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Cover

Federal Agency and Organization Element to Which Report is Submitted:	4900
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Project Title:	Unidata 2018: Transforming Geoscience through Innovative Data Services
PD/PI Name:	Mohan K Ramamurthy, Principal Investigator
Recipient Organization:	University Corporation For Atmospheric Res
Project/Grant Period:	04/01/2014 - 03/31/2019
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Submitting Official (if other than PD/PI):	Mohan K Ramamurthy Principal Investigator
Submission Date:	02/23/2018
Signature of Submitting Official (signature shall be submitted in accordance with agency specific instructions)	Mohan K Ramamurthy

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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 2017 – March 2018.

* 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 fourth 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 national weather services of Spain and South Korea, private companies, and others.)

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 fourth 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 fourth 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. Adoption of MetPy in the education community has ramped up in the past year, as have community contributions to the MetPy code base.

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 fourth year of the current award, three of the five Equipment Award grants are supporting universities' creation and maintenance of data servers that make geoscience data available to students and the university community at large.

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. Of special interest has been the UPC technical staff's active involvement in the Eighth Symposium on Advances in Modeling and Analysis Using Python at the 98th AMS Annual Meeting, and with the separately-funded "Modeling Research in the Cloud" workshop hosted by Unidata.

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 32 Terabytes per day, up from an average of 30 Terabytes per day in 2016. As a result of the GOES-16 spacecraft coming on-line and the data becoming operational in late 2017, the volume of data served via remote access methods (most notably ADDE) have increased from roughly 27 Gbytes/day to roughly 740 Gbytes/day.

In 2016, NOAA/NESDIS funded installation of equipment to ingest imagery and products from the GOES-16 spacecraft. In 2017 the UPC continued its collaboration with NOAA to propose a similar installation for the next satellite in the series, currently referred to as GOES-S. Funding for the next installation has been approved, and plans call for placement of the new satellite receiver dish at the NCAR Mesa Lab in Boulder, CO during 2018.

Cloud Technologies

Building upon our previous containerization efforts, Unidata staff are developing a *Unidata Science Gateway* on NSF-funded XSEDE Jetstream Cloud: <http://science-gateway.unidata.ucar.edu/>. A collection of Unidata-related technologies can be found here for our community to make use of directly or with client applications such as the IDV. The following resources are available:

- An experimental JupyterHub server containing Unidata Jupyter notebook projects
- A THREDDS Data Server supplying a good portion of the data available on the IDD with a five day archive.
- An EDEX server
- A RAMADDA instance containing IDV bundles that retrieve data from Jetstream data servers.
- Two LDM nodes
- An ADDE Server
- An IDV Jetstream plugin allows easy access to Jetstream installations of the TDS, RAMADDA and ADDE from within the IDV.

Technical staff have continued to employ Docker container technology to streamline building, deploying, and running Unidata technology offerings in cloud-based environments, and have been experimenting with these Docker containers in the NSF XSEDE Jetstream cloud.

Of special interest has been the operation of a community-accessible cloud-based AWIPS Environmental Data Exchange (EDEX) server in the XSEDE Jetstream cloud. More than 40 universities access this server in their testing and classroom use of the Unidata AWIPS system. (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 or operational.)

Software Development Workshops

MetPy:

The MetPy project, which is a collection of Python tools for reading, visualizing, and performing calculations with weather data, made significant progress in 2017. In addition to releases 0.4.3 through 0.7.0, MetPy developers presented progress to

the community at the 2017 annual meeting, and the 2017 SciPy conference, and provided Python training at workshops at Millersville University, the University of Wisconsin, the University of Oklahoma, and a “Short Course” at the American Meteorological Society annual meetings in Seattle, WA. MetPy’s open source community grew significantly over the fourth year of this award; as of early 2018 there are more than two dozen contributors to the MetPy code base *outside the Unidata Program Center*.

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 early 2018 version 17.1.1-5 of the AWIPS package was made available to university users. Unidata’s tailored version of AWIPS was downloaded more than 2000 times by individuals associated with U.S. universities in 2017.

IDV:

Unidata’s Integrated Data Viewer version 5.4 was released in May 2017. It contained several changes including the integration of the netCDF-Java 4.6.10 library, latest VisAD, new 3D trajectory display, and new 3D trajectory display types.

LDM:

Local Data Manager version 6.13.6 were released in 2017. Additionally, work on a “multicast” version of the LDM employing virtual circuit technology is under way as part of a two-year research grant in collaboration with the University of Virginia.

NetCDF:

The netCDF-C library version 4.5.0 was made available in October 2017, bringing enhancements to improve read/write times for some complex files and support for HDF5 collective metadata operations, among other features.

Siphon:

The Siphon project is a collection of Python utilities for accessing data from Unidata data technologies such as the THREDDS Data Server. While still in the early stages of development, Siphon has continued to gain functionality in releases 0.4.0 through 0.6.1. Though not yet considered completely stable, it has been used successfully in Unidata’s python-focused training during 2017.

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 4.6.9 through 4.6.11 were released in 2017, and version 4.6.11 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 2018.

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 fourth year UPC staff, including a student intern, worked with community members to continue refining 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.

Each year, the Unidata Users Committee presents the Russell L. Desouza award to a community member whose energy, expertise, and active involvement enable the Unidata Program to better serve geoscience. Honorees personify Unidata’s ideal of a community that shares data, software, and ideas through computing and networking technologies. The 2017 award was given to long-time community member Kevin Tyle from the University at Albany, SUNY, whose readiness to embrace new techniques and technologies — and his willingness to assist others in their efforts to understand and use them — led to his selection.

During the third and fourth years of the award, UPC staff worked closely with the Strategic Advisory Committee to define Unidata’s strategic goals for the next five to ten years. The result was the *Unidata Strategic Vision 20/20* (https://www.unidata.ucar.edu/publications/2017stratplan/Strategic_plan.pdf), which will help guide the program’s efforts to serve and build its community into the next decade.

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

EarthCube Projects

achievements:

UPC staff are involved in EarthCube projects in collaboration with the University of Miami and Columbia University-Lamont-Doherty Earth Observatory. In addition, Unidata is leading a collaborative effort for the funded activity *EarthCube IA: Collaborative Proposal: Advancing netCDF-CF for the Geoscience Community*.

Scientific Conferences

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

- American Meteorological Society summer and annual meetings
- American Geophysical Union annual meeting
- European Geosciences Union annual meeting
- ESIP Federation summer and winter meetings
- EarthCube All Hands meeting
- Research Data Alliance Plenary meetings
- National Data Service meetings
- Open Geospatial Consortium Technical Committee meetings
- 2018 Ocean Sciences Meeting

NSF Site Visit

A National Science Foundation Site Visit Team (SVT) met with Unidata Program Center staff on 6-7 March 2017. The meeting was productive for both the SVT and the Unidata staff, and resulted in several constructive recommendations for Unidata's future activities. After the SVT recommendations were shared with Unidata, Program Center staff created a response to those recommendations, which was delivered to NSF on 12 May 2017. The response concluded with the following:

The SVT's summary report touches on numerous topics that the UPC has been grappling with for several years. Their recommendations give us a heightened awareness of the importance of addressing these issues, along with some possible approaches. Where technical work is suggested or recommendations require additional resources, UPC staff will discuss the feasibility, costs, and benefits of the SVT's specific recommendations and take appropriate actions. We will take the insights gained in the process of this review into our planning for Unidata's future activities and projects.

Python Training

UPC staff conducted three regional workshops in the summer of 2017 focused mainly on teaching Python skills in the context of the atmospheric sciences. The workshops began with basic Python concepts and worked up to using Unidata technologies including MetPy, Siphon, and the Python AWIPS Data Access Framework. Materials from these workshops were used to augment Unidata's Online Python Training resource (<http://unidata.github.io/online-python-training/>), and additional material will be included as resources are available.

UPC staff have also begun producing a series of weekly postings on Python topics, centered on the use of MetPy. The "MetPy Mondays" series began in July 2017, and brings a short discussion of a MetPy related topic to the Unidata developer's blog every Monday, most often with an accompanying short video tutorial.

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. 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.

Modeling Research in the Cloud Workshop

With separate support from NSF, Unidata convened a community workshop titled "Modeling Research in the Cloud" at UCAR in Boulder, CO, May 31- June 2, 2017. Information is available at the workshop web page at <https://www.unidata.ucar.edu/events/2017CloudModelingWorkshop/>. Specific goals of the workshop were to:

- raise awareness of the emerging technologies in the age of cloud computing and data-driven science in the atmospheric prediction community;
- explore the different cloud options that are available, the benefits of conducting modeling research in the cloud, and understand the associated challenges;
- investigate what types of modeling research, scales of problems, and operational situations are likely to benefit from moving to the cloud vs. using local clusters and HPC facilities; and
- discuss a way forward and the steps to take to develop an end-to-end data, computational, software and modeling ecosystem in the cloud.

Committee Membership Changes

Each year, a portion of the membership of each of Unidata's advisory committees "turns over," with members who have served a three-year term rotating off and new members joining the mix. In 2017, the committees changed as follows:

Ibrahim Demir from the University of Iowa and Gretchen Mullendore from the University of North Dakota finished their terms on the Users Committee.

Bill Gallus from Iowa State University and David Santek from the University of Wisconsin, Madison finished their terms on the Strategic Advisory Committee

John Allen from Central Michigan University and Shawn Riley from the University of Oklahoma joined the Users Committee. Kevin Goebbert from Valparaiso University began a second three-year term on the Users Committee

Gretchen Mullendore from the University of North Dakota joined the Strategic Advisory Committee. Sepideh Yalda from Millersville University began a three-year term as chair of the Strategic Advisory Committee.

Warren Pettee from the University of North Carolina, Charlotte finished his term as the Users Committee Student Representative. Tomer Burg from the University at Albany, SUNY began a two-year term as the Users Committee Student Representative.

* 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 2017, UPC staff decided to evaluate the viability of holding multiple regional workshops rather than a single workshop in Boulder, CO. This strategy of bringing the training to the learners, rather than forcing them to travel to Colorado, meant that staff could reach some 108 learners from three regions: the East coast (workshop held at Millersville University); the midwest (workshop held at the University of Wisconsin, Madison); and the central plains (workshops held at the University of Oklahoma and Texas Tech University). Not only did the choice to focus on regional workshops increase the number of participants, it increased the proportion of university students and faculty who were able to attend. The UPC staff are currently polling the larger community to determine how to proceed in 2018 and future years.

Unidata's summer internship program invited four students to spend the summer working at the Unidata Program Center in 2017. Tyler Wixtrom and Matthew Wilson were "traditional" software development interns; they both contributed to the MetPy project. Intern Briah' Davis came to Unidata through the Significant Opportunities in Atmospheric Research and Science (SOARS) program; she focused on using Python to visualize GOES-16 datasets. Intern Aubrey Kane joined the UPC community services team to work on the ADDIT project, creating case studies for the Data Management Resource Center.

* 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 a three-year term to enhance two-way communication between the Program and the geoscience educators who form our core community.

In 2017, planning began for the 2018 Unidata Users Workshop; a proposal to the NSF to fund the Workshop was submitted in December. The most recent Unidata Users Workshop, in June 2015, 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. Both the UPC and individual staff members also communicate with the community via social media channels including Facebook and Twitter.

* 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

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

Licenses

Other Conference Presentations / Papers

Chastang, Julien and Signell, Rich and Fischer, Jeremy L. (2018). *A Unidata JupyterHub Server: An Online PyAOS Resource for Students and Educators*. Proceedings, Eighth Symposium on Advances in Modeling and Analysis Using Python, 98th AMS Annual Meeting. Austin, TX. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Benedict, Karl K. and Lenhardt, W. Christopher and Young, Joshua Wellzie and Gordon, Larissa Chamley and Hughes, Steve and Vannan, Suresh Kumar Santhana (2017). *Agile Data Curation Case Studies Leading to the Identification and Development of Data Curation Design Patterns*. Proceedings of the AGU 2017 Fall Meeting. New Orleans, LA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Wilson, Matthew B. and Leeman, J. R. and May, Ryan M. (2018). *Bulk Shear, Supercell Composite, Precipitable Water, and More: Exploring MetPy's New CAPE-abilities with an Interactive Sounding Plotter*. Proceedings, Eighth Symposium on Advances in Modeling and Analysis Using Python, 98th AMS Annual Meeting. Austin, TX. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Fisher, Ward (2017). *Data-Proximate Analysis and Visualization in the Cloud using Cloudstream, an Open-Source Application Streaming Technology Stack*. Proceedings of the AGU 2017 Fall Meeting. New Orleans, LA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Ramamurthy, Mohan K. (2018). *Data-Proximate Computing, Analytics, and Visualization Using Cloud-Hosted Workflows and Data Services*. Proceedings, 34th Conference on Environmental Information Processing Technologies, 98th AMS Annual Meeting. Austin, TX. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Mapes, Brian and Ho, Yuan and Cheedela, Suvarchal Kumar and McWhirter, Jeff (2018). *Drilling down from Python Statistical Analyses to Rich Interactive Case Study Visualizations, within Jupyter Notebooks*. Proceedings, Eighth Symposium on Advances in Modeling and Analysis Using Python, 98th AMS Annual Meeting. Austin, TX. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Ramamurthy, Mohan K. and Lehnert, Kerstin and Zanker, Eva E. (2017). *EarthCube Cyberinfrastructure: The Importance of and Need for International Strategic Partnerships to Enhance Interconnectivity and Interoperability*. Proceedings of the AGU 2017 Fall Meeting. New Orleans, LA.

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van Maanen, Peter-Paul and Appleton, Rick and Fisher, Ward I. and Krijnen, Robbert (2017). *Meteorological Data Visualization in Multi-User Virtual Reality*. Proceedings of the AGU 2017 Fall Meeting. New Orleans, LA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Leeman, J. R. and May, R. M. (2017). *Meteorologists and their CAPEs (poster)*. Proceedings, SciPy 2017. Austin, TX. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Davis, Ethan and Zender, Charles S. and Arctur, David K. and O'Brien, Kevin and Jelenak, Aleksandar and Santek, David and Dixon, Michael John and Whiteaker, Timothy L. and Yang, Kent (2017). *NetCDF-CF: Supporting Earth System Science with Data Access, Analysis, and Visualization*. Proceedings of the AGU 2017 Fall Meeting. New Orleans, LA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Fisher, Ward (2018). *Open-Source Application Streaming with Docker and Unidata's Cloudstream Technology Stack*. Proceedings, 34th Conference on Environmental Information Processing Technologies, 98th AMS Annual Meeting. Austin, TX. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Chastang, Julien and Signell, Richard P. and Fischer, Jeremy L. (2017). *Reducing Time to Science: Unidata and JupyterHub Technology Using the Jetstream Cloud*. Proceedings of the AGU 2017 Fall Meeting. New Orleans, LA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Arms, Sean C. and May, R. M. and Leeman, J. R. (2018). *Siphon -- Simplifying Data Access and Expanding Data Sources*. Proceedings, Eighth Symposium on Advances in Modeling and Analysis Using Python, 98th AMS Annual Meeting. Austin, TX. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Ho, Yuan and Weber, Jeff (2017). *The Comparison of Point Data Models for the Output of WRF Hydro Model in the IDV*. Proceedings of the AGU 2017 Fall Meeting. New Orleans, LA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Leeman, J. R. and May, R. M. (2018). *The MetPy Roadmap: Replacing Legacy Meteorological Tools*. Proceedings, Eighth Symposium on Advances in Modeling and Analysis Using Python, 98th AMS Annual Meeting. Austin, TX. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Ho, Yuan and Rink, Thomas (2018). *The New Trajectory Display in the UNIDATA's IDV*. Proceedings, 34th Conference on Environmental Information Processing Technologies, 98th AMS Annual Meeting. Austin, TX. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Arms, Sean and Tsontos, Varids and Lam, Chi and Quach, Nga and Thompson, Charles and Platt, Flynn and Roberts, Joe (2017). *The Oceanographic In-situ Interoperability project (OIIP) - a year in review*. Proceedings of OCEANS '17 MTS/IEEE Anchorage. Anchorage, AK. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Arms, Sean C. and Tsontos, V. M. and Lam, C. H. and Quach, N. and Thompson, C. K. and Platt, F. and Roberts, J. (2018). *Tuna and Data Standards: The Use of Rosetta in the Oceanographic In Situ Data Interoperability Project (OIIP)*. Proceedings, 34th Conference on Environmental Information Processing Technologies, 98th AMS Annual Meeting. Austin, TX. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Mapes, Brian E. and Ho, Yuan and Cheedela, Suvarchal Kumar and McWhirter, Jeff (2017). *Understand your Algorithm: Drill Down to Sample Visualizations in Jupyter Notebooks*. Proceedings of the AGU 2017 Fall Meeting. New Orleans, LA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Emmerson, S. (2017). *Unidata LDM*. Proceedings, 2017 USGS 2017 Community for Data Integration Annual Workshop. Denver, CO. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Chastang, J. and Ramamurthy, M. K. (2017). *Unidata Science Gateway on the XSEDE Jetstream Cloud*. Gateways 2017. Ann Arbor, Michigan, USA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Ramamurthy, M. K. and Chastang J. and May, R. M. and James M. (2017). *Unidata and data-proximate analysis and visualization in the cloud*. Proceedings, ESIP Summer Meeting 2017. Bloomington, IN USA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Wixtrom, Tyler J. and May, Ryan M. and Leeman, J. R. and Goebbert, Kevin H. (2018). *Vertical Interpolation with MetPy*. Proceedings, Eighth Symposium on Advances in Modeling and Analysis Using Python, 98th AMS Annual Meeting. Austin, TX. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Davis, Briah A. (2018). *Visualizing in Python: Analyzing GOES-16 Datasets in the Cloud*. Proceedings, Eighth Symposium on Advances in Modeling and Analysis Using Python, 98th AMS Annual Meeting. Austin, TX. 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>University of Wisconsin</p> <p>Organization Type: Academic Institution</p> <p>Organization Location: Madison, WI</p> <p>Partner's Contribution to the Project:</p> <p>Financial support</p> <p>In-Kind Support</p> <p>Facilities</p> <p>Collaborative Research</p> <p>More Detail on Partner and Contribution:</p>
--

What other collaborators or contacts have been involved?

Nothing to report

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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 2017 in journals of the American Meteorological Society shows 44 articles containing citations of Unidata software and data services. (Of these, 36 refer to Unidata software packages but make no mention of the Unidata program itself.) In the same period, an additional 74 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 2017 indicated that Unidata software and data services were cited 2126 times in the full range of scholarly literature encompassed by the search engine. Of these, 1777 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 2017:

- Number of U.S. universities receiving software: 295
- Number of universities outside the U.S.: 801
- Number of attendees of 2017 training workshops: 108

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 2017 include:

University/PI	Project Title
Central Michigan University John Allen	Enhancing Undergraduate Python and Modeling Skills: A Jupyter Notebook Multi-Core Server at Central Michigan University
College of DuPage Victor Gensini	Eyes in the Sky: Installation of a GOES-16 Data Server at College of DuPage
Embry-Riddle Aeronautical University Chris Herbster	Infrastructure Enhancements to Support Educational Use of GOES-16
University of Hawaii Steven Businger	Pacific THREDDS Data Server
University of Miami Brian Mapes	University of Miami Data Server 2017

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.

UPC staff activities in the fourth year of this award have focused on working with NWC and NCAR personnel to tune the netCDF files output by the NWM to be more compliant with existing standards. This will make the model output more accessible with Unidata and 3rd party analysis and visualization tools.

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 several awarded "Building Blocks" proposals. Currently, Unidata is teaming with the University of Miami on an EarthCube Building Blocks Collaborative Proposal titled *That dot is a world! Drilling down from a statistics scatterplot to pre-populated case Notebooks*, and with Columbia University, NCAR, and Continuum Analytics on *Pangeo: An Open Source Big Data Climate Science Platform*.

What is the impact on information resources that form infrastructure?

The UPC created and continues to coordinate the Internet Data Distribution system (IDD), in which hundreds of universities, government agencies, and others cooperate to disseminate earth observations via the Internet in near real time. As of early 2018, the traffic handled by servers operated by the UPC itself -- a fraction of the total IDD system -- was more than 32 Tbytes/day, or an average of nearly 12 petabytes over the course of a year.

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. Of particular interest is the recent increase in access to satellite data via Unidata’s ADDE servers. Since the GOES-16 satellite became operational in late 2017, volumes have increased from roughly 27 Gbytes/day to roughly 740 Gbytes/day, a more than twentyfold increase in six weeks.

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 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 MetPy project is aimed at bringing GEMPAK-like meteorology functionality to the Python environment. The package has seen strong adoption within the atmospheric sciences research and education community, with more than ninety students and faculty attending MeyPy-focused workshops in the past year. In addition, the number of community contributors to the open source project has also grown significantly, with more than two dozen contributors who are *not* UPC staff members.

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 2017, individuals from 90 universities received the Unidata version of AWIPS, and more than 40 universities have become regular users of Unidata’s cloud-based EDEX server. 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:

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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