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## Preview of Award 1344155 - Annual Project Report

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### Cover

Federal Agency and Organization Element to Which Report is Submitted:	<b>4900</b>
Federal Grant or Other Identifying Number Assigned by Agency:	<b>1344155</b>
Project Title:	<b>Unidata 2018: Transforming Geoscience through Innovative Data Services</b>
PD/PI Name:	<b>Mohan K Ramamurthy, Principal Investigator</b>
Recipient Organization:	<b>University Corporation For Atmospheric Res</b>
Project/Grant Period:	<b>04/01/2014 - 03/31/2019</b>
Reporting Period:	<b>04/01/2016 - 03/31/2017</b>
Submitting Official (if other than PD/PI):	<b>Mohan K Ramamurthy Principal Investigator</b>
Submission Date:	<b>03/08/2017</b>
Signature of Submitting Official (signature shall be submitted in accordance with agency specific instructions)	<b>Mohan K Ramamurthy</b>

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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 2018: Transforming Geoscience through Innovative Data

Services” (NSF 1344155). The proposal for that funding award grouped the Unidata program’s activities into the following four strategic goals:

- Enabling widespread, efficient access to geoscience data
- Developing and providing open-source tools for effective use of geoscience data
- Providing cyberinfrastructure leadership in data discovery, access, and use
- Building, supporting, and advocating for the geoscience community

Note: While Unidata approaches these goals from a variety of directions, the activities and results described below reflect a special focus on adapting Unidata technologies to take advantage of new capabilities emerging from the cloud computing paradigm.

The following sections detail the program’s activities and results during the period April 2016 – March 2017.

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

#### Major Activities:

This section summarizes Unidata’s main focus areas during the third year of the five-year grant. Additional information on the outcome of these activities can be found under “Significant Results,” below.

#### Data Distribution

Helping researchers and educators acquire and use real-time meteorological data was one of the Unidata program’s founding goals, and continues to be one of the core activities of the program. By participating in Unidata’s Internet Data Distribution (IDD) system, educators and researchers can subscribe to one or more of the 30 streams of current data that interest them. The IDD system comprises over 600 machines at 260+ sites running Unidata’s Local Data Manager (LDM) software to receive (and in many cases retransmit to “downstream” institutions) real-time weather data.

(Note that a number organizations use the LDM to move substantial amounts of data but do not report statistics to Unidata. Among these organizations are NOAA, NASA, USGS, USACE, the governments of Spain and South Korea, private companies, and others.)

In collaboration with NOAA, Unidata received funding to purchase, install, and configure equipment needed to ingest imagery and products from the initial instantiation of the next generation U.S. geostationary spacecraft, GOES-R, at the NCAR Mesa Lab in Boulder, CO. In 2016 hardware installation was completed, and the UPC stands ready to begin distributing data from the GOES-16 spacecraft when it becomes available in mid-2017.

#### Cloud Technology Experiments

Finding ways to leverage the strengths of the cloud computing environment to enhance universities’ access to geoscience data and tools is one of Unidata’s highest priorities during the period of this award. During the third year of the award, UPC staff have made significant progress toward these goals, establishing successful cloud-based data distribution mechanisms (notably AWIPS EDEX servers and THREDDS Data Servers), working with cloud service providers to enable access to historical and real-time data, and creating demonstrations of cloud-based application services (most notably for remote access to the IDV visualization software). The program continues to build relationships with cloud technology providers, and has received research access to cloud computing resources on the XSEDE Jetstream cloud computing platform, the Open Commons Consortium, Microsoft, and Amazon Web Services.

#### Software Development

Developing free, open-source software to help researchers and educators manage their access to and use of geoscience data is one of Unidata’s primary activities. During the third year of this award, Unidata’s development staff has mixed ongoing work toward well-defined, long-term development goals for existing technologies with newer technologies and initiatives aimed at addressing our community’s evolving technology needs. In particular, the growing popularity of the Python programming language in geoscience researchers’ and educators’ scientific workflows has prompted UPC staff to focus additional efforts on ensuring that Unidata technologies mesh well with Python-based tools and processes. The MetPy and Siphon projects are examples of Unidata efforts that are gaining traction with the expanding segment of the community that is embracing Python-based workflows.

In the third year of this award UPC developers have focused their efforts on using the Docker containerization technology to deliver software to scientists in a more reliable and effective way. While these technologies are evolving quickly, Docker has become a clear community favorite. Unidata’s embrace of this popular and increasingly capable component of the modern computing environment has the potential to remove some of the barriers to adoption of Unidata technologies, especially at universities where IT resources are scarce.

#### Community Building

Unidata sponsors or participates in a wide variety of events and activities that bring community members together to share ideas and techniques, aids in participation, or enlarges the existing community.

Perhaps most important to the ongoing success of the Unidata program is a community-based governance structure. Unidata calls on members of its core academic community to serve on its two governing committees: the Unidata Users Committee and the Unidata Strategic Advisory Committee. Users Committee members are charged with serving as an interface between the Unidata Program Center and individuals and organizations who use Unidata data streams and services, reporting on challenges they face and shedding light on the scientific and technical environment in which they work. Members of the Strategic Advisory Committee are asked to weigh in on the larger, longer-term trends and issues they see evolving in the geosciences, guiding the program to areas where community leadership is needed and valuable. These stable avenues of communication between the UPC and the community it serves have been instrumental in helping the program meet its members evolving cyberinfrastructure needs.

Unidata's Community Equipment Awards program serves to build capacity at member universities, allowing them to better serve their own students and the Unidata community at large. In the third year of the current award, three of the five Equipment Award grants are supporting universities' experiments with moving cloud-computing-based processes for analyzing and visualising geoscience data.

Additionally, UPC staff members participate actively in scientific societies and other organizations that serve our community members. Unidata participates actively in the American Meteorological Society, the American Geophysical Union, the European Geosciences Union, the ESIP Federation, the Open Geospatial Consortium, Research Data Alliance, and the NSF EarthCube initiative, among others. Staff activities in association with these groups range from highly technical work with scientific data formats and software development issues, to member assistance and support, to capacity-building for other organizations.

In early 2016, in coordination with the Unidata Users Committee, UPC staff polled the Unidata community via the 2016 Unidata Community Survey. The survey was conducted online and 260 responses from the United States and 24 other countries were collected. Results were discussed with both of Unidata's governing committees; a brief analysis of the survey results is available in this blog posting:

<http://www.unidata.ucar.edu/blogs/news/entry/2016-community-survey-results>

Specific  
Objectives:  
Significant  
Results:

This section lists some of the most significant results attained as a result of the work described in the "Major Activities" section above.

### **Data Distribution**

The volume of observational data and model output delivered to Unidata community members and institutions in near real-time continues to grow. As of January 2017, Unidata's Internet Data Distribution (IDD) cluster nodes is handling volumes averaging roughly 30 Terabytes per day, up from an average of 23 Terabytes per day in 2015.

Using resources provided by a Microsoft research grant, Unidata has established an AWIPS Environmental Data EXchange (EDEX) server on the Microsoft Azure cloud service. Access to this server is being made available to Unidata community sites, allowing them to use or test the AWIPS CAVE client software without the need to maintain a local EDEX server. In early 2017, Unidata's cloud-based EDEX server is providing approximately 16 GB per day of data to AWIPS users at more than 40 universities.

### **Cloud Technologies**

Unidata is investigating how its technologies can best take advantage of cloud computing. To this end, we have been employing Docker container technology to streamline building, deploying, and running Unidata technology offerings in cloud-based resources. Our preliminary efforts are available on various Docker-related Unidata github and dockerhub repositories and cloud demonstration servers. Specifically:

LDM: We have developed an LDM container that is currently running in the Azure cloud as a relay node and leaf node and supplying data to RAMADDA and THREDDS Data Server containers.

RAMADDA: We have collaborated with Unidata Users Committee member Warren Pettee to enhance a RAMADDA Docker container. This container is running without issue on the Azure Cloud.

THREDDS Data Server and TDM: We are currently collaborating with Axiom Data Science to construct a TDS/TDM container that will satisfy Unidata and Axiom objectives and avoid duplication of effort. We have a demonstration server running on the Azure Cloud that will soon be replaced by the efforts of this collaboration.

ADDE: We have informally asked the University of Wisconsin/SSEC to allow us to make freely available a

containerized distribution of the ADDE server component of McIDAS-X. A formal petitioning is anticipated in 2017.  
 CloudIDV: We are in the process of obtaining feedback on this IDV-in-the-cloud implementation from beta users.

We have received research and development grants of cloud-computing resources from the XSEDE Jetstream project, the Open Commons Consortium, Microsoft Azure, and Amazon Web Services. These resources are in use testing Unidata technologies, creating products for delivery via the IDD, and serving as community-accessible test data servers.

Of special interest is the Azure for Research Grant for Unidata AWIPS, which has allowed us to create a community-accessible cloud-based AWIPS Environmental Data Exchange (EDEX) server. More than 40 universities are currently accessing this server in their testing of the AWIPS system for university use. (An EDEX server on-site at the UPC is available as a replacement for any periods of time during which a cloud-based server is not funded.) This grant has enabled the development of a RedHat 7 supported EDEX and CAVE build, which can take advantage of the Azure file sharing architecture to create a distributed EDEX environment, scalable to data requirements.

### **Software Development**

AWIPS and GEMPAK:

Unidata's AWIPS efforts have been focused on creating a modified version of the package tailored for the needs of the university community. In late 2016 version 16.2.2 of the AWIPS package was made available to university users. Unidata's tailored version is currently running at approximately 60 universities.

IDV:

Unidata's Integrated Data Viewer version 5.3 was released in May 2016. It contained several changes including the integration of the netCDF-Java 4.6.5 library, latest VisAD, new 3D Volume Vector display, volume trajectories display as well as new trajectory display types.

LDM:

Local Data Manager versions 6.13.0 through 6.13.5 were released 2016. Additionally, work on a "multicast" version of the LDM employing virtual circuit technology has been under way as part of a two-year research grant in collaboration with the University of Virginia.

NetCDF:

The netCDF C++ library version 4.3.0 and the netCDF-FORTRAN library version 4.4.4 were released in May, 2016. The netCDF-C library version 4.4.1 was made available in July 2016, with a minor release (version 4.4.1.1) following in November, 2016.

Python:

The MetPy project, which is a collection of Python tools for reading, visualizing, and performing calculations with weather data, made significant progress in 2016. In addition to releases 0.3.0 through 0.4.2, MetPy developers presented progress to the community at the 2016 AMS annual meeting, and the 2016 SciPy conference, and provided Python training at workshops at the University of Wisconsin and the Unidata Program Center.

The Siphon project is a collection of Python utilities for downloading data from Unidata data technologies. It is still in an early stage of development, and is not yet considered stable, but it was used successfully during Unidata's 2016 software training workshop.

UPC staff are also contributors to the netcdf4-python project, which is a Python interface to the netCDF C library, and are also actively working on contributions to the popular matplotlib Python module.

Rosetta:

An instance of the Rosetta server is now hosted at the UPC for testing purposes. Rosetta now has the ability to publish converted files directly to RAMADDA and the ACADIS Gateway

TDS:

The THREDDS Data Server versions 4.6.4 through 4.6.6 were released in 2016, and version 4.6.8 is currently running on Unidata's TDS server at thredds.ucar.edu. THREDDS Version 5.0 is in a testing phase; release is planned for 2017.

### **Community Building**

During the second year of the award, Unidata solicited atmospheric science researchers or research groups to participate in a pilot project (ADDIT, supported by supplemental funding from NSF) aimed at designing and implementing robust data management workflows that satisfy NSF and other federal funding agency requirements. During the third year UPC staff, including a student intern, worked with community members to create an initial group of data management case studies for inclusion in Unidata's Data Management Resource Center. In addition to documenting the data workflows of these

participants, UPC staff were able to help with designing and implementing data management workflows hinging on Unidata-created and -supported technologies including the netCDF, Rosetta, and RAMADDA.

Key outcomes  
or Other  
achievements:

This section briefly notes some Unidata activities and achievements not listed in the “Significant Results” section, above.

As of January 2017, Unidata’s IDD cluster delivers roughly 30 Tbytes/day to downstream IDD sites. Unidata continues its involvement in the the Ocean Data Interoperability Platform (ODIP) project. UPC staff are involved in EarthCube projects in collaboration with George Mason University, the University of Texas, OPeNDAP, and IRIS. In addition, Unidata is leading a collaborative effort for the funded activity *EarthCube IA: Collaborative Proposal: Advancing netCDF-CF for the Geoscience Community*.

Program Center staff participated in numerous scientific conferences in the third year of the award, including:

- American Meteorological Society summer and annual meetings
- American Geophysical Union annual meeting
- European Geosciences Union annual meeting
- ESIP Federation meeting
- EarthCube All Hands meeting
- Research Data Alliance Plenary meetings
- National Data Service meetings
- Open Geospatial Consortium Technical Committee meetings

### Python Training

In addition to the supplemental funding from the National Science Foundation used to implement the initial version of the Data Management Resource Center, Unidata received supplemental funding aimed at easing the transition to use of the Python programming language by creating a corpus of online training materials geared toward the geoscience community’s specific needs. An initial version of Unidata’s Online Python Training resource (<http://unidata.github.io/online-python-training/>) has been created, and additional material will be included as resources are available.

### EarthCube Science Support Office

Unidata Program Director Mohan Ramamurthy is the Principal Investigator on the EarthCube Science Support Office (ESSO) project, which is supported by a cooperative agreement with the NSF. Unidata staff played a role in the transition of the EarthCube support function from the University of Arizona and the Arizona State Geological Survey, where it resided under the auspices of the EarthCube Test Enterprise Governance project, to UCAR in Boulder. The ESSO is co-located with the Unidata Program Center, and several UPC staff members contribute a fraction of their work time to supporting the EarthCube project.

### \* 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. In 2016, the workshops were attended by 33 participants from the university, government, and commercial spheres. UPC staff provided software training for an additional 50 participants at a regional workshop at the University of Wisconsin/Space Science Engineering Center in June 2016.

Unidata’s summer internship program invited students Alex Haberlie and Kristen Pozsonyi to spend the summer working at the Unidata Program Center in 2016. A report on the various projects Alex and Kristen undertook while at the Program Center is available at:

<http://www.unidata.ucar.edu/blogs/news/entry/unidata-interns-wrap-up-summer>

### \* 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, European Geosciences Union, the Open Geospatial Consortium, and the Earth Science Information Partners (ESIP) Federation.
- 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.
- The 2015 Unidata Users Workshop brought 74 community members together for four days of seminars, hands-on learning, and discussion. While the majority of the workshop sessions were led by community members, UPC staff also presented work being done at the Program Center, and, there was ongoing discussion about how Unidata could assist community members in navigating the changing technology landscape.

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.

### \* What do you plan to do during the next reporting period to accomplish the goals?

The Unidata program will continue to undertake the activities described in the “Plan of Action” section of the grant proposal for this award. For reference, this document is available on the Unidata web site (described as our “Five-Year Plan”):

[http://www.unidata.ucar.edu/publications/Unidata\\_2018.pdf](http://www.unidata.ucar.edu/publications/Unidata_2018.pdf)

An Operating Plan for the next reporting period will be submitted separately, along with a budget justification.

Using remaining supplemental funding for ADDIT project described in Major Activities (Community Building) above, the Program Center will continue to engage in additional activities not described in the “Plan of Action.” Specifically, we will pursue ongoing work with community members who have chosen to participate in the ADDIT project. Work will include refining these participants’ data management processes, assisting with implementation of Unidata data management technologies where desired, and documenting the resulting process for community benefit.

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## Products

### Books

### Book Chapters

### Inventions

### Journals or Juried Conference Papers

Katz, Daniel S. and Choi, Sou-Cheng T. and Niemeyer, Kyle E. and Hetherington, James and Loffler, Frank and Gunter, Dan and Idaszak, Ray and Brandt, Steven R. and Miller, Mark A. and Gesing, Sandra and Jones, Nick D. and Weber, Nic and Marru, Suresh and Allen, Gabrielle and Penzenstadler, Birgit and Venters, Colin C. and Davis, Ethan and Hwang, Lorraine and Todorov, Ilian and Patra, Abani and de Val-Borro, Miguel (2016). Report on the Third Workshop on Sustainable Software for Science: Practice and Experiences (WSSSPE3). *Journal of Open Research Software*. 4 e37. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; DOI: <https://doi.org/10.5334/jors.118>

### Licenses

### Other Conference Presentations / Papers

Chen, Shuoshuo and Ji, X. and Veeraraghavan, M. and Emmerson, S. and Slezak, S. and Decker, S. G. (2016). *A Cross-Layer Multicast-Push Unicast-Pull (MPUP) Architecture for Reliable File-Stream Distribution*. Proceedings, the 40th IEEE Computer Society International Conference on Computers, Software & Applications (COMPSAC). Atlanta, GA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

May, R. M. (2016). *Bootstrapping an Open Source Library: How MetPy Got Up and Running with Lazy Developers*. Proceedings, SciPy 2016. Austin, TX. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Chastang, J. and Yoksas, T. and Ramamurthy, M. K. (2017). *Geoscientific Data Distribution in the XSEDE Jetstream Cloud*. Proceedings, 33rd

Conference on Environmental Information Processing Technologies, 97th AMS Annual Meeting. Seattle, WA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Haberlie, Alex M. and May, R. M. (2017). *Implementation and Comparison of Interpolation Techniques for the Meteorological Python (MetPy) Package*. Proceedings, Seventh Symposium on Advances in Modeling and Analysis Using Python, 97th AMS Annual Meeting. Seattle, WA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

May, R. M. (2017). *MetPy's Recent Updates and the Road to 1.0*. Proceedings, Seventh Symposium on Advances in Modeling and Analysis Using Python, 97th AMS Annual Meeting. Seattle, WA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

May, R. M. (2017). *Python: Its Past, Present, and Future in Meteorology (Core Science Keynote)*. Proceedings, Seventh Symposium on Advances in Modeling and Analysis Using Python, 97th AMS Annual Meeting. Seattle, WA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Arms, S. (2016). *THREDDS Data Server: OPeNDAP and other tales from the server side*. Proceedings, 2016 Earth System Grid Federation Face-to-Face meeting. Washington, DC. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Chastang, J. and May, R. M. (2017). *Unidata Online Python Training*. Proceedings, Seventh Symposium on Advances in Modeling and Analysis Using Python, 97th AMS Annual Meeting. Seattle, WA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Weber, J. and May, R. M. (2017). *Unidata and the Big Data Project*. Proceedings, 33rd Conference on Environmental Information Processing Technologies, 97th AMS Annual Meeting. Seattle, WA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Ho, Y. and Weber J. (2017). *WRF Hydro Stream Flow Display in the IDV*. Proceedings, 33rd Conference on Environmental Information Processing Technologies, 97th AMS Annual Meeting. Seattle, WA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

## Other Products

## Other Publications

## Patents

## Technologies or Techniques

## 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.

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## Participants/Organizations

What individuals have worked on the project?

**Information about Unidata Program Center 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
University of Wisconsin	Academic Institution	Madison, WI

Full details of organizations that have been involved as partners:

<p><b>University of Wisconsin</b></p> <p><b>Organization Type:</b> Academic Institution</p> <p><b>Organization Location:</b> Madison, WI</p> <p><b>Partner's Contribution to the Project:</b></p> <ul style="list-style-type: none"> <li>Financial support</li> <li>In-Kind Support</li> <li>Facilities</li> <li>Collaborative Research</li> </ul> <p><b>More Detail on Partner and Contribution:</b></p>
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What other collaborators or contacts have been involved?

The Unidata Program has active, unfunded collaborations with:

- Open Geospatial Consortium (OGC)
- Copernicus Marine Environment Monitoring Service (CMEMS)
- NOAA/National Centers for Environmental Prediction (NCEP)

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## Impacts

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

A survey of papers published in 2016 in journals of the American Meteorological Society shows 40 articles containing citations of Unidata software and data services. (Of these, 32 refer to Unidata software packages but make no mention of the Unidata program itself.) In the same period, an additional 63 papers published in journals of the American Geophysical Union cited Unidata software and data services.

### What is the impact on other disciplines?

A review of citations reported by the Google Scholar search engine in 2016 indicated that Unidata software and data services were cited 2004 times in the full range of scholarly literature encompassed by the search engine. Of these, 1651 refer to Unidata software packages but make no mention of the Unidata program itself. This correlates with anecdotal evidence of widespread use of Unidata products (especially netCDF) beyond the communities traditionally served by Unidata.

### What is the impact on the development of human resources?

Because providing data and tools for use in educational settings is a core part of Unidata's mission, the bulk of the program's activities can be thought of as helping develop human resources in the geosciences. Of special note are the following metrics, collected in late 2016:

Number of U.S. universities receiving software: 310

Number of universities outside the U.S.: 811

Number of attendees of 2016 training workshops: 33

### 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.

Projects funded in 2016 include:

<b>University/PI</b>	<b>Project Title</b>
Oregon State University Karen M. Shell	A Jupyter server for the Oregon State University Climate Science Program
Pennsylvania State University Charles F. Pavloski	A Prototype Cloud-Based Visualization System for Unidata Applications
University of Iowa Bong Chul Seo	A Pilot Project for Cloud-based NEXRAD Data Processing, Analysis, and Visualization for Flood Forecasting and Water Resources Management
University of Louisiana at Monroe Todd Murphy	AWIPS-II Infrastructure Upgrade at the University of Louisiana at Monroe
University of North Dakota Gretchen Mullendore	UND Big Weather Web: Distributed Data Solutions

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, and the EGU ESSI Division was formally launched in 2008 with the active involvement of UPC staff. Both sessions have grown significantly.

### National Water Center

The National Water Model (NWM) is a hydrologic model that simulates observed and forecast streamflow over the entire continental United States. Based in large part on the community-developed Weather Research and Forecasting Model Hydrologic modeling extension package (WRF-Hydro), the NWM integrates terrestrial hydrology and atmospheric conditions to provide streamflow predictions for approximately 2.7 million river reaches. Several Unidata technologies are in use in connection with the NWM and at the National Water Center (NWC) in Tuscaloosa, Alabama:

Output from the NWM is delivered in netCDF format, making it easy to analyze and visualize the model output using a variety of standard software tools, from coding-focused workflows in Python or R to full-featured applications such as the IDV and ESRI's ArcGIS.

NWM output is made available via NOAA's National Operational Model Archive and Distribution System (NOMADS) project, which incorporates the TDS and lists Unidata as a "Core Collaborator."

LDM software is used for data transfer at the NWC, both to acquire data for NWM initialization and to transfer the model output to NOMADS.

In addition, UPC staff have provided guidance in configuring data systems and using Unidata tools at the NWC. UPC staff were also involved in the National Flood Interoperability Experiment sponsored by the NWC and CUAHSI during 2015-2016.

### EarthCube Activities

Unidata's director (Dr. Mohan Ramamurthy) currently serves as the director of the EarthCube Science Support Office (ESSO), which is co-located with the Unidata Program Center. In his capacity as ESSO director, he coordinates closely with the EarthCube governance committees and Leadership Council. Dr. Ramamurthy also represents Unidata on the EarthCube Council of Data Facilities.

Unidata participates in a variety of EarthCube activities, including collaboration on five awarded "Building Blocks" proposals. Most recently, a Unidata was awarded an EarthCube Building Blocks Collaborative Proposal titled *That dot is a world! Drilling down from a statistics scatterplot to pre-populated case Notebooks*, in collaboration with the University of Miami.

## 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 earth observations via the Internet in near real time. As of early 2017, the traffic handled by servers operated by the UPC itself -- a fraction of the total IDD system -- was more than 30 Tbytes/day. 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 99.98% 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.

Unidata works closely with the National Weather Service and the National Centers for Environmental Prediction to create a version of the AWIPS software tailored for use by the university community. In 2016, individuals from 63 universities received the Unidata version of AWIPS, and 44 of these have made use of a cloud-based EDEX server hosted by Unidata. In addition, Unidata has supported university use of the GEneral Meteorology PAcKage (GEMPAK) for many years, and continues to do so now that GEMPAK is part of the AWIPS environment.

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

**MetPy:** The MetPy project is an effort aimed at bringing GEMPAK-like meteorology functionality to the Python environment. While still relatively new, MetPy has a strong following in the open source Python community.

**Siphon:** The Siphon project is a collection of Python utilities for downloading data from Unidata data technologies. Siphon's current functionality focuses on access to data hosted on a THREDDS Data Server. Siphon is still in an early stage of development.

**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.

## 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.

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## 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.

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The National Science Foundation, 2415 Eisenhower Avenue, Alexandria, Virginia 22314, USA Tel: (703) 292-5111, FIRS: (800) 877-8339 | TDD: (800) 281-8749