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## Preview of Award 1901712 - Annual Project Report

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### Cover

Federal Agency and Organization Element to Which Report is Submitted:

**4900**

Federal Grant or Other Identifying Number Assigned by Agency:

**1901712**

Project Title:

**Unidata: Next-generation Data Services and Workflows to Advance Geoscience Research and Education**

PD/PI Name:

**Mohan K Ramamurthy,  
Principal Investigator**

Recipient Organization:

**University Corporation For  
Atmospheric Res**

Project/Grant Period:

**05/01/2019 - 04/30/2024**

Reporting Period:

**05/01/2021 - 04/30/2022**

Submitting Official (if other than PD\PI):

**Mohan K Ramamurthy  
Principal Investigator**

Submission Date:

**04/04/2022**

Signature of Submitting Official (signature shall be submitted in accordance with agency specific instructions)

**Mohan K Ramamurthy**[Back to the top](#)

### Accomplishments

\* What are the major goals of the project?

This report details activities that took place under the five-year core-funding award “Unidata: Next-generation Data Services and Workflows to Advance Geoscience Research and Education” (NSF 1901712). The proposal for that funding award grouped the Unidata program’s activities into the following focus areas identified in the Unidata Strategic Plan:

Managing Geoscience Data

Providing Useful Tools

Supporting People

Note: While Unidata has identified a number of different initiatives that fall under these broad categories of service, the activities and results described below share a continuing 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 2021 – March 2022.

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

Major Activities:

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

### **Data Distribution**

Helping researchers and educators acquire and use real-time meteorological data was one of the Unidata program’s founding goals, and continues to be one of the core activities of the program. By participating in Unidata’s Internet Data Distribution (IDD) system, educators and researchers can subscribe to one or more of the 35 streams of current data that interest them. Voluntary reporting from IDD system sites indicates that more than 600 machines at roughly 220 sites are 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 of 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, universities, and others.)

Unidata also facilitates data distribution by developing and supporting remote data access server technologies. While we do not require licensing or registration of the THREDDS Data Server (TDS), we have received information from thousands of unique IP addresses running the server. Of these, 191 are publicly accessible and providing data to other community members.

Finally, many community members connect directly to remote access servers managed directly by the Unidata Program Center. Unidata’s TDS, McIDAS ADDE, and AWIPS EDEX servers together provide terabytes of data to remote users every day.

### **Cloud Technology Experiments**

Continuing to find ways to leverage the strengths of the cloud computing environment to enhance universities’ access to geoscience data and tools is one of Unidata’s highest priorities during the period of this award. During the third year of the award, UPC staff have made significant progress toward these goals, most notably through the expansion of the Unidata Science Gateway on NSF’s Jetstream Cloud, including preparations to incorporate Jetstream 2 features as Unidata allocations become available.

The Science 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. During the 2021-2022 academic year, with many universities relying heavily on remote-learning techniques as the COVID-19 pandemic continues, Unidata continued its program of offering to set up JupyterHub systems to support atmospheric and related science courses. Courses serving over 700 students at 15 universities have now taken advantage of this Unidata resource.

As part of the Science Gateway, Unidata also operates cloud-based data distribution mechanisms (notably AWIPS EDEX servers and THREDDS Data Servers). Additionally, Unidata continues to work with cloud service providers to enable access to historical and real-time data.

## Software Development

Developing free, open-source software to help researchers and educators manage their access to and use of geoscience data is one of Unidata's primary activities. During the third year of this award, Unidata's development staff has mixed ongoing work toward well-defined, long-term development goals for existing technologies with newer technologies and initiatives aimed at addressing our community's evolving technology needs.

## 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. In addition, in the third year of this award, the Program has enhanced its focus on outreach and provision of services to underserved communities within the atmospheric and related sciences.

In order to build better relationships with underserved communities, Unidata staff have begun participating in the Society for Advancement of Chicanos/Hispanics & Native Americans in Science (SACNAS) National Diversity in STEM Conference and the American Indian Science and Engineering Society (AISES) National Conference. Participation in the AISES conference has already borne fruit in the form of a collaborative effort between the Southwestern Indian Polytechnic Institute, Navajo Technical University, and Unidata. This group was awarded an NSF CISE Community Research Infrastructure grant (with Unidata as an unfunded collaborator), described in the Key Outcomes section of this report.

This year, most of Unidata's more traditional venues for community interaction and outreach have been affected by COVID-19 travel restrictions. Staff members generally engage with community members at the American Meteorological Society (AMS) and American Geophysical Union (AGU) annual meetings, spending time talking about Program activities at UCAR's booth in both conferences' exhibition halls. The number of conversations we were able to have at these conferences was certainly reduced by their remote nature; we are looking forward to meeting in person with community members at future conferences.

We maintain an online presence via the News@Unidata weblog and a variety of social media channels. All of these forms of interaction allow us to hear directly from community members about their data access and cyberinfrastructure issues and concerns.

We attribute the ongoing success of the Unidata program, in large part, to our 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.

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.

### Specific Objectives:

One area of special focus during the period of this grant has been Unidata's program of outreach to underserved communities. In order to build better relationships with communities that have not previously been heavily involved with Unidata, in the third year of the award Unidata staff have continued participation in the Society for Advancement of Chicanos/Hispanics & Native Americans in Science (SACNAS) National Diversity in STEM Conference and the American Indian Science and Engineering Society (AISES) National Conference. One direct, positive outcome of this participation is a collaborative effort between the Southwestern Indian Polytechnic Institute (SIPI), Navajo Technical University (NTU), and Unidata. This group received an NSF CISE Community Research Infrastructure grant titled "A Sovereign Network System for Environmental Monitoring, Data and Information Exchange, and Collaboration among Tribal Colleges and Universities," with Unidata staff members contributing data management and analysis expertise. (Unidata staff, including one of the project's Co-Investigators, are serving as unfunded collaborators.) The project seeks to build capacity for

environmental data monitoring and data sharing among Tribal colleges and universities, creating a network that addresses issues of data sovereignty while enabling cooperation with other scientific endeavors. The grant was awarded in late 2021, and already the group has forged collaborative ties with the Department of Energy's SAIL project and NOAA's SPLASH project. Unidata staff members held an in-person data management and analysis workshop at SIPI in March, 2022.

Additionally, with the goal of encouraging participation by underserved individuals and institutions, Unidata's Diversity, Equity, and Inclusion committee has suggested and helped to implement structural changes to several Unidata programs, including modifications to how equipment awards, internships, workshops, and committee placements are announced and selected. The DEI committee and other interested staff members are working with the program Director to develop plans to address the results of UCAR's 2021 Culture Survey, with similar goals.

## 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 March 2022, Unidata's Internet Data Distribution (IDD) clusters deliver roughly 70 Terabytes per day to downstream systems, up from roughly 57 Terabytes per day in 2021. The volume of data served via remote access methods (TDS, ADDE, and vanilla web servers) now averages approximately 4.1 Terabytes per day, an increase of nearly 60 percent over the previous year's average.

Because relaying data from the National Weather Service's NOAAPort system is an important component of Unidata's data services, UPC staff have created new technologies to improve the quality of this data stream. The project, nicknamed "blender," merges NOAAPort broadcasts from geographically dispersed sites into a single stream that can be distributed via the IDD.

Unidata's collaboration with the University of Wisconsin's Space Science and Engineering Center (SSEC) continues to be productive and beneficial for the atmospheric science community. Unidata receives data from SSEC's GOES-16/17 fanout servers, and SSEC feeds from Unidata's GOES Rebroadcast (GRB) ingest system. This sharing of the feed streams has allowed SSEC and Unidata to minimize the effects of solar and terrestrial interference on our satellite data reception.

### Cloud Technologies

Cloud-computing related activities during the third year of this award have focused on making Unidata Science Gateway resources available to university courses and workshops as a remote computing environment. The Unidata JupyterHub servers have proven to be the most popular feature of the Science Gateway; they have been deployed for workshops and courses including:

- Ongoing semester-long data science classes at Southern Arkansas University.

- Semester-long projects for NSF REU students at the University of Oklahoma.

- A Python workshop at the Annual Student Conference for the American Meteorological Society 2022 annual meeting, supporting 65 student participants.

Additional discussion of Unidata's Science Gateway work can be found in "Impact on institutional resources that form infrastructure," below.

### Software Development

MetPy:

The MetPy project, which is a collection of Python tools for reading, visualizing, and performing calculations with weather data, made its version 1.1 release in August of 2021 and its version 1.2 release at the beginning of 2022. These releases are notable for the ongoing community code contributions and general project participation, including contributions from 2021 and earlier Unidata summer interns.

Unidata's MetPy developers continue to engage with the Pangeo project, a grass-roots effort to develop a community stack of tools serving the atmospheric, oceanic, land, and climate science. This engagement is enhanced by work on the Pangeo EarthCube award. Over the past year at least 34 new scholarly publications have cited MetPy, a large increase over the total count of 22 publications prior to 2021.

## AWIPS and GEMPAK:

Since July 2021, the Unidata AWIPS development team have provided a series of updates to the version 18.2.1 software release. Unidata contributions to the AWIPS package have included more robust data ingest for non-operational (e.g. university) sites, the ability to ingest and display a variety of additional GOES satellite products, and usability improvements in the CAVE interface.

Near future development plans include merging Unidata's AWIPS code base with more recent builds from the primary NWS developer (Raytheon), which includes transitioning from Python 2 to 3 and Java 8 to openJDK 11.

In early 2021, in consultation with the Unidata Users Committee, the Program Center initiated a process for transitioning Unidata's GEMPAK distribution into a community supported and maintained open source project. Volunteers from the GEMPAK-using community are continuing to provide fixes and updates to Unidata's GEMPAK repository on Github. Unidata continues to provide space for the GEMPAK "gembud" electronic mailing list, and for GEMPAK user documentation.

## IDV:

The most recent version of Unidata's Integrated Data Viewer, version 6.0 update 1, was released in July 2021. Version 6 of the IDV is a major release of the software that features a new grid coverage data type that eases the process of creating spatial subsets that cross grid boundaries, enhancements to the IDV's volume rendering engine, and improvements to the quality of images captured from the display. Under-the-hood improvements include a switch to the OpenJDK Java libraries and updated software certificates. In addition, this release includes updates to existing features and incorporates the latest netCDF-Java library.

Version 6.0 update 2, currently in beta testing, incorporates the Advanced Dvorak Technique (ADT), which uses longwave-infrared temperature measurements from geostationary satellites to estimate tropical cyclone (TC) intensity. The IDV development team intends to release this feature officially in the summer of 2022.

## LDM:

Local Data Manager versions 6.13.14, 6.13.15, and 6.13.16 were released in the past year. In addition, to mitigate issues with lost data frames from NWS NOAAPort broadcasts, the LDM team has developed a new technology to merge multiple broadcasts from geographically dispersed sites into a single, more nearly complete data stream. The data stream from this technology, currently nicknamed "blender," can then be processed into data-products that the LDM distributes.

## NetCDF:

The netCDF-C library version 4.8.0 was released in April of 2021, introducing netCDF compatibility with widely used key-value pair cloud storage systems (such as Amazon's S3, for example). This feature, known as NCZarr, provides a mapping from a subset of the full netCDF Enhanced data model to a variant of the Zarr data model. Version 4.8.1 of the netCDF-C library, released in August of 2021, continued the development of this technology.

In addition, version 4.5.4 of the netCDF FORTRAN library was released, building on features in netCDF-C version 4.8.x. Corresponding work on the netCDF C++ library is under way.

## TDS:

The initial feature-complete implementation of the THREDDS Data Server (TDS) version 5 was released in September 2021. Beta-test versions of the TDS version 5 have been in use in the community for over a year, but the version 5.0 release marks a milestone in the server's stability.

Unidata's THREDDS Data Server (TDS) team faced setbacks in the third year of this award, with the departure of a key developer. Despite this, the team responded quickly to a cybersecurity vulnerability raised by a widely-used third-party software library, releasing a series of updates to both the version 4.x and version 5.x branches of the TDS along with corresponding updates to the netCDF-Java library.

While many community TDS sites have remained on the version 4.x branch through the development phase, we expect to see increases in adoption of the 5.x version as a result of the official release and the subsequent security-related updates. Currently, TDS versions 4.x and 5.x are deployed at roughly 190 non-Unidata sites, with at least 56 of those sites running version 5.0 or later.

Thanks to supplemental NSF funding during the third year of this award, Unidata was able to hire a software engineer to assist with TDS development and maintenance. The process of hiring a new developer using the additional resources

was underway when a long-time developer departed. A search is currently underway for an engineer to fill the position of the developer who left the team.

Key outcomes  
or Other  
achievements:

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

### **Unidata Users Workshops**

Unidata Users Workshops gather participants from across the community to discuss topics such as useful tools to access data and strategies for teaching computational concepts. The workshops bring together geoscience educators, pedagogical experts, and Unidata staff to discuss and share best practices for helping students engage in data-enabled science.

Traditionally, workshops are held every three years. Due to COVID-19 related uncertainty about prospects for workshop attendance, along with the strong preference for an in-person workshop, the Unidata Users Committee made the decision to delay the next Users Workshop until such time as physical gatherings were allowed at UCAR facilities. While there were hopes for a workshop in the summer of 2022, movement toward allowing physical gatherings has happened too slowly to allow for workshop planning. Discussion of the Users Workshop schedule is slated for the Unidata Users Committee meeting to be held in June 2022.

### **Artificial Intelligence/Machine Learning (AI/ML)**

As a result of new non-core funding, in the third year of the award the UPC was able to hire an engineer to focus on artificial intelligence/machine learning topics with the end goal of reducing the “time to machine learning.” In its initial instantiation, this program worked to provide guidance for best practices to prepare existing Unidata packages (such as the MetPy and Siphon Python libraries, or the netCDF libraries) for use with modern AI/ML systems, with a focus on interpretability and trustworthiness. Additionally, the program begins a process of engagement with the Unidata scientific community to help us better understand their needs, and facilitate AI/ML-centric conversations between the Unidata community and internal software development teams.

The engineer hired to take on these responsibilities chose to leave Unidata less than one year after joining the team. Efforts to hire a replacement are currently underway.

### **EarthCube Projects**

UPC staff are involved in the following ongoing EarthCube projects:

Pangeo: An Open Source Big Data Climate Science Platform (collaboration with NCAR/CISL, and Columbia University-Lamont-Doherty Earth Observatory)

Project Pythia: A Community Learning Resource for Geoscientists (collaboration with NCAR/CISL, NCAR/CGD, and the University at Albany, SUNY)

### **Scientific Conferences**

Participation by Program Center staff at scientific conferences in the third year of the award was somewhat reduced by COVID-19 travel restrictions. Staff members were able to participate virtually in a range of conferences, 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 Annual meeting

Research Data Alliance Plenary meetings

National Data Service meetings

Open Geospatial Consortium Technical Committee meetings

### **Software Training**

UPC staff conducts workshops focused on building skills with Unidata software packages in the context of the atmospheric sciences. During the second year of this award, COVID-19 travel restrictions severely limited our ability to

hold interactive software training workshops. Workshops we were able to conduct virtually included:

A half-day virtual synchronous MetPy training in September 2021. The workshop had roughly 25 registrants, most of whom were graduate students, faculty, and project/operational scientists.

A workshop at the American Meteorological Society Student Conference, held in association with the AMS Annual Meeting in January, 2022. The workshop had roughly 65 attendees consisting of undergraduate, masters, and doctoral students.

Unidata staff members participated in providing a four-session AMS Python short course, held in March 2021, teaching one half-day session and supporting the others sessions. Roughly 50 participants attended virtually.

A full-day in-person short course originally intended for the 2022 AMS meeting was reconfigured as a virtual workshop held in March, 2022. The workshop hosted 45 participants.

A series of five IDV training workshops at George Mason University, spread between April and September 2021.

Two virtual IDV training workshops at Guangdong Ocean University, China, in April and May of 2021.

An introduction to using the IDV for WRF model dataset analysis at Istanbul Technical University in November of 2021.

A Local Data Manager (LDM) training for roughly 30 staff members from NOAA's National Centers for Environmental Prediction (NCEP) over three days in September of 2021.

While conducting workshops virtually allowed Unidata staff to expand their geographic reach, we are beginning to add in-person training workshops back into our mix of offerings by the summer of 2022. Our first in-person training event since 2020 is being held at the Southwestern Indian Polytechnic Institute in Albuquerque, NM (SIPI) for students of SIPI and Navajo Technical University (NTU) in March, 2022.

UPC staff also produce two distinct series of asynchronous learning materials published on the web. The "MetPy Mondays" series, centered on the use of MetPy but including other general Python programming topics, has continued uninterrupted since 2018. MetPy Mondays 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 225 installments on a wide range of MetPy related topics, and has been viewed more than 50,000 times in the past year. The "AWIPS Tips" series began publishing in mid-2021 to provide short explanations of AWIPS features and techniques; the 22 installments of the series have been viewed more than 6800 times since its inception.

Another new training initiative in the third year of the award was the creation of an asynchronous learning management system (LMS) site named <https://elearning.unidata.ucar.edu/>

This site, which uses the Moodle learning management software, is designed to provide asynchronous learning experiences for Unidata software packages. The inaugural training experience, created in the spring of 2022, guides learners through the process of getting familiar with the Common AWIPS Visualization Environment (CAVE) software.

### **Committee Membership Changes**

Each fall, 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 2021, the committees changed as follows:

Enrique Curchitser from Rutgers University and Lena Heuscher from the University of Alabama, Huntsville finished their terms on the Users Committee.

Christopher Hennon from the University of North Carolina, Asheville and Kevin Tyle from the University at Albany-SUNY finished their terms on the Strategic Advisory Committee.

Jon Thielen from Colorado State University joined the Users Committee as a graduate student representative.

Eric Bruning from Texas Tech University joined the Strategic Advisory Committee.

### **Program Center Staffing**

As a result of new development initiatives, new non-core funding, and normal staff turnover, the Unidata Program Center has added two new members to the technical staff, and are seeking to hire replacement staff for three additional positions. Newly hired personnel are focusing on the Unidata Science Gateway and THREDDS Data Server projects; open positions relate to our Artificial Intelligence/Machine Learning, THREDDS, and Community Service initiatives.

The Program Center continues to work to foster diversity in our technical staff. As of spring 2022, our technical team

includes six women, five of whom have joined the program since August 2019.

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

In a year when Unidata's traditional training venues were significantly curtailed by travel restrictions, we were able to conduct our summer internship program as an entirely virtual experience. The program invited three students to spend the summer working "at" the Unidata Program Center in 2021. Lydia Bunting came to Unidata this summer with the goals of helping with the development of new MetPy features, working on fixing existing problems, and gaining a better understanding of the software development process. She tackled an issue dealing with projection attributes of a specific set of netCDF archive files when used with the pyproj interface for cartographic projections and coordinate transformations. Connor Cozad spent his summer with Unidata building MetPy features. He was able to add GEMPAK-style "region modifiers" for regional plots, making it easier to zoom in and out of maps. He also spearheaded the development of MetPy's new PlotGeometry class, making it easy to plot data from geoJSON files and shapefiles. Both of these features will appear in the MetPy 1.1.0 release. Izzy (Isabelle) Pfander came to her internship hoping to work on the Network Common Data Form (netCDF) libraries. She contributed to the netCDF-Java documentation by updating tutorial code, testing code snippets, and modernizing tutorial text to improve user understanding. Izzy also had time to focus on performance testing in Python. She compared file read performance with several data formats, including netCDF-3, netCDF-4, HDF5, and Zarr.

### \* Have the results been disseminated to communities of interest? If so, please provide details.

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.

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. Committee meetings in 2021 were entirely virtual; as a result, in an effort to combat "Zoom Fatigue," we shifted to a meeting schedule that consists of shorter meetings (2-4 hours maximum) held over the course of several days or weeks. The committees have expressed their strong preference for hybrid meetings with the possibility for in-person gathering; as a result, spring 2022 meetings have been delayed until early summer.

Unidata staff members conducted virtual training sessions and workshops over the course of the year, with varying levels of formality.

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 Twitter, LinkedIn, and Facebook.

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

During the fourth year of this award, the Unidata program will continue to undertake the activities described in the "Plan of Action" section of the grant proposal. For reference, this document is available on the Unidata web site:

[http://www.unidata.ucar.edu/publications/Unidata\\_2024.pdf](http://www.unidata.ucar.edu/publications/Unidata_2024.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

**View all journal publications currently available in the [NSF Public Access Repository](#) for this award.**

The results in the NSF Public Access Repository will include a comprehensive listing of all journal publications recorded to date that are associated with this award.

Meyer, Tiffany and Krocak, Makenzie J. and Smith, Travis M. and Stumpf, Greg and Gerard, Alan. (2021). The Experimental Warning Program of NOAA's Hazardous Weather Testbed. *Bulletin of the American Meteorological Society*. 102 (12) . Status = Deposited in NSF-PAR [doi:https://doi.org/10.1175/BAMS-D-21-0017.1](https://doi.org/10.1175/BAMS-D-21-0017.1) ; Federal Government's License = Acknowledged. (Completed by Ramamurthy, null on 03/21/2022 ) [Full text](#) [Citation details](#)

Tan, Yuanlong and Veeraraghavan, Malathi and Lee, Hwajung and Emmerson, Steven and Davidson, Jack W.. (2021). High-performance reliable network-multicast over a trial deployment. *Cluster Computing*. . Status = Deposited in NSF-PAR [doi:https://doi.org/10.1007/s10586-021-03519-6](https://doi.org/10.1007/s10586-021-03519-6) ; Federal Government's License = Acknowledged. (Completed by Ramamurthy, null on 03/21/2022 ) [Full text](#) [Citation details](#)

Arms, Sean and Chastang, Julien and Grover, Maxwell and Thielen, Jon and Wilson, Matthew and Dirks, Douglas. (2020). Introducing Students to Scientific Python for Atmospheric Science. *Bulletin of the American Meteorological Society*. 101 (9) E1492 to E1496. Status = Deposited in NSF-PAR [doi:https://doi.org/10.1175/BAMS-D-20-0069.1](https://doi.org/10.1175/BAMS-D-20-0069.1) ; Federal Government's License = Acknowledged. (Completed by Ramamurthy, null on 03/22/2021 ) [Full text](#) [Citation details](#)

Snowden, Derrick and Tsontos, Vardis M. and Handegard, Nils Olav and Zarate, Marcos and O' Brien, Kevin and Casey, Kenneth S. and Smith, Neville and Sagen, Helge and Bailey, Kathleen and Lewis, Mirtha N. and Arms, Sean C.. (2019). Data Interoperability Between Elements of the Global Ocean Observing System. *Frontiers in Marine Science*. 6 . Status = Deposited in NSF-PAR [doi:10.3389/fmars.2019.00442](https://doi.org/10.3389/fmars.2019.00442) ; Federal Government's License = Acknowledged. (Completed by Ramamurthy, Mohan on 03/31/2020 ) [Full text](#) [Citation details](#)

## Licenses

## Other Conference Presentations / Papers

McMahon, Rio and Carter, Shay and Meyer, Tiffany (2022). *Machine Learning Visualization Infrastructure for AWIPS*. Proceedings, 102nd AMS Annual Meeting. . Status = PUBLISHED; Acknowledgement of Federal Support = Yes

McMahon, Rio and Carter, Shay and Meyer, Tiffany (2021). *Machine Learning Visualization via Containerization with AWIPS*. Proceedings, American Geophysical Union Annual Meeting. . Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Camron, D. and Corbin, N. and May, R. M. and Chastang, J (2022). *Student Python Workshop for the 102nd AMS Annual Meeting*. Proceedings, 102nd AMS Annual Meeting. Houston, Texas, USA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Ramamurthy, M. K. and Chastang, J. (2021). *The Use of the Unidata Science Gateway as a Resource for Facilitating Education and Research During COVID*. 2021 AGU Fall Meeting. New Orleans, Louisiana, USA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Ramamurthy, M. K. and Chastang, J. (2021). *The Use of the Unidata Science Gateway as a Resource for Facilitating Education and Research During COVID-19*. 17th IEEE eScience 2021. Innsbruck, Austria. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Meyer, T. C. and Carter, S. and Corbin, N. (2022). *Unidata AWIPS Update*. Proceedings, 102nd AMS Annual Meeting. Houston, Texas, USA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

= PUBLISHED; Acknowledgement of Federal Support = Yes

Chastang, J. and Maull, K. (2022). *Unidata Partners with UCAR SOARS Program to Help Protégés and Their Mentors with Atmospheric Science Internships*. Proceedings, Third Symposium on Diversity, Equity, and Inclusion, 102nd AMS Annual Meeting. Houston, Texas, USA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

## Other Products

## Other Publications

## Patent Applications

## Technologies or Techniques

## Thesis/Dissertations

## Websites or Other Internet Sites

### *Unidata E-Learning*

<https://elearning.unidata.ucar.edu/>

Unidata's new (in 2022) E-learning site will serve as a repository of Unidata-created online learning materials. The site is freely available, although site registration is required. Initial content published in early 2022 supports learners new to the Common AWIPS Visualization Environment (CAVE); additional modules are in the planning stages, as are mechanisms by which university educators can repurpose Unidata-created content in their own courses.

### *Unidata Website*

<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?

Name	Most Senior Project Role	Nearest Person Month Worked
Ramamurthy, Mohan	PD/PI	8
Arms, Sean	Other Professional	4
Camron, Michael	Other Professional	7
Carter, Shaylina	Other Professional	11
Chastang, Julien	Other Professional	11
Corbin, Nicole	Other Professional	11
Davis, Ethan	Other Professional	9
Dirks, Doug	Other Professional	10
Emmerson, Steve	Other Professional	8
Espinoza, Roberto	Other Professional	2
Fisher, Ward	Other Professional	11
Heimbigner, Dennis	Other Professional	12
Ho, Yuan	Other Professional	11
ILES, Mustapha	Other Professional	11
Johnson, Hailey	Other Professional	8
May, Ryan	Other Professional	6
McMahon, Rio	Other Professional	8
Meyer, Tiffany	Other Professional	11
Mitchell-Sur, Terry	Other Professional	1
Neidigh, Joshua	Other Professional	3
Oxelson, Jennifer	Other Professional	11
Perna, Matthew	Other Professional	11
Purvis, Inken	Other Professional	8
Ruscetta, Sheri	Other Professional	5
Schmidt, Mike	Other Professional	10
Weber, Jeff	Other Professional	11
Yoksas, Tom	Other Professional	10
Young, Joshua	Other Professional	6
Bunting, Lydia	Undergraduate Student	3

Cozad, Connor	Undergraduate Student	3
Pfander, Isabelle	Undergraduate Student	3

## Full details of individuals who have worked on the project:

### Mohan K Ramamurthy

**Email:** mohan@ucar.edu

**Most Senior Project Role:** PD/PI

**Nearest Person Month Worked:** 8

**Contribution to the Project:** Program Director - Administration and Management

**Funding Support:** No other funding support

**Change in active other support:** Yes [cp-468240 \(1\).pdf](#)

**International Collaboration:** No

**International Travel:** No

### Sean Arms

**Email:** sarms@ucar.edu

**Most Senior Project Role:** Other Professional

**Nearest Person Month Worked:** 4

**Contribution to the Project:** Software Engineer - program development

**Funding Support:** No other funding support

**International Collaboration:** No

**International Travel:** No

### Michael Camron

**Email:** dcamron@ucar.edu

**Most Senior Project Role:** Other Professional

**Nearest Person Month Worked:** 7

**Contribution to the Project:** Software Engineer - program development

**Funding Support:** No other funding support

**International Collaboration:** No

**International Travel:** No

### Shaylina Carter

**Email:** srcarter@ucar.edu

**Most Senior Project Role:** Other Professional

**Nearest Person Month Worked:** 11

**Contribution to the Project:** Software Engineer - program development

**Funding Support:** No other funding source

**International Collaboration:** No

**International Travel:** No

### Julien Chastang

**Email:** chastang@ucar.edu

**Most Senior Project Role:** Other Professional

**Nearest Person Month Worked:** 11

**Contribution to the Project:** Software Engineer - program development

**Funding Support:** No other funding source

**International Collaboration:** No

**International Travel:** No

**Nicole Corbin**

**Email:** ncorbin@ucar.edu

**Most Senior Project Role:** Other Professional

**Nearest Person Month Worked:** 11

**Contribution to the Project:** Software Engineer - program development

**Funding Support:** No other funding source

**International Collaboration:** No

**International Travel:** No

**Ethan Davis**

**Email:** edavis@ucar.edu

**Most Senior Project Role:** Other Professional

**Nearest Person Month Worked:** 9

**Contribution to the Project:** Software Engineer & Technical Manager - program development & project management

**Funding Support:** No other funding source

**International Collaboration:** Yes, Germany, Ireland, Italy, United Kingdom

**International Travel:** No

**Doug Dirks**

**Email:** ddirks@ucar.edu

**Most Senior Project Role:** Other Professional

**Nearest Person Month Worked:** 10

**Contribution to the Project:** Program Editor/Writer - community service outreach

**Funding Support:** No other funding source

**International Collaboration:** No

**International Travel:** No

**Steve Emmerson**

**Email:** emmerson@ucar.edu

**Most Senior Project Role:** Other Professional

**Nearest Person Month Worked:** 8

**Contribution to the Project:** Software Engineer - program development

**Funding Support:** No other funding source

**International Collaboration:** No

**International Travel:** No

**Roberto Espinoza**

**Email:** respinoza@ucar.edu

**Most Senior Project Role:** Other Professional

**Nearest Person Month Worked:** 2

**Contribution to the Project:** Software Engineer - program development

**Funding Support:** No other funding source

**International Collaboration:** No

**International Travel:** No

**Ward Fisher**

**Email:** wfisher@ucar.edu

**Most Senior Project Role:** Other Professional

**Nearest Person Month Worked:** 11

**Contribution to the Project:** Software Engineer - program development

**Funding Support:** No other funding source

**International Collaboration:** No

**International Travel:** No

**Dennis Heimbigner**

**Email:** dmh@ucar.edu

**Most Senior Project Role:** Other Professional

**Nearest Person Month Worked:** 12

**Contribution to the Project:** Software Engineer - program development

**Funding Support:** No other funding source

**International Collaboration:** No

**International Travel:** No

**Yuan Ho**

**Email:** yuanho@ucar.edu

**Most Senior Project Role:** Other Professional

**Nearest Person Month Worked:** 11

**Contribution to the Project:** Software Engineer - program development

**Funding Support:** No other funding source

**International Collaboration:** Yes, Italy, Spain, Turkey

**International Travel:** No

**Mustapha ILES**

**Email:** mustapha@ucar.edu

**Most Senior Project Role:** Other Professional

**Nearest Person Month Worked:** 11

**Contribution to the Project:** Software Engineer - program development

**Funding Support:** No other funding source

**International Collaboration:** No

**International Travel:** No

**Hailey Johnson**

**Email:** hajohns@ucar.edu

**Most Senior Project Role:** Other Professional

**Nearest Person Month Worked:** 8

**Contribution to the Project:** Software Engineer - program development

**Funding Support:** No other funding source

**International Collaboration:** No

**International Travel:** No

**Ryan May**

**Email:** rmay@ucar.edu

**Most Senior Project Role:** Other Professional

**Nearest Person Month Worked:** 6

**Contribution to the Project:** Software Engineer & Technical Manager - program development & project management

**Funding Support:** No other funding source

**International Collaboration:** No

**International Travel:** No

**Rio McMahon**

**Email:** rcmcmahon@ucar.edu

**Most Senior Project Role:** Other Professional

**Nearest Person Month Worked:** 8

**Contribution to the Project:** Software Engineer - program development

**Funding Support:** No other funding source

**International Collaboration:** No

**International Travel:** No

**Tiffany Meyer**

**Email:** tiffanym@ucar.edu

**Most Senior Project Role:** Other Professional

**Nearest Person Month Worked:** 11

**Contribution to the Project:** Software Engineer - program development

**Funding Support:** No other funding source

**International Collaboration:** No

**International Travel:** No

**Terry Mitchell-Sur**

**Email:** tmitchel@ucar.edu

**Most Senior Project Role:** Other Professional

**Nearest Person Month Worked:** 1

**Contribution to the Project:** Program Manager - program administration and management

**Funding Support:** No other funding source

**International Collaboration:** No

**International Travel:** No

**Joshua Neidigh**

**Email:** jwneidigh@ucar.edu

**Most Senior Project Role:** Other Professional

**Nearest Person Month Worked:** 3

**Contribution to the Project:** Senior Program Administrator - program administration and management

**Funding Support:** No other funding source

**International Collaboration:** No

**International Travel:** No

**Jennifer Oxelson****Email:** oxelson@ucar.edu**Most Senior Project Role:** Other Professional**Nearest Person Month Worked:** 11**Contribution to the Project:** Software Engineer - program development**Funding Support:** No other funding source**International Collaboration:** No**International Travel:** No**Matthew Perna****Email:** mperna@ucar.edu**Most Senior Project Role:** Other Professional**Nearest Person Month Worked:** 11**Contribution to the Project:** Systems Administration**Funding Support:** No other funding source**International Collaboration:** No**International Travel:** No**Inken Purvis****Email:** ipurvis@ucar.edu**Most Senior Project Role:** Other Professional**Nearest Person Month Worked:** 8**Contribution to the Project:** Administrative Support**Funding Support:** No other funding support**International Collaboration:** No**International Travel:** No**Sheri Ruscetta****Email:** ruscetta@ucar.edu**Most Senior Project Role:** Other Professional**Nearest Person Month Worked:** 5**Contribution to the Project:** Administrative Support**Funding Support:** No other funding source**International Collaboration:** No**International Travel:** No**Mike Schmidt****Email:** mschmidt@ucar.edu**Most Senior Project Role:** Other Professional**Nearest Person Month Worked:** 10**Contribution to the Project:** Systems Administration**Funding Support:** No other funding source**International Collaboration:** No**International Travel:** No**Jeff Weber**



**Email:** jweber@ucar.edu

**Most Senior Project Role:** Other Professional

**Nearest Person Month Worked:** 11

**Contribution to the Project:** Project Manger - project management

**Funding Support:** No other funding source

**International Collaboration:** No

**International Travel:** No

**Tom Yoksas**

**Email:** yoksas@ucar.edu

**Most Senior Project Role:** Other Professional

**Nearest Person Month Worked:** 10

**Contribution to the Project:** Software Engineer - program development

**Funding Support:** No other funding source

**International Collaboration:** Yes, Costa Rica

**International Travel:** No

**Joshua Young**

**Email:** jwyong@ucar.edu

**Most Senior Project Role:** Other Professional

**Nearest Person Month Worked:** 6

**Contribution to the Project:** Community Services Manager - community outreach & management

**Funding Support:** No other funding source

**International Collaboration:** No

**International Travel:** No

**Lydia Bunting**

**Email:** lbunting@ucar.edu

**Most Senior Project Role:** Undergraduate Student

**Nearest Person Month Worked:** 3

**Contribution to the Project:** Student Intern - program development

**Funding Support:** No other funding source

**International Collaboration:** No

**International Travel:** No

**Connor Cozad**

**Email:** ccozad@ucar.edu

**Most Senior Project Role:** Undergraduate Student

**Nearest Person Month Worked:** 3

**Contribution to the Project:** Student Intern - program development

**Funding Support:** No other funding source

**International Collaboration:** No

**International Travel:** No

**Isabelle Pfander**

**Email:** irpfander@ucar.edu

**Most Senior Project Role:** Undergraduate Student

**Nearest Person Month Worked:** 3

**Contribution to the Project:** Student Intern - program development

**Funding Support:** No other funding source

**International Collaboration:** No

**International Travel:** No

What other organizations have been involved as partners?

Name	Type of Partner Organization	Location
Leeman Geophysical LLC	Other Organizations (foreign or domestic)	Siloam Springs, AR
University of Wisconsin	Academic Institution	Madison, WI

Full details of organizations that have been involved as partners:

#### Leeman Geophysical LLC

**Organization Type:** Other Organizations (foreign or domestic)

**Organization Location:** Siloam Springs, AR

**Partner's Contribution to the Project:**

Other: Production of MetPy Monday videos

**More Detail on Partner and Contribution:** John Leeman with Leeman Geophysical LLC was the originator of MetPy Mondays while he was at Unidata and has taught many of the Python workshops with us. He is continuing the MetPy Monday videos and keeping up their regular releases and growing success to continue growing our Python portfolio.

#### 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:**

Were other collaborators or contacts involved? If so, please provide details.

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 2021 in journals of the American Meteorological Society shows 87 articles containing citations of Unidata software and data services. In the same period, an additional 208 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 2021 indicated that Unidata software and data services were cited 3870 times in the full range of scholarly literature encompassed by the search engine. Of these, 3373 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?

Unidata's efforts to provide software training contribute directly to levels of computational and data science literacy among geoscience students and educators.

## What was the impact on teaching and educational experiences?

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 improve teaching and educational experiences in the geosciences. Of special note are the following metrics, collected in late 2021:

Number of U.S. universities receiving software: 195

Number of universities outside the U.S.: 547

Approximate number of attendees of 2021-2022 training workshops (virtual): 365

## What is the impact on physical resources that form infrastructure?

### Community Equipment Awards

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 2021 include:

University/PI	Project Title
College of DuPage Paul Sirvatka	The Next Generation of NEXLAB – Server Upgrade for College of DuPage's Meteorology Lab
Iowa State University Richard Cruse	Iowa State University / Unidata Community Equipment Proposal
South Dakota School of Mines William J. Capehart	Reimagining SD Mine's Weather and Climate Program's Cyberinfrastructure
University of North Carolina at Pembroke/Charlotte Xin Zhang and Wenwu Tang	Remote Collaborative Geoscience Learning through Distributed File Servers and Dedicated Web Server System
University of Wisconsin-Milwaukee A. Clark Evans	Upgrading THREDDS and Deploying JupyterHub at the University of Wisconsin-Milwaukee to Support Education and Research

Valparaiso University

Kevin Goebbert

## A JupyterHub Server to Enhance the Use of Python in Meteorology Coursework at Valparaiso University

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:

### Unidata Science Gateway

The Unidata Science Gateway on NSF's Jetstream Cloud 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. During the 2021-2022 academic year, with many universities relying heavily on remote-learning techniques as the COVID-19 pandemic continues, Unidata continued its program of offering to set up JupyterHub systems to support atmospheric and related science courses. Courses serving over 700 students at 15 universities have now taken advantage of this Unidata resource. In addition, a workshop associated with the AMS 2022 Student Conference provided resources for 65 students.

Unidata Science Gateway resources have been used in UCAR's Significant Opportunities in Atmospheric Research and Science (SOARS) for several years now. In the summer of 2021, we helped two SOARS protégés, Allysa Dallmann (Iowa State University, Meteorology) and Miranda Miranda (UT El Paso, Environmental Sciences), gain access to specialized scientific computing environments and colocated datasets. A synopsis of this work was presented at the Third Symposium on Diversity, Equity, and Inclusion of the 2022 AMS meeting under the title "Unidata Partners with UCAR SOARS Program to Help Protégés and Their Mentors with Atmospheric Science Internships" (<https://ams.confex.com/ams/102ANNUAL/meetingapp.cgi/Paper/398651>).

The growing acceptance and use of the Unidata Science Gateway has led the program to allocate additional resources to the project from our core funding. In addition, supplemental NSF funding has allowed us to hire an additional software engineer fully dedicated to the operation and enhancement of the Science Gateway.

Of special interest has been the operation of a community-accessible cloud-based AWIPS Environmental Data EXchange (EDEX) server. Unidata's distribution of the CAVE client points to this EDEX server by default, allowing university users to get up and running quickly without the need to configure a local data server. Unidata's cloud-based EDEX server provides roughly 28 Gigabytes per day to remote access users. A separate cloud-based EDEX server is used for development and testing, and is available as a failover replacement for the primary hosted EDEX in the event of technical difficulties.

### 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. While travel restrictions during the past year have reduced conference attendance somewhat, UPC staff members have remained involved in the above areas through virtual participation.

### Open Geospatial Consortium

Unidata has a long history of involvement with the Open Geospatial Consortium (OGC) working towards implementation and adoption of data standards. A Unidata staff member is currently co-chair of the OGC netCDF Standards Working Group (SWG); this group is discussing a draft OGC standard document "OGC Encoding Linked Data Graphs in NetCDF Files" that provides a mapping for netCDF metadata into linked data graphs in RDF and other formats.

Unidata staff members also attend meetings of the OGC MetOcean Domain Working Group (DWG) which includes representatives from a number of

national meteorology services. A recent focus of this group is development of an OGC web API for Environmental Data Retrieval (OGC API - EDR) which supports common environmental data request patterns. A related effort is to bring the CoverageJSON standard into OGC process as an OGC Community Standard.

## 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.

## EarthCube Activities

Unidata's director (Dr. Mohan Ramamurthy) 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 Columbia University, NCAR, and Continuum Analytics on *Pangeo: An Open Source Big Data Climate Science Platform*, and with NCAR and the University at Albany, SUNY on *Project Pythia: A Community Learning Resource for Geoscientists*.

## 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 2022, the traffic handled by servers operated by the UPC itself -- a fraction of the total IDD system -- was more than 70 Tbytes/day, or an average of more than 25 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-16 and GOES-17 satellites, the UPC now provides more than 4.1 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.

Unidata's primary top-level IDD relay cluster, `idd.unidata.ucar.edu`, normally operates out of the NCAR Wyoming SuperComputer (NWSC) facility in Cheyenne, WY. During the summer of 2021, a week long power down at the NWSC forced Unidata to create a new instance of `idd.unidata.ucar.edu` at the NCAR Mesa Lab. Transition from the NWSC instance of `idd.unidata.ucar.edu` to the Mesa Lab instance was done seamlessly by a DNS change; after the work was complete at NWSC, `idd.unidata.ucar.edu` was returned to the cluster there. Very few support inquiries were received as a result of this temporary change.

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 hundreds of students and faculty attending MetPy-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 thirty 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 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 development has slowed as Program Center staff have been allocated to other projects, but the package continues to gain functionality slowly, for example when requirements are revealed in the course of MetPy 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. Over time, the community using the visualization functions of McIDAS-X has adopted different technologies (many of the functions have been incorporated into the IDV, for example). This, coupled with the small number of software developers available to contribute to development and maintenance efforts, has led Unidata to explore ways to transition away from providing resources for the software's continued development. Discussions with SSEC about ways to continue supporting existing users are under way.

Another portion of the McIDAS-X software involves data distribution. Abstract Data Distribution Environment (ADDE) servers are in wide use in the Unidata community; traffic on Unidata-maintained ADDE servers constitutes roughly one third of all remote access data traffic. Unidata is committed to maintaining access to this server technology as a data distribution mechanism, even if we no longer support McIDAS-X as an end-user visualization tool.

**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. Rosetta development has slowed as Program Center staff have been allocated to other projects.

## 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.

## What percentage of the award's budget was spent in a foreign country?

Nothing to report.

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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

In recent years, Unidata has had increasing difficulty recruiting and retaining software engineers at the salary levels mandated by UCAR's human resources policies. Relatively low (compared with non-UCAR opportunities) software developer salary levels have led to both increased turnover and difficulty attracting qualified candidates for open positions in several of Unidata's project areas. The resulting unfilled positions have both slowed progress on important initiatives (including Unidata's fledgling Artificial Intelligence/Machine Learning program and work on the THREDDS Data Server) and slowed the program's rate of expenditures.

Unidata is not alone in experiencing problems hiring and retaining technical staff; programs across UCAR report similar difficulties. While this trend has become especially noticeable during the COVID-19 pandemic, it has also been partially mitigated by greater institutional openness to hiring full-time remote staff. As staff members begin returning to the physical workplace, we envision additional headwinds especially when attempting to hire software engineers in the Boulder area, which has become a hub for many information technology companies including Google, Apple, and Microsoft.

### 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.

### Change in primary performance site location

Nothing to report.

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