netCDF-4 format. NetCDF is also used in other disciplines, including chromatography, neuro-imaging, molecular dynamics, and fusion research.
- **Integrated Data Viewer.** Among a wide variety of improvements to the IDV were support for analysis and visualization of ensemble model output, improved handling of sub-minute data and long range climate data, and addition of trajectory functionality. The IDV is now in use at more than 180 US-based, degree granting universities, colleges and technical schools, and at over 200 academic institutions abroad.
- **AWIPS II.** The UPC has been actively collaborating with NCEP and the NWS Office of Science and Technology to ensure that the AWIPS II software will be available to the academic community soon after it is operational. To that end, the UPC has been working to implement AWIPS II software on the types of computer systems that would typically be available in universities, and has partnered with universities in a beta testing program. The UPC is preparing to release the software more broadly to the university community by the end of 2013.
- **EarthCube Activities.** UPC staff have been active in NSF's EarthCube initiative,

contributing several whitepapers, participating in the EarthCube charrettes and meetings, and being involved in four EAGER-award projects that generated roadmaps for EarthCube's further development. In December 2012, the UPC organized and hosted an NSF-sponsored workshop titled "Shaping the Development of EarthCube to Enable Advances in Data Assimilation and Ensemble Prediction."

- **Equipment awards.** During 2009-2013, the UPC provided 30 equipment grants to 27 universities, encouraging new members from diverse disciplinary backgrounds in the geosciences to join the Unidata community and to allow existing members to continue and enhance their active participation. The facilities developed with funding from these awards are transforming faculty instruction and student learning at those universities in a demonstrable manner.
- **Community Workshops.** In addition to its annual training workshops, the UPC organized and hosted triennial Users Workshops in 2009 and 2012, each of which brought nearly 100 community members together to share tools, techniques, and educational strategies. UPC staff also helped community universities organize and present regional workshops at California University of Pennsylvania and San Jose State University.
- **Move to Open Source Development Methods.** The UPC software team has adopted Open Source development methods including community access to source code, issue tracking, and release planning information to encourage community participation and contribution.
- **RAMADDA.** RAMADDA was originally developed by Unidata and released during the award period. RAMADDA is an information management and data repository framework for the geosciences that provides a turnkey system enabling data providers and users to upload, manage, and share data holdings.
- **GOES Data.** The UPC continues to ingest GOES-East, West, and South America imager data for injection into the IDD. GOES imagery remains one of the most-used data services in the Unidata suite, serving over 3 TB of data per month, and providing support for major field campaigns.
- **THREDDS Data Server and Common Data Model.** Unidata's TDS and its underlying CDM library have matured significantly and seen major enhancements in the last five years. As a result, the TDS is now in use in a large number of universities, organizations, and data centers; many third-party tools build on the CDM library.

Specific Objectives:

Significant Results:

The following tables provide a snapshot of the Unidata program in May 2013, with comparisons to metrics from the previous NSF proposal (where available).

Table 1: Data Services	2008	2013
Institutions Participating in the IDD network[1]	170	263
Host machines on the IDD network1	460 (250 unique sites)	520 (232 unique sites)
Data streams in the IDD	22	34
Approximate volume of data ingested into the IDD	100 GB/day	315 GB/day

Volume of data pushed to IDD sites	2.7 TB/day	13 TB/day
Volume of data pulled via remote access protocols	44.3 GB/day	659 GB/Day
Uptime of UPC data and support infrastructure	99.96%	

Table 2: Software Package Downloads	2008-2012
GEMPAK	11,801
IDV	43,944
Local Data Manager	11,455
McIDAS	857
netCDF-C Libraries (includes FORTRAN, C++ support) [2]	408,250
netCDF-Java Libraries (Common Data Model)	89,416
THREDDS Data Server	7,176
UDUNITS	26,265

Table 3: Workshops	2003-2007	2008-2012
Training Workshop Participants	335	475
Training Workshop Courses	38	33
Users Workshop Participants	164	183
Regional Workshop Participants	44	162

Table 4: Miscellaneous	2013
Number of community members registered with Unidata	44,231
Number of countries where Unidata software and services are used	214
Number of academic institutions participating (U.S.)	743
Number of academic institutions participating (worldwide)	2,495

Number of organizations participating worldwide	3,032
Number of community electronic mail lists	58
User support e-mail transactions, 2008-2012	21,388
Number of Community Equipment Awards, 2008-2012	30
Average staff FTEs at the UPC, 2008-2012	25

[1] These metrics are limited to sites of which Unidata is aware. Sites can use the LDM and participate in the IDD without reporting statistics to the UPC; we *suspect* the number of unreported sites is large.

[2] UPC source code downloads only. This number does not include downloads from repositories at the University of Kyoto and on the Github site, or binary distributions available via package managers on unix-like systems.

Key outcomes or Other achievements:

In addition to the above-listed achievements, the following sections provide a snapshot of the proposed objectives and achievements in each of the six thematic areas.

Broadening Participation and Expanding Community Services

Objective	Accomplishments
Foster community ownership of the program	Moved several Unidata software projects to the Open Source environment Github. We are already seeing the fruits of this in the form of code contributions from community members.
Entrain community colleges into the Unidata community	Unidata now has 44 community college members. Provided equipment awards to Lyndon State College and Madison Area Technical College.
Bring community together through workshops, meetings, conferences, etc.	Hosted an NSF-sponsored EarthCube workshop focused on the meteorological domain in December 2012. Hosted and participated in several AccessData science education outreach workshops 2008-2010. Hosted OGC Technical Committee Meeting September 2011.
Develop global partnerships with geoscience data providers	Established working relationships with the British Atmospheric Data Center, ESSI Labs (Italy), ECMWF, EUMETSAT, and CPTEC (Brazil).

Advancing Data Services

Objective	Accomplishments
Develop and provide high-level interfaces to geoscience data	The Common Data Model (CDM) allows data servers to provide seamless access to data in a wide variety of geoscience formats (netCDF, GRIB, GEMPAK, *etc*.)

Adopt, develop, and promote open standards, conventions, and protocols	Worked closely with the OGC to establish netCDF as an international data standard. Actively participated in efforts to standardize and implement the Climate and Forecast (CF) conventions for metadata, which are used by the IPCC and many others. Implemented OPeNDAP client access.
Enable users with data holdings to contribute and share their data easily	The TDS now makes it possible to publish a wide range of scientific data for access by any client that implements the OPeNDAP protocol. RAMADDA makes it easy to publish small to medium-sized datasets. Both servers integrate tightly with the IDV.
Provide frameworks for creating dynamic case study datasets	RAMADDA facilitates the creation of dynamic case study materials by providing the ability to “federate” servers so that data from different locations appears as part of a single dataset.

Developing and Deploying Useful Tools

Objective	Accomplishments
Enhance the usefulness of the Integrated Data Viewer (IDV)	Major releases spanning versions 2.6 to 4.0. The IDV can now access and visualize every data stream provided by Unidata, including ensemble model output, sub-minute data such as lightning flash data, and long-range climate data. Collaborations with developers at other facilities have led to improved graphics capabilities.
Continue to package and support GEMPAK for the university community	Major releases spanning versions 5.11 to 6.7. Began distributing GEMPAK releases as source-code rather than binary form in 2009. GEMPAK usage has remained strong, with downloads averaging more than 200 per month in 2012.
Continue to support McIDAS-X for the university community	Unidata continues to support and release versions of McIDAS-X, which is developed at the University of Wisconsin-Madison’s Space Science Engineering Center.
Build expertise with the AWIPS II system	AWIPS II has not yet been released to the Unidata community by NCEP. UPC developers are actively collaborating with NCEP to refine the AWIPS II package and prepare a version for release to universities. Five universities are participating in a beta test program.
Deploy RAMADDA	The RAMADDA scientific content management system was released to the Unidata community. Ongoing development has been transitioned to the open source community, and the UPC continues to provide support and training to the university community.
Develop new tools to make it easier to access geoscience	Initial work on the Rosetta project began in 2011. Rosetta is a web-based service that will provide the ability to read from and write to a wide variety of scientific data formats.

data	

Enhancing Support Services

Objective	Accomplishments
Foster effective communication among community members	In addition to traditional electronic mailing lists, the UPC has begun using blogs and social media channels communicate with community members. Ninety technical articles are now available on the Unidata developers' blog.
Harness advances in online collaboration technologies	The UPC has adopted open source community tools like Github to foster collaboration with software developers individually or in other organizations around the world.
Simplify download, installation, and maintenance of supported packages	Made major improvements to the process of building and using netCDF in the Microsoft Windows environment. Streamlining the process of installing and configuring web-based services like the TDS, RAMADDA, and Rosetta.
Document available datasets, datastreams, and services	Created a series of data flowcharts to clarify the relationship between Unidata tools and different types of data provided via the IDD.

Providing Leadership in Cyberinfrastructure

Objective	Accomplishments
Provide stewardship for standards, data formats, conventions, and protocols	UPC staff have worked closely with the OGC to recognize netCDF as an international standard and provided the C reference client for the OPeNDAP protocol standard. Staff continue to work to extend the netCDF standard.
Take a leadership role in setting future directions for geoscience cyberinfrastructure	UPC staff have been active in the NSF's EarthCube initiative, hosting a workshop in 2012. Staff have also worked with the OGC to define data encoding standards, advocated for solutions to problems with the WMO's GRIB format, and worked to advance adoption of the Climate and Forecast (CF) metadata conventions.
Help guide the evolution of international data system standards	Outreach collaborations by Unidata staff include: Marine Metadata Interoperability (MMI) Project Steering Team, IOOS DMAC Steering Team, CUAHSI Standing Committee, UCAR-wide representative to OGC Technical Committee, AGU ESSI Focus Group Board, ESIN Journal Editorial Board, Liaison to OOI Cyberinfrastructure Project, several collaborations with EarthCube teams, member of Steering Committee for international Ocean Data Interoperability Platform (ODIP), Chair of European Space Agency (ESA) Earth Observation Product Trees Project.

Serve as a testbed for deployment of emerging technologies	The UPC has worked closely with NCEP and Raytheon to test the AWIPS II system in preparation for non-operational university deployment.

Promoting Diversity by Expanding Opportunities

Objective	Accomplishments
Engage a highly diverse population of educators and researchers	Unidata's governing committees include educators and researchers from large and small institutions across the U.S. UPC staff engage with a variety of scientists worldwide through conferences, electronic communications, and organizations such as the AMS, AGU, and OGC. In order to reach out to students, the UPC has begun attending student conferences and career fairs, and continues to have a student representative on its Users committee.
Develop/promote specific opportunities to broaden participation from underrepresented communities	In partnership with UCAR's Community Development Program, Unidata staff made presentations to and worked with collaborators from Tribal College and Alaska Native communities for establishing closer ties between UCAR and those communities. Made equipment awards to HBCU and HSI institutions.
Continue participation in the UCAR-led SOARS program	UPC staff have participated actively as mentors for three SOARS protégés over four of the past five years, and will continue in 2013.

*** What opportunities for training and professional development has the project provided?**

Users of Unidata software and data rely on the UPC for comprehensive support services. UPC software developers provide hands-on software training workshops to community members each year. The workshops, which have been attended by more than 450 participants from the university, government, and commercial spheres in the past five years, provide attendees with a chance to learn about Unidata developed and supported technologies from the individuals who created those technologies, and give UPC developers with an excellent opportunity to interact with software users face-to-face.

In addition to the yearly software training workshops, UPC staff taught courses to 162 participants in Regional workshops hosted by university community members. Regional workshops allow attendees to learn about Unidata technologies with a focus on specific disciplines or areas of interest chosen by the host institution.

Program Center staff also make training materials available online for distance-learning situations. Course materials, data, and notes are available on the Unidata web site; code used in workshops is made available on Unidata's GitHub site (https://github.com/Unidata/).

Finally during the proposal period UPC staff began creating short video tutorials for selected Unidata software are available on Unidata's YouTube channel (http://www.youtube.com/user/unidatanews).

*** How have the results been disseminated to communities of interest?**

Unidata communicates with community members in a variety of ways, both electronic and otherwise. The most important channels of communication for the Program during the proposal period have been:

- Participation in scientific organizations, conferences, and meetings, including the American Meteorological Society, the American Geophysical Union, the Open Geospatial Consortium, and the Earth Science Information Partners (ESIP)

Federation.
- Unidata-hosted community workshops and meetings, including two Unidata Users Workhsops that brought a total of 183 participants together to share information and resources related to geoscience research and education.
- Twice-yearly meetings of Unidata's two governing committees. The governing committees are made up of representatives of Unidata's academic community, and serve as a means of two-way communication between the Program and the geoscience educators who form our core community.

In addition to in-person forums like these, Unidata staff publish their results and discuss ongoing research in academic journals, and through Unidata's own web site and News@Unidata blog.

Products

Books

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Book Chapters

Inventions

Journals or Juried Conference Papers

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Licenses

Other Conference Presentations / Papers

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Other Products

Other Publications

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Patents

Technologies or Techniques

Climate and Forecast (CF) Metadata Conventions

In April 2010, the NASA Earth Science Data Systems Standards Working Group (ESDS-RFC-021 Technical Working Group) completed a review of the Climate and Forecast (CF)metadata conventions RFC, with an endorsement of the metadata conventions as a NASA Recommended Standard.

NetCDF Classic and 64-bit Offset File Formats

In September 2009, the NASA Earth Science Data Systems Standards Working Group (ESDS-RFC-011 Technical Working Group) completed a review of the netCDF Classic File Format, with an endorsement of the format as a NASA Recommended Standard.

Thesis/Dissertations

Websites

Unidata Website
http://www.unidata.ucar.edu/

The Unidata website serves as a primary mechanism for Unidata Program Center staff to provide information about the program to community members and the general public. The site:

provides information about the program overall
provides descriptions of individual projects that are currently underway, along with summaries of completed projects
describes data available via the Internet Data Distribution system, and provides information on how to access that data
collects historical documents including funding proposals, annual and final project reports, and archives of governing committee records
serves as a gateway to Unidata's technical support system, and provides access to archived support information
allows community members to download software developed by the program
links to current program information and community news via the News@Unidata weblog

Unidata YouTube Channel
https://www.youtube.com/user/unidatanews

The Unidata YouTube channel serves as a conduit for video tutorials for Unidata software packages. While many of the video tutorials are created by Unidata Program Center staff, we also publish tutorials created by community members.

The YouTube channel also makes available video recordings of talks and presentations that are part of the Unidata Seminar Series.

Participants/Organizations

What individuals have worked on the project?

Name	Most Senior Project Role	Nearest Person Month Worked

Information about Unidata Program Cener staff has been removed from the public version of this report.

What other organizations have been involved as partners?

Name	Type of Partner Organization	Location
Consortium of Universities for the Advancement of Hydrolog	Academic Institution	Medford, MA
Earth and Space Science Informatics Laboratory	Academic Institution	Rome, Italy
U.S. Geological Survey	Other Organizations (foreign or domestic)	Reston, VA
NASA Earth Science Division	Other Organizations (foreign or domestic)	Greenbelt, MD
NCAR Computational Information Systems Laboratory	Other Organizations (foreign or domestic)	Boulder, CO
NCAR Earth Observing Laboratory	Other Organizations (foreign or domestic)	Boulder, CO
NOAA Earth System Research Laboratory	Other Organizations (foreign or domestic)	Boulder, CO
NOAA National Centers for Environmental Prediction	Other Organizations (foreign or domestic)	College Park, MD
NOAA National Climatic Data Center	Other Organizations (foreign or domestic)	Asheville, NC
Open Geospatial Consortium	Other Nonprofits	Wayland, MA
The HDF Group	Other Nonprofits	Champaign, IL

Full details of organizations that have been involved as partners:

Consortium of Universities for the Advancement of Hydrolog

Organization Type: Academic Institution
Organization Location: Medford, MA

Partner's Contribution to the Project:
Collaborative Research

More Detail on Partner and Contribution:

Earth and Space Science Informatics Laboratory

Organization Type: Academic Institution
Organization Location: Rome, Italy

Partner's Contribution to the Project:

Collaborative Research

More Detail on Partner and Contribution:

NASA Earth Science Division

Organization Type: Other Organizations (foreign or domestic)
Organization Location: Greenbelt, MD

Partner's Contribution to the Project:
Collaborative Research

More Detail on Partner and Contribution:

NCAR Computational Information Systems Laboratory

Organization Type: Other Organizations (foreign or domestic)
Organization Location: Boulder, CO

Partner's Contribution to the Project:
Collaborative Research

More Detail on Partner and Contribution:

NCAR Earth Observing Laboratory

Organization Type: Other Organizations (foreign or domestic)
Organization Location: Boulder, CO

Partner's Contribution to the Project:
Collaborative Research

More Detail on Partner and Contribution:

NOAA Earth System Research Laboratory

Organization Type: Other Organizations (foreign or domestic)
Organization Location: Boulder, CO

Partner's Contribution to the Project:
Collaborative Research

More Detail on Partner and Contribution:

NOAA National Centers for Environmental Prediction

Organization Type: Other Organizations (foreign or domestic)
Organization Location: College Park, MD

Partner's Contribution to the Project:
In-Kind Support
Collaborative Research

More Detail on Partner and Contribution:

NOAA National Climatic Data Center

Organization Type: Other Organizations (foreign or domestic)
Organization Location: Asheville, NC

Partner's Contribution to the Project:
Collaborative Research

More Detail on Partner and Contribution:

Open Geospatial Consortium

Organization Type: Other Nonprofits
Organization Location: Wayland, MA

Partner's Contribution to the Project:
Collaborative Research

More Detail on Partner and Contribution:

The HDF Group

Organization Type: Other Nonprofits
Organization Location: Champaign, IL

Partner's Contribution to the Project:
Collaborative Research

More Detail on Partner and Contribution:

U.S. Geological Survey

Organization Type: Other Organizations (foreign or domestic)
Organization Location: Reston, VA

Partner's Contribution to the Project:
Collaborative Research

More Detail on Partner and Contribution:

What other collaborators or contacts have been involved?

NO

Impacts

What is the impact on the development of the principal discipline(s) of the project?

A survey of papers published between 2008 and 2012 in journals of the American Meteorological Society shows 110 citations of Unidata software and data services. In the same period, an additional 52 papers published in journals of the American Geophysical Union cited Unidata software and data services. In both cases, papers published between 2008 and 2012 account for nearly half the total number of citations recorded over more than a quarter century of Unidata history – an indicator of the growing reach of Unidata's software and services.

In 2012, the Unidata Program Center (UPC) surveyed longstanding academic community members to find what types of research Unidata software and data services are enabling today. Among the comments were:

- *We use Unidata software/facilities quite extensively from getting global model analysis/forecast fields in real time for high-resolution coupled model development and forecasting experiments, getting satellite data for analysis, and to display our model results in IDV.*
- *Several Professors are involved with field programs that have intensive observing periods that include aircraft, etc. Unidata-provided weather and model information is integral (anywhere from minor to absolutely essential) to the field program and operational decisions. In addition, software and real-time data provided by Unidata is part of the post-field program analysis.*

Looking beyond the self-reported activities of Unidata community members, a survey of some recent academic journal citations highlights the use of Unidata technologies in a wide range of contexts including:

- The Gulf of Mexico Coastal Ocean Observing System (Simoniello *et al*., 2011)
- Algorithms for Detecting and Tracking Tropical Cloud Clusters (Hennon *et al*., 2011)
- Bridging the gap between Hydrologic and Atmospheric communities (Boldrini *et al*. 2012)

What is the impact on other disciplines?

A review of citations reported by the Google Scholar search engine indicated that Unidata software and data services were cited 1150 times in the full range of scholarly literature encompassed by the search engine. Interestingly, Google Scholar returned an additional 3690 articles mentioning Unidata's Network Common Data Form (netCDF), but which did not include mention of its connection to Unidata. This correlates with anecdotal evidence of widespread netCDF use beyond the communities traditionally served by Unidata. As with citations in the journals mentioned above, which are more commonly associated with Unidata's core academic community, comparing the number of citations recorded in the past five years with a complete history indicates that roughly half of the citations have come in since 2008.

What is the impact on the development of human resources?

Unidata software and data services are in use at nearly 750 U.S. colleges and universities and more than twice that many in other countries. Unidata reaches across geoscience disciplines to provide data and tools to researchers, educators, and students in the atmospheric sciences, hydrology, and oceanography fields, among others. From research universities to community colleges, Unidata provides timely support and service to the academic organizations that are training the next generation of geoscientists. In the process, it is estimated that more than 100,000 users are exposed to products generated using Unidata software and systems, and more than three quarters of all graduate students in the atmospheric and related sciences now use software provided by Unidata.

For example, Pennsylvania State University considers Unidata's IDD feed, along with analysis/display software packages including GEMPAK/NAWIPS and IDV, to be vital tools for research, instruction and outreach. Unidata software allows students to explore current and past weather scenarios as part of upper-level undergraduate meteorology courses, and is also used for the generation of graphics for the popular and publicly-available Penn State electronic map wall.

Unidata strives to promote diversity in the geosciences by supporting use of its technologies in a wide array of educational institutions. Unidata software and data services are used at universities in all 31 EPSCoR jurisdictions, including many institutions that have a large number of students from underrepresented communities.

Users of Unidata software and data rely on the UPC for comprehensive support services. UPC software developers handle user support directly, together responding to an average of more than 250 technical support questions each month. Developers also create product documentation, training materials, and provide hands-on training workshops each year. The workshops, which have been attended by more than 450 participants from the university, government, and commercial spheres in the past five years, provide UPC developers with an excellent opportunity to interact with software users

face-to-face.

What is the impact on physical resources that form infrastructure?

Each year, the UPC sets aside $100,000 to fund the Unidata Community Equipment Awards program. The program provides funds to encourage new geoscience departments to join the Unidata community and to allow existing members to continue and enhance their participation. During the past five years, 30 awards were made to a diverse group of institutions, from major U.S. research universities to community colleges to educational institutions in Europe and Central America.

Projects funded in the past five years include:

- **Madison Area Technical College** used award funding to introduce modern weather software into its meteorology curriculum, ingesting data from Unidata's IDD for display using McIDAS and IDV.
- The **Coastal Ocean Observation Lab at Rutgers University** (RU-COOL) used award funding to install Unidata and other open source technologies to collect, process, and make available a wide range of ocean data for use by students and researchers.
- **Iowa State University** used award funding to establish THREDDS and RAMADDA servers that provide access to the university's weather data archive to students and the Unidata community.

A complete list of projects funded under the Community Equipment Awards program and the many creative applications of Unidata software and systems by the recipient universities to advance education and research is available online at http://www.unidata.ucar.edu/community/equipaward/.

What is the impact on institutional resources that form infrastructure?

Unidata community members look to the UPC not only for technological solutions, but for guidance on emerging trends in cyberinfrastructure and to represent their interests in collaborations with standards bodies and organizations that work across scientific disciplines. As standards-based solutions have become increasingly important to the conduct of international science, Unidata has assumed a central role in identifying and articulating standards, conventions, and data formats. Unidata's standards efforts have enabled ongoing collaboration with dozens of international organizations – especially those represented in the OGC MetOceans, Earth System Science, and Hydrology Domain Working Groups.

Unidata undertakes a variety of activities with the goal of building a vibrant community in the geosciences and beyond. The following are a sampling of these activities:

- **Scientific Society Meetings**
  Unidata staff are active in convening sessions and making presentations at AGU, AMS, and EGU meetings as well as at other national and international conferences and workshops. UPC staff members helped create AGU's Earth and Space Science Informatics session in 2004; participation in the AGU ESSI program has grown to over 400 abstracts for the 2012 Fall Meeting. The EGU ESSI Division was formally launched in 2008 with the active involvement of UPC staff; it has grown significantly, receiving over 300 papers at the 2013 EGU Geosciences Meeting.
- **GALEON**
  Unidata has been a core participant in the Open Geospatial Consortium GALEON (Geo-interface for Air, Land, Earth, Oceans NetCDF) Interoperability Experiment. GALEON aims to specify and use standard interfaces to foster interoperability between data systems used by the traditional GIS community and those in the atmospheric and oceanographic science or Fluid Earth Systems (FES) communities. (Read more online at http://bit.ly/12WI75U)
- **OPULS**: The OPeNDAP-Unidata Linked Servers project, funded by NOAA, reflects the intentions of the two organizations to better align, link, and eventually integrate software that they independently offer as open source. The union of the capabilities provided by the TDS and Hyrax software offerings has become increasingly important as basic infrastructure for scientific data exchange.

What is the impact on information resources that form infrastructure?

The UPC coordinates the Internet Data Distribution system (IDD), in which hundreds of universities cooperate to disseminate more than 13 Tbytes/day of near real-time earth observations via the Internet (as of 2013). While the "push" data services provided by the IDD system are the backbone of Unidata's data distribution services, the UPC also provides on-demand "pull" data services via THREDDS, ADDE, and RAMADDA data servers.

The UPC's data servers are not classified as "operational" resources, but they nonetheless have a 99.96% uptime record and are used heavily by educational sites that lack the resources to store IDD-provided data locally, or to operate their own data servers. UPC's servers are housed in a UCAR co-location computer facility for reliability, and share UCAR's Internet2/National Lambda Rail connectivity, which provides access to ample bandwidth for Unidata's needs.

The Unidata Local Data Manager (LDM) system includes network client and server programs designed for event-driven data distribution. It is the fundamental component of the IDD system. The LDM is used by hundreds of sites worldwide, and is integrated into the National Weather Service's AWIPS II package.

Unidata's Network Common Data Form (netCDF) is a set of freely-available, open-source technologies for efficiently storing scientific data. Ongoing development of netCDF has led to its wide adoption by the atmospheric sciences community, and it is especially popular among climate and ocean modelers. For example, model output datasets for the Fifth Assessment Report of the Intergovernmental Panel on Climate Change must be submitted in netCDF format, using the associated Climate and Forecast (CF) metadata conventions. The resulting large base of netCDF users and data has led to support for the format in more than 80 open source packages and many commercial applications including ArcGIS, MATLAB, and IDL.

Unidata's THREDDS Data Server (TDS) allows for browsing and accessing collections of scientific data via electronic networks. Data published on a TDS are accessible through a variety of remote data access protocols including OPeNDAP, OGC Web Map Service (WMS) and Web Coverage Service (WCS), NetCDF Subset Service (NCSS), and HTTP. The TDS is widely used in the United States (by NOAA, USGS, NASA, and the Earth System Grid, for example) and internationally, and are part of the deep infrastructure on which next generation capabilities are being built by other organizations. Additionally, many other tools build on the TDS (NOAA PMEL's LAS and Ferret-TDS, for example), and on Unidata's Common Data Model (CDM) on which the TDS is built.

Unidata's Integrated Data Viewer (IDV) is a 3D geoscience visualization and analysis tool that gives users the ability to view and analyze a rich set of geoscience data in an integrated fashion. The IDV brings together the ability to display and analyze satellite imagery, gridded data (such as numerical weather prediction model output), surface observations (METARs), upper air soundings, NWS NEXRAD Level II and Level III RADAR data, NOAA National Profiler Network data, and GIS data, all within a unified interface. The IDV integrates tightly with common scientific data servers (including Unidata's TDS) to provide easy access to many real-time and archive datasets. It also provides collaborative features that enable users to easily share their own data holdings and analysis products with others.

In addition, Unidata develops and supports numerous other software packages to help scientists and educators manage and use geoscience data:

- AWIPS II: A weather forecasting, display, and analysis package currently being developed by the National Weather Service and the National Centers for Environmental Prediction. It is being modified and supported for use by the university community by Unidata.
- GEMPAK: The GEneral Meteorology PAcKage was developed by NCEP to display and analyze weather data. It is distributed to the university community and supported by Unidata.
- McIDAS: The Man-computer Interactive Data Access System (McIDAS) is a large, research-quality suite of applications used for decoding, analyzing, and displaying meteorological data. The older McIDAS-X system, developed by the University of Wisconsin's Space Science Engineering Center and supported by Unidata, is gradually being replaced by the IDV and by McIDAS-V (which is based on the IDV).
- UDUNITS: Unidata's UDUNITS supports conversion of unit specifications between formatted and binary forms, arithmetic manipulation of units, and conversion of values between compatible scales of measurement.
- Rosetta: The Rosetta project at the UPC is an effort to improve the quality and accessibility of observational data sets collected via datalogging equipment. The initial goal of Rosetta is to transform unstructured ASCII data files of the type commonly generated by datalogging equipment into the netCDF format, while minimizing disruption to existing scientific workflows.

What is the impact on technology transfer?

While Unidata's mission is to support the academic research and education community, all software packages developed by Unidata are freely available and open source. As noted previously, netCDF libraries are incorporated in more than 80 open source packages and many commercial applications.

What is the impact on society beyond science and technology?

Unidata technologies help community members reach out to their own communities, facilitating the provision of meteorological data and displays through dozens of popular web sites. For example, the College of DuPage, Iowa State University, University of Wyoming, University of Oklahoma, and University of Utah's Mesowest all make extensive use of Unidata services in their outreach. In addition, several museums (the Boston Museum of Science and San Francisco's Exploratorium among them) make use of either data or software provided by Unidata.

Changes/Problems

Changes in approach and reason for change
Nothing to report.

Actual or Anticipated problems or delays and actions or plans to resolve them
Nothing to report.

Changes that have a significant impact on expenditures
Nothing to report.

Significant changes in use or care of human subjects
Nothing to report.

Significant changes in use or care of vertebrate animals
Nothing to report.

Significant changes in use or care of biohazards
Nothing to report.