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# Preview of Award 1344155 - Annual Project Report

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## Cover

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|---|---|
| Federal Agency and Organization Element to Which Report is Submitted: | 4900 |
| Federal Grant or Other Identifying Number Assigned by Agency: | 1344155 |
| 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 - 03/31/2020** |
| Reporting Period: | **04/01/2018 - 03/31/2019** |
| Submitting Official (if other than PD\PI): | **Mohan K Ramamurthy Principal Investigator** |
| Submission Date: | **03/14/2019** |
| 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 2018 – March 2019.

## * 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 fifth 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 35 streams of current data that interest them. The IDD system comprises over 575 machines at 245+ 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 fifth year of the award, UPC staff have made significant progress toward these goals, most notably through the creation of the Unidata Science Gateway on NSF's Jetstream Cloud. The Gateway collects Unidata-related technologies and demonstrates a workflow involving combining cloud-based resources to create end-to-end scientific workflows. One of the most exciting tools in the Unidata Science Gateway is a JupyterHub server, which allows students and educators to access Unidata-provided Jupyter notebooks illustrating atmospheric science concepts. Beyond the Science Gateway, in the fifth year of this award Unidata continued to establish and operate cloud-based data distribution mechanisms (notably AWIPS EDEX servers and THREDDS Data Servers), work with cloud service providers to enable access to historical and real-time data, and create demonstrations of cloud-based application services (most notably for remote access to the IDV visualization software). The data services and Jupyter notebooks on the Science Gateway are now used by more than 60 universities in their courses, labs, and other projects.

### 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 fifth 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. While the THREDDS Data Server development team underwent some staff changes during this year, contributions to the user interface by a student intern made some very visible improvements to the server. The MetPy and Siphon projects continue to gain 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 fifth year of the current award, two of the six Equipment Award grants are directly supporting Minority Serving universities' efforts make geoscience data and modern software available to students.

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 Ninth Symposium on Advances in Modeling and Analysis Using Python at the 99th AMS Annual Meeting in Phoenix, AZ in January 2019.

**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 August 2018, Unidata's Internet Data Distribution (IDD) clusters deliver roughly 35 Terabytes per day to downstream systems, up from roughly 32 Terabytes per day in 2017. 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) has increased from roughly 659 GB/day to roughly 1.58 TB/day.

In 2016, NOAA/NESDIS funded installation of equipment to ingest imagery and products from the GOES-16 spacecraft. In 2018, Unidata began ingesting and distributing imagery and products from the GOES-17 spacecraft. With GOES-17's transition to operational status on 12 February 2019, Unidata is preparing for increased community interest in receiving and using the new satellite data.

### Cloud Technologies

Cloud-computing related activities during the fifth year of this award have focused on provision of data to cloud service providers (both commercial and not-for-profit), adding resources to the Unidata Science Gateway and opening the system to a larger number of users, and continuing to create containerized versions of Unidata software for use in cloud environments.

As the Unidata Science Gateway project continues, UPC began making its resources available to university courses and workshops as a remote computing environment. The Unidata JupyterHub server has proved particularly popular in this regard; UPC provided JupyterHub resources to courses at Notre Dame of Maryland University and Southern Arkansas University in the fall of 2018.

Technical staff have continued to employ Docker container technology to streamline building, deploying, and running Unidata technology offerings in cloud-based environments. A containerized version of the Common AWIPS Visualization Environment (CAVE) client is now available for testing and debugging.

Of special interest has been the operation of a community-accessible cloud-based AWIPS Environmental Data Exchange (EDEX) server. At the beginning of 2019, 68 universities are actively accessing 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

MetPy

The MetPy project, which is a collection of Python tools for reading, visualizing, and performing calculations with weather data, made significant progress in 2018. In addition to releases 0.7 through 0.10.0, MetPy developers presented progress to the community at the 2019 AMS annual meeting and the 2018 SciPy conference. Developers led a Python-focused software training workshop at the UPC in Boulder, and provided regional Python training at workshops at Colorado State University, Jackson State University, and San Jose State University. Two additional regional workshops, one at Metro State University

of Denver and another at Valparaiso University, took place in March 2019.

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. Releases spanning version 17.1.1-6 through 18.1.1-5 of the AWIPS package were made available to university users. Unidata's tailored version of AWIPS has been downloaded an average of more than 600 times per month by individuals associated with U.S. universities during the fifth year of the award.

Although the GEMPAK software is no longer actively developed, enhancements to allow use of data from the GOES-R series satellites have been added. Unidata released versions 7.4.3, 7.4.5, and 7.5.1 to the university community in the past year.

IDV:

Unidata's Integrated Data Viewer version 5.5 was released in May 2018. This version introduced tools for isentropic analysis, scatter analysis, and display of data from the GOES-R series satellites' Geostationary Lightning Mapper (GLM).

LDM:

Local Data Manager versions 6.13.7 and 6.13.8 were released in early 2019. Work on a "multicast" version of the LDM employing virtual circuit technology continues under a research grant in collaboration with the University of Virginia.

NetCDF:

The netCDF-C library versions 4.6.0 through 4.6.3 were released during the fifth year of the award. These releases introduced support for HDF5 dynamic filters, improved DAP2 and DAP4 capabilities, improved attribute read speeds, generally improved netCDF performance. The netCDF project also updated its software license to the standard 3-Clause BSD License. This change does not result in any new restrictions; it is part of a broader push by Unidata to adopt modern, standardized licensing in place of the historic licenses written at Unidata.

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 during the fifth year of the award with releases 0.7.0 and 0.8.0. Though not yet considered completely stable, it has been used successfully in Unidata's python-focused training since 2017.

Rosetta:

Rosetta continues to progress following a very successful NASA ACCESS grant (the Oceanographic In-situ data Interoperability Project, or OIIP), in which Unidata is partnering with the PO.DAAC at JPL and UMASS-Boston. A poster was presented at the Fall AGU 2018 meeting with respect to the advances in Rosetta related to OIIP.

TDS:

The THREDDS Data Server versions 4.6.12 and 4.6.13 were released during the fifth year of this award, and version 4.6.13 is currently running on Unidata's TDS server at thredds.ucar.edu. THREDDS Version 5.0 development was slightly delayed due to the departure from UPC of a member of the development team; it is still in a testing phase; with release now planned for 2019.

**Community Building**

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 2018 award was given to long-time community member Prof. Steven Lazarus from the Florida Institute of Technology, whose ongoing efforts to help Unidata improve the way it serves its community of researchers and educators, his tireless evangelism for Unidata software among colleagues and students, and his cogent insights into ways the program can grow and become more effective led to his selection.

In the fifth year of the award, the Unidata Strategic Plan (https://www.unidata.ucar.edu/publications/2017stratplan/Strategic_plan.pdf) created in the third and fourth years helped form the basis of the UPC's proposal to NSF to extend the program for an additional five years: "Unidata: Next-generation Data Services and Workflows to Advance Geoscience Research and Education." The new proposal was awarded by NSF in early 2019.

**Unidata Users Workshop**

With separate funding from NSF, the 2018 Unidata Users Workshop took place June 25-28 at UCAR's Center Green facility in Boulder, Colorado. The workshop's theme — Reducing Time to Science: Evolving Workflows for Geoscience Research and Education — drew participants from across the atmospheric and other geosciences communities. The 76 attendees took

part in a series of presentations and hands-on exercises that explored approaches to data-proximate computing, uses of machine learning techniques in the geosciences, and interaction with data from new satellites and output from ensemble modeling systems.

**Key outcomes or Other achievements:**

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

### EarthCube Projects

UPC staff are involved in EarthCube projects in collaboration with the University of Miami and Columbia University-Lamont-Doherty Earth Observatory.

### Scientific Conferences

Program Center staff participated in numerous scientific conferences in the fifth 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
> 2019 OceanObs Meeting

### Python Training

UPC staff conducted three regional workshops in the spring and summer of 2018 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. Two additional regional training workshops were held in March 2019.

UPC staff have also begun producing a series of weekly postings on Python topics, centered on the use of MetPy. The "MetPy Mondays" series, which has continued uninterrupted through the 2018 and into 2019, 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. The series now has more than 70 installments; plans exist to continue producing weekly postings into the future.

### EarthCube Science Support Office

Unidata Program Director Mohan Ramamurthy is the Principal Investigator on the EarthCube Science Support Office (ESSO), 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, with funding from ESSO.

### 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 2018, the committees changed as follows:

> Steve Decker from Rutgers University, Wendilyn Flynn from the University of Northern Colorado, Victor Gensini of Northern Illinois University, and Pete Pokrandt from the University of Wisconsin, Madison finished their terms on the Users Committee.
> Jennifer Collins from the University of South Florida, Steven Lazarus from the Florida Institute of Technology, and Lynn McMurdie from the University of Washington finished their terms on the Strategic Advisory Committee.
> Alexander Davies from the U.S. Naval Academy, Casey Davenport from the University of North Carolina, Charlotte, Enrique Curchitser from Rutgers University, and Eric Bruning from Texas Tech University joined the Users Committee.
> Victor Gensini from Northern Illinois University joined the Strategic Advisory Committee.

> Russ Schumacher, from Colorado State University departed the Users Committee before the end of his second three-year term when he was assumed the post of Colorado State Climatologist. Users Committee member Kevin Goebbert from Valparaiso University stepped into Schumacher's role as Chair of the committee.

## * 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; three regional workshops in that year attracted 108 participants. In 2018, following a survey of the Unidata community indicating interest in a series of software training workshops at the UPC in Boulder, CO, workshops were held in October. A total of 36 individuals took part in the Boulder training sessions. The relatively low number of community members who were able to travel to Boulder for software training reinforces the idea that UPC's efforts are better spent visiting universities to provide training.

Broadening participation and proactively engaging institutions with a significant number of underrepresented student populations remains a high priority for Unidata. In that regard and in addition to the workshops held at the Program Center in Boulder, UPC developers conducted regional workshops at two Minority Serving Institutions (MSIs) in the summer and fall of 2018: Jackson State University in Jackson, MS (28 participants) and San Jose State University in San Jose, CA (38 participants).

Unidata's summer internship program invited two students to spend the summer working at the Unidata Program Center in 2018. Haley Johnson from the University of Florida contributed to the THREDDS Data Server project in several ways, including a major revision of the system's visual appearance. Jonathan Thielen from Iowa State University contributed to the MetPy project.

## * 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.
The 2018 Unidata Users Workshop, described in "Significant Results," above, brought together 76 community members 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?

During the No Cost Extension period of this award, 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 has been submitted separately, along with a budget justification.

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# Products

## Books

## Book Chapters

## Inventions

## Journals or Juried Conference Papers

Ansari, Steve and Del Greco, Stephen and Kearns, Edward and Brown, Otis and Wilkins, Scott and Ramamurthy, Mohan and Weber, Jeff and May, Ryan and Sundwall, Jed andLayton, Jeff andGold, Ariel and Pasch, Adam and Lakshmanan, Valliappa (2018). Unlocking the Potential of Nexrad Data Through NOAA's Big Data Partnership. *Bulletin of the American Meteorological Society*. 99 (1), 189-204. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1175/BAMS-D-16-0021.1

## Licenses

## Other Conference Presentations / Papers

Chastang, J. and Ramamurthy, M. K. (2018). *A Cloud-based Science Gateway for the Geoscience Community*. OGC TC/PC Meetings. Fort Collins, Colorado, USA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Ramamurthy, M. K. and Chastang, J. (2018). *A Cloud-based Science Gateway for the Geoscience Community with End-to-end Workflows on the {Jetstream} Cloud System*. 2018 EGU Spring Meeting. Vienna, Austria. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

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

Tsontos, Vardis M. and Thompson, Charles K. and Quach, Nga and Arms, Sean Cody and Lam, Chi Hin and Platt, Flynn and Roberts, Joe T. (2018). *Addressing the Challenge of Electronic Tagging Data Interoperability: The Oceanographic In situ data Interoperability project ({OIIP})*. Proceedsings, 2018 Ocean Sciences Meeting. Portland, OR. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Leeman, J. R. and May, R. M. (2018). *Building Communities Around Open-Source Geoscience Projects (Poster)*. Proceedings, SciPy 2018. Austin, TX. 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

Johnson, H. A. and Arms, S. C. (2019). *Customizing THREDDS Data Server Web Interfaces to Promote Data Discovery and Accessibility*. Proceedings, 35th Conference on Environmental Information Processing Technologies, 99th AMS Annual Meeting. Phoenix, AZ. 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

May, R. M. and Leeman, J. R. (2018). *Development of MetPy's Declarative Plotting Interface*. Proceedings, SciPy 2018. 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

Thompson, Charles K. and Platt, Flynn and Roberts, Joe T. and Tsontos, Vardis M. and Lam, Chi Hin and Quach, Nga T. and Arms, Sean Cody (2018). *Enabling Interactive Synthesized Visualization, Exploration, and Access of In Situ and Satellite Ocean Datasets*. Proceedsings, 2018 Ocean Sciences Meeting. Portland, OR. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

May, Ryan M. and Leeman, J. R. (2018). *MetPy Advancement and Community-Driven Development*. 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 (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

Signell, Rich and Ready, John and Chastang, Julien and Jelenak, Aleksander (2018). *Scalable, {D}ata-{P}roximate {A}nalysis of {N}ational {W}ater {M}odel {D}ata in the {C}loud*. NOAA Environmental Management Meeting. Silver Spring, MD. Status = PUBLISHED;  Acknowledgement of Federal Support = Yes

Sarajlic, Semir and Chastang, Julien and Marru, Suresh and Fischer, Jeremy and Lowe, Mike (2018). *Scaling JupyterHub Using Kubernetes on Jetstream Cloud: Platform As a Service for Research and Educational Initiatives in the Atmospheric Sciences*. Proceedings of the Practice and Experience on Advanced Research Computing. New York, NY, USA. 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

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

Tsontos, V. M. and Thompson, C. K. and McGibbney, L. J. and Quach, N. and Roberts, J. T. and Platt, F. and Arms, S. C. and Lam, C. H. (2018). *Tools \& Services for Integrated Oceanographic Data Access: The Oceanographic In situ data Interoperability project (OIIP)*. Proceedings of the AGU 2018 Fall Meeting. Washington, DC. Status = PUBLISHED;  Acknowledgement of Federal Support = Yes

Arms, S. C. and Tsontos, V. M. and Oxelson Ganter, J. and Lam, C. H. and Thompson, C. K. and Quach, N. and McGibbney, L. J. and Platt, F. and Roberts, J. T. (2018). *Transformative Tuna: How Electronic Animal Tags Improved Rosetta for Everyone*. Proceedings of the AGU 2018 Fall Meeting. Washington, DC. 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

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 Web Site*

https://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:

**University of Wisconsin**

**Organization Type:** Academic Institution
**Organization Location:** Madison, WI

**Partner's Contribution to the Project:**
Financial support
In-Kind Support
Facilities
Collaborative Research

**More Detail on Partner and Contribution:**

## What other collaborators or contacts have been involved?

Nothing to report

# Impacts

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

A survey of papers published in 2018 in journals of the American Meteorological Society shows 24 articles containing citations of Unidata software and data services. (Of these, 13 refer to Unidata software packages but make no mention of the Unidata program itself.) In the same period, an additional 113 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 2018 indicated that Unidata software and data services were cited 2593 times in the full range of scholarly literature encompassed by the search engine. Of these, 2188 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 2018:

    Number of U.S. universities receiving software: 298
    Number of universities outside the U.S.: 833
    Number of attendees of 2018 training workshops: 133
    Number of attendees at 2018 Unidata Users Workshop: 76

## 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 2018 include:

| University/PI | Project Title |
| --- | --- |
| Jackson State University Duanjun Lu | Upgrade the JSU Meteorology Computing Lab by installation of AWIPS II EDEX Server and CAVE Clients |
| Pennsylvania State University George Young | Upgrading the Penn State IDD Relay for the Next Generation |
| San Jose State University Alison Bridger | San Jose State University Unidata Equipment Proposal |
| Texas Tech University Eric Bruning | Cloud-ready Processing and Dissemination of GOES-16 Geostationary Lighting Mapper Gridded Imagery |
| University of Nebraska-Lincoln Natalie Umphlett | Enhanced Accessibility of Climate Data for Research and Teaching through a THREDDS Data Server |
| University of Wisconsin-Madison Gregory Tripoli | A community THREDDS/ADDE data server and IDD infrastructure upgrade at UW-Madison |

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 fifth 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 late 2018, the traffic handled by servers operated by the UPC itself -- a fraction of the total IDD system -- was more than 35 Tbytes/day, or an average of nearly 13 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. With the inclusion of image data from the GOES-R series satellites, the UPC now provides more than 1.58 Tbytes of data per day to the community via remote access mechanisms.

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 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 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 one hundred 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 2018, individuals from 101 universities received the Unidata version of AWIPS, and nearly 70 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. Rosetta helps scientists transform unstructured ASCII data files of the type commonly generated by datalogging equipment into the netCDF format and other well-documented formats, 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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