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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:	**05/01/2019 - 04/30/2020**
Submitting Official (if other than PD\PI):	**Mohan K Ramamurthy Principal Investigator**
Submission Date:	**03/31/2020**
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: 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 2019 – March 2020.

* 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 activities during the first 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 600 machines at 230+ 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 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, 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 tens of thousands of unique IP addresses running the server. Of these, 161 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 first 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. 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. The Science Gateway JupyterHub server concept has been implemented for use during a semester-long data science class at Southern Arkansas University, several two-day workshops, and supported roughly 140 students during a short workshop at the AMS 2020 Student Conference. During the spring of 2020, when many universities have transitioned to remote-learning during the COVID-19 outbreak, Unidata offered to set up JupyterHub systems to support atmospheric and related science courses finishing out the spring term. As of this writing, two universities have already requested custom JupyterHubs for this purpose.

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, and create demonstrations of cloud-based application services (most notably for remote access to the IDV visualization software).

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 first 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. The MetPy and Siphon development team underwent some staff changes during this year, but the 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. In addition, in the first 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.

Unidata has a number of venues for community interaction and outreach. Staff members 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. We engage with instructors and students at software training workshops hosted by community member universities or at scientific and technical meetings. And 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. Of special interest has been the UPC technical staff's active involvement in the Tenth Symposium on Advances in Modeling and Analysis Using Python at the 100th AMS Annual Meeting in Boston, MA in January 2020.

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 September 2019, Unidata's Internet Data Distribution (IDD) clusters deliver roughly 54 Terabytes per day to downstream systems, up from roughly 35 Terabytes per day in 2018. As a result of the GOES-17 spacecraft coming on-line and the data becoming operational in 2019, the volume of data served via remote access methods (most notably ADDE) has also increased significantly, now averaging approximately 1.6 Terabytes per day.

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 first 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 server has proven to be the most popular feature of the Science Gateway; it has been deployed for workshops and courses including:

> A semester-long data science class at Southern Arkansas University
> An ongoing instructional group at the U.S. Naval Academy

A Python workshop at the Annual Student Conference for the American Meteorological Society 2020 annual meeting, supporting roughly 140 student participants

Unidata regional workshops at the University of Oklahoma and the University of North Carolina, Charlotte

In addition, as a response to the COVID-19 outbreak and the resulting move by many universities to conduct all classes online, Unidata is offering to provide Science Gateway JupyterHub resources to schools through the end of the spring semester of 2020. As of this writing, instructors at Valparaiso University, the University of Oklahoma, and Embry Riddle Aeronautical University have already made arrangements to take advantage of Unidata Science Gateway resources for spring semester classes.

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. 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.

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 the first year of this grant period. Releases 0.8 through 0.12 led to a "release candidate" of version 1.0 that coincided with the 2020 AMS annual meeting. MetPy version 1.0 is an important milestone because it marks a commitment by the developers to keep the software's Application Programming Interface (API) stable over a longer time period -- ideally until development advances to the level of a version 2 release.

In addition MetPy developers presented progress to the community at the 2020 AMS annual meeting and the 2019 SciPy conference. Developers led Python-focused software training workshops at Metro State University of Denver, the State University of New York at Albany, Valparaiso University, the 2020 AMS Annual Meeting, and the University of Manitoba.

AWIPS and GEMPAK:

In 2019, Unidata suffered the tragic loss of our primary AWIPS and GEMPAK software developer in a boating accident. While a second AWIPS developer had already been hired at the time of the accident, she had not yet begun work at the Program Center. The new developer joined the Unidata team in September, and we were fortunate to be able to contract with an experienced local AWIPS developer to help out on a part-time basis. Even so, Unidata's efforts have been limited to supporting the existing Unidata AWIPS release (currently version 18.1.1-6) as our new developer comes up to speed.

In addition to user support work, we have been able to maintain Unidata's cloud-based EDEX server for university use, and re-establish the availability of the NUCAPS and PIREP data sets.

In February 2020, a second AWIPS developer agreed to join the Program Center. She will begin remote work for Unidata in mid-May, with the intention to move to Boulder in the next year.

The Program Center has also contracted with an outside software developer experienced with the GEMPAK software to address several known issues in the most recent release of Unidata's GEMPAK distribution (version 7.5.1). Following the resolution of those issues, Unidata plans to transition its GEMPAK distribution, which is already open source, to a purely community-developed and -supported package.

IDV:

Unidata's Integrated Data Viewer version 5.6 was released in June 2019. This version introduced new features including an isentropic advection derived parameter, a 3D streamline display, new display types for the 3D grid tracer display, and a chooser for Geostationary Lightning Mapper data from ADDE servers.

Unidata's Integrated Data Viewer version 5.7 was released in February 2020. This version features enhanced color tables, support for NWS Hazard Warning KML files, enhanced support for vertical profiles, and several new formulas.

In addition, a number of new screencasts describing concepts and techniques related to using the IDV were posted to the Unidata YouTube channel as part of one of the Unidata 2019 summer interns' summer projects. The videos cover a variety of basic IDV tasks using the most recent IDV release.

LDM:

Local Data Manager versions 6.13.9 and 6.13.11 were released in 2019. Work on a "multicast" version of the LDM employing virtual circuit technology continues activities begun in collaboration with the University of Virginia.

NetCDF:

The netCDF-C library versions 4.7.0 through 4.7.2 were released during the first year of the award. These releases began work aimed at making the netCDF libraries compatible with widely used key-value pair cloud storage systems (such as Amazon's S3, for example). Work continues on the implementation of a netCDF-ZARR (NCZarr) data model to support this functionality.

In addition, version 4.3.1 of the netCDF C++ library was released, supporting new netCDF C library features.

Siphon:

The Siphon project is a collection of Python utilities for accessing data from Unidata data technologies such as the 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 as when requirements are revealed in the course of MetPy development.

Rosetta:

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

TDS:

The THREDDS Data Server (TDS) version 5.0 is currently in a beta-testing phase, but is currently deployed at 42 non-Unidata sites. Progress toward an official TDS 5.0 release has been slowed by the departure of key development staff.

The NetCDF-Java library that underlies the TDS has seen releases 5.0.0, 5.1.0, and 5.2.0 in the first year of the award.

Key outcomes or Other achievements:	This section briefly notes some Unidata activities and achievements not listed in the "Significant Results" section, above.

Outreach to Underserved Communities

In the first year of the award, the Program Center staff have begun to focus on outreach and provision of services to underserved communities within the atmospheric and related sciences. Staff members have participated in the American Indian Science and Engineering Society (AISES) Annual Conference and the Society for Advancement of Chicanos/Hispanics & Native Americans in Science (SACNAS) National Diversity in STEM Conference, as well as engaging with UCAR's Rising Voices program for Climate Resilience through Indigenous and Earth Sciences. Progress has been made in designing structural changes to Unidata programs, including modifications to how equipment awards, internships, workshops, and committee placements are announced and selected.

Unidata Users Workshops

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. Funding granted for the workshop but not used during the 2018 event was reallocated to two regional one-day workshops, one at the University of Oklahoma and one at the University of North Carolina, Charlotte. (A third workshop, to be held at the University of Alaska, Fairbanks, was cancelled due to COVID-19 travel restrictions.) The follow-on workshops explored tools to access data and strategies for teaching computational concepts, and brought together geoscience educators, pedagogical experts, and Unidata staff to discuss and share best practices for helping students engage in data-enabled science.

New Data Streams

Texas Tech University (specifically Dr. Eric Bruning) is creating value-added Level 2 products from GOES-16/17 Geostationary Lightning Mapper (GLM) images as a precursor for similar products potentially being added to NOAAPort. Unidata has added the Texas Tech Level 2 products to the NIMAGE IDD datastream; they are directly usable by all of the analysis and display packages that we make available with the exception of GEMPAK.

A new "FSL2" feed has been added to the top level IDD relay clusters. This feed currently contains only Alaskan wind profiler data in BUFR format. We will add other profiler data we are currently receiving from NOAA/GSD in a test mode to the feed in the very near future.

In 2019, Unidata took over the data distribution of GPS radio occultation solutions from COSMIC. COSMIC will still gather incoming GPS data and create the solutions, but due to hardware constraints COSMIC has requested that Unidata provide distribution from our top level IDD relay clusters to the community. The solutions (Precipitable Water Vapor and Total Electron Content-Ionosphere) are in netCDF format and are available in the GPS feedtype.

DeSouza Award

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 2019 award was

given to long-time community member Pete Pokrandt from the University of Wisconsin, Madison. Through his support for Unidata software and services at the University of Wisconsin and his development of tools to help people use GOES satellite data, he has truly become a "go-to" person in the Unidata community.**EarthCube Projects**

UPC staff are involved in the following ongoing EarthCube projects:

> Advancing netCDF-CF for the Geoscience Community (collaboration with the University of California, Irvine; the University of Texas, Austin; the University of Washington/JISAO; the University of Wisconsin, Madison/SSEC; and the HDF Group, along with numerous unfunded collaborators)
> Pangeo: An Open Source Big Data Climate Science Platform (collaboration with NCAR/CISL, and Columbia University-Lamont-Doherty Earth Observatory)
> That dot is a world! Drilling down from a statistics scatterplot to pre-populated case Notebooks (collaboration with the University of Miami Rosenstiel School of Marine & Atmospheric Sciences)

Scientific Conferences

Program Center staff participated in numerous scientific conferences in the first 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 Annual meeting
> Research Data Alliance Plenary meetings
> National Data Service meetings
> Open Geospatial Consortium Technical Committee meetings
> 2020 OceanObs Meeting

Python Training

UPC staff conducted four regional workshops in the first year of this award, 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 and Siphon. Materials from these workshops were used to augment Unidata's online Python Training resource (https://unidata.github.io/python-training/), and additional material will be included as resources are available. Two additional Python workshops were held at the AMS 2020 Annual Meeting:

> a day-long "Short Course," which had 25 attendees
> a 90-minute Python Workshop, held as part of the AMS Student Conference, that had roughly 140 student attendees

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 since 2018, 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 110 installments on a wide range of MetPy related topics.

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 2019, the committees changed as follows:

> Daryl Herzmann from Iowa State University and Tomer Burg from the University at Albany (Graduate Student Representative) finished their terms on the Users Committee.
> Martin Baxter from Central Michigan University finished his term on the Strategic Advisory Committee.
> Kimberly Wood from Mississippi State University joined the Users Committee. Lena Heuscher from the University of Alabama in Huntsville began a two-year term as the Users Committee's Graduate Student Representative.

> Chris Hennon from the University of North Carolina Asheville and Nicole Mölders from the University of Alaska, Fairbanks joined the Strategic Advisory 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. Because a diminishing number of community members are able to travel to Boulder for software training, the Program Center has made the decision to focus on conducting regional workshops hosted by community institutions instead. In 2019, four stand-alone regional workshops were held, in addition to workshops conducted as part of other scientific meetings.

Broadening participation and proactively engaging institutions with a significant number of underrepresented student populations remains a high priority for

Unidata. In addition to ramping up Unidata's outreach efforts (see the "Key Outcomes or Other Achievements" section, above), UPC developers conducted a regional workshop at Metro State University of Denver in the spring of 2019. A workshop planned for the University of Alaska, Fairbanks has been postponed due to the COVID-19 epidemic.

Unidata's summer internship program has provided notable professional development opportunities for students. The program invited three students to spend the summer working at the Unidata Program Center in 2019. Jessica Blunt from the University of Oklahoma spent some of her time working in the IDV code base to improve the way polygons from National Weather Service warnings are shown, but focused mainly on explaining IDV features in a series of video tutorials published on Unidata's YouTube channel. Max Grover from the University of Illinois spent the summer adding METAR functionality to the MetPy package.Aodhan Sweeney from the University of Washington spent his summer at Unidata expanding functionality for both the netCDF C++ library and the Python data access tool Siphon. The 2019 interns -- along with interns from 2017 and 2018 -- were instrumental in the creation of a successful Python workshop presented to roughly 140 students at the 2020 American Meteorological Society Student Conference.

* How 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.
> 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.
> Unidata staff members conducted a total of eight workshops during the year: four regional software training workshops, two Python-focused events at the AMS 2020 Annual Meeting, and two regional events building on the 2018 Unidata Users Workshop.

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 second 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

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.

Licenses

Other Conference Presentations / Papers

Davis, Ethan and Castelao, Guilherme P. and Hassell, David and Hausman, Jessica and Jelenak, Aleksandar and Lee, Daniel and O'Brien, Kevin (2019). *2019 CF Conventions for netCDF Workshop (Poster)*. Proceedings of the AGU 2019 Fall Meeting. San Francisco, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Chastang, Julien (2019). *A JupyterHub for Atmospheric Science Research and Education on the Unidata Science Gateway*. Gateways 2019. San Diego, California, USA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Bruick, Zachary S. and May, Ryan M. and Goebbert, Kevin H. (2020). *A One-Stop Shop for Atmospheric Science Python: The Unidata Python Training Site (Poster)*. Proceedings, 10th Symposium on Advances in Modeling and Analysis Using Python, 100th AMS Annual Meeting. Boston, MA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Goebbert, Kevin H. and May, Ryan M. and Bruick, Zach S. (2020). *An Interactive Demonstration of MetPy's Declarative Language: Moving from GEMPAK to MetPy as the Primary Analysis and Visualization Tool of Atmospheric Scientists (Poster)*. Proceedings, 29th Conference on Education, 100th AMS Annual Meeting. Boston, MA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Yu, Wei and Xue, Z. George and Yin, Dongxiao and Ho, Yuan (2019). *An Update In Hydrology Model Development And Application (Poster)*. Proceedings of the AGU 2019 Fall Meeting. San Francisco, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Barnes, Tim and Aquino, Janine and Weber, Jeff (2020). *Being an Atmospheric Science Wizard*. Proceedings, 29th Conference on Education, 100th AMS Annual Meeting. Boston, MA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Arms, Sean Cody and Wilcox, Kyle and Signell, Richard P. (2019). *Bringing Unstructured Grid Support to the THREDDS Stack (Poster)*. Proceedings of the AGU 2019 Fall Meeting. San Francisco, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Thielen, Jonathan E. and May, Ryan M. (2020). *Bringing WRF into MetPy (and the Rest of the Atmospheric Sciences Python Ecosystem)*. Proceedings, 30th Conference on Weather Analysis and Forecasting (WAF)/26th Conference on Numerical Weather Prediction (NWP) , 100th AMS Annual Meeting. Boston, MA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

May, Ryan M. (2019). *Building up xarray and smoothing the rough edges to bring the CDM to Python*. Proceedings, 2019 Earthcube Annual Meeting. Denver, CO. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Davis, Ethan and Castelao, Guilherme and Hassell, David and Hausman, Jessica K. and Jelenak, Aleksandar and Lee, Daniel and O'Brien, Kevin M. (2020). *CF Conventions for netCDF: Support for Data Access, Analysis, and Visualization (Poster)*. Proceedings, 36th Conference on Environmental Information Processing Technologies, 100th AMS Annual Meeting. Boston, MA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Blunt, Jessica Michael and Ho, Yuan (2020). *Data Visualization for All! Videos for Unidata's Integrated Data Viewer (Poster)*. Proceedings, 36th Conference on Environmental Information Processing Technologies, 100th AMS Annual Meeting. Boston, MA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Grover, Maxwell and May, Ryan M. and Bruick, Zach (2020). *Declarative Surface Station Plots: The Next Stop on the GEMPAK Replacement Roadmap for MetPy (Poster)*. Proceedings, 30th Conference on Weather Analysis and Forecasting (WAF)/26th Conference on Numerical Weather Prediction (NWP) , 100th AMS Annual Meeting. Boston, MA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Chastang, Julien (2019). *Deploying a {U}nidata {J}upyter{H}ub on the {NSF} {J}etstream Cloud, Lessons Learned and Challenges Going Forward*. ESIP Summer Meeting 2019. Tacoma, WA, USA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Ho, Yuan and Yu, Wei (2019). *Hydrology Model Water Resource Estimation with Advanced 3D Visualization and Analysis (Poster)*. Proceedings of the AGU 2019 Fall Meeting. San Francisco, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Schweitzer, Roland and Davis, Ethan and Arms, Sean Cody and Simons, Robert and O'Brien, Kevin and Neufeld, David (2019). *Managing a Community Data Collection with Open Source Software*. Proceedings of the AGU 2019 Fall Meeting. San Francisco, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

May, Ryan M. and Bruick, Zach S. and Goebbert, Kevin H. (2020). *MetPy 1.0: An Upgrade from GEMPAK for Twenty-First Century Atmospheric Science Data Analysis and Visualization*. Proceedings, 10th Symposium on Advances in Modeling and Analysis Using Python, 100th AMS Annual Meeting. Boston, MA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

May, Ryan and Bruick, Zack (2019). *MetPy: An Community-Driven, Open-Source Python Toolkit for Meteorology*. Proceedings of the AGU 2019 Fall Meeting. San Francisco, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Fisher, Ward (2019). *NetCDF in the Cloud: modernizing storage options for the netCDF Data Model with Zarr (Poster)*. Proceedings of the AGU 2019 Fall Meeting. San Francisco, VA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Sweeney, Aodhan and Arms, Sean C. and May, Ryan M. and Bruick, Zach (2020). *Remote Access of National Hurricane Center Storm Tracks and Storm Prediction Center Storm Reports with Siphon*. Proceedings, 10th Symposium on Advances in Modeling and Analysis Using Python, 100th AMS Annual Meeting. Boston, MA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Arms, Sean C. and May, Ryan M. and Dirks, Douglas (2020). *The Unidata Summer Internship Program—Seven Years of Providing Students with Software Carpentry Skills (Poster)*. Proceedings, 29th Conference on Education, 100th AMS Annual Meeting. Boston, MA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Other Products

Other Publications

Patent Applications

Technologies or Techniques

Thesis/Dissertations

Websites or Other Internet Sites

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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	12
Arms, Sean	Other Professional	12
Bruick, Zachary	Other Professional	6
Camron, Michael	Other Professional	3
Carter, Shaylina	Other Professional	8
Chastang, Julien	Other Professional	12
Davis, Ethan	Other Professional	12
Dirks, Doug	Other Professional	12
Emmerson, Steve	Other Professional	12
Fisher, Ward	Other Professional	12
Hedrick, Cece	Other Professional	2
Heimbigner, Dennis	Other Professional	12
Ho, Yuan	Other Professional	12
James, Michael	Other Professional	1
Jennifer, Oxelson	Other Professional	12
Leeman, John	Other Professional	1
May, Ryan	Other Professional	12
Mitchell-Sur, Terry	Other Professional	12
Perna, Matthew	Other Professional	12
Purvis, Inken	Other Professional	12
Ruscetta, Sheri	Other Professional	12
Schmidt, Mike	Other Professional	12
Van Dam II, Howard	Other Professional	12
Weber, Jeff	Other Professional	12
Yoksas, Tom	Other Professional	12
Young, Joshua	Other Professional	12

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: 12

Contribution to the Project: Program Director - Administration and Management

Funding Support: NSF Grant - AGS 1344155, NSF Grant 1901712, NSF COOP R1623751, NSF Grant 1450180

International Collaboration: Yes, Australia, Finland, Germany, Italy, United Kingdom
International Travel: No

Sean Arms

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Most Senior Project Role: Other Professional

Nearest Person Month Worked: 12

Contribution to the Project: Software Engineer - program development

Funding Support: NSF 1901712, NSF Grant - AGS 1344155, IOOS Model Data - NA18NOS0120157

International Collaboration: No

International Travel: No

Zachary Bruick

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Most Senior Project Role: Other Professional

Nearest Person Month Worked: 6

Contribution to the Project: Software Engineer - program development

Funding Support: NSF Grant - AGS 1344155, NSF Grant 1901712, NSF Grant 1541031, NSF Grant 1740315,

International Collaboration: No

International Travel: No

Michael Camron

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Most Senior Project Role: Other Professional

Nearest Person Month Worked: 3

Contribution to the Project: Software Engineer - program development

Funding Support: NSF Grant 1901712

International Collaboration: No

International Travel: No

Shaylina Carter

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Most Senior Project Role: Other Professional

Nearest Person Month Worked: 8

Contribution to the Project: Software Engineer - program development

Funding Support: NSF Grant 1901712

International Collaboration: No

International Travel: No

Julien Chastang

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Most Senior Project Role: Other Professional

Nearest Person Month Worked: 12

Contribution to the Project: Software Engineer - program development

Funding Support: NSF Grant 1901712, NSF Grant - AGS 1344155

International Collaboration: No

International Travel: No

Ethan Davis

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Most Senior Project Role: Other Professional

Nearest Person Month Worked: 12

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

Funding Support: NSF Grant 1541031 EarthCube netCDF-CF 2.0, NSF Grant 1901712, NSF Grant - AGS 1344155

International Collaboration: Yes, United Kingdom
International Travel: No

Doug Dirks
Email: ddirks@ucar.edu
Most Senior Project Role: Other Professional
Nearest Person Month Worked: 12

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

Funding Support: NSF COOP R1623751, NSF Grant 1901712, NSF Grant AGS - 1344155

International Collaboration: No
International Travel: No

Steve Emmerson
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Most Senior Project Role: Other Professional
Nearest Person Month Worked: 12

Contribution to the Project: Software Engineer - program development

Funding Support: NSF Grant 1901712, NSF Grant - AGS 1344155

International Collaboration: No
International Travel: No

Ward Fisher
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Most Senior Project Role: Other Professional
Nearest Person Month Worked: 12

Contribution to the Project: Software Enginner - program development

Funding Support: NSF Grant 1901712, NSF Grant - AGS 1344155

International Collaboration: No
International Travel: No

Cece Hedrick
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Most Senior Project Role: Other Professional
Nearest Person Month Worked: 2

Contribution to the Project: Software Engineer - program development

Funding Support: NSF AGS 1344155, NSF Grant 1901712

International Collaboration: No
International Travel: No

Dennis Heimbigner
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Most Senior Project Role: Other Professional
Nearest Person Month Worked: 12

Contribution to the Project: Software Engineer - program development

Funding Support: NSF AGS 1344155, NSF Grant 1901712

International Collaboration: No
International Travel: No

Yuan Ho
Email: yuanho@ucar.edu
Most Senior Project Role: Other Professional
Nearest Person Month Worked: 12

Contribution to the Project: Software Engineer - program development

Funding Support: NSF Grant - AGS 1344155, NSF Grant 1901712, NSF Grant 1639648

International Collaboration: No
International Travel: No

Michael James
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Most Senior Project Role: Other Professional
Nearest Person Month Worked: 1

Contribution to the Project: Software Enginner - program development

Funding Support: NSF Grant - AGS 1344155

International Collaboration: No
International Travel: No

Oxelson Jennifer
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Most Senior Project Role: Other Professional
Nearest Person Month Worked: 12

Contribution to the Project: Software Engineer - program development

Funding Support: NSF Grant - AGS 1344155, NSF Grant 1901712

International Collaboration: No
International Travel: No

John Leeman
Email: jleeman@ucar.edu
Most Senior Project Role: Other Professional
Nearest Person Month Worked: 1

Contribution to the Project: Software Engineer - program development

Funding Support: NSF Grant 1740315

International Collaboration: No
International Travel: No

Ryan May
Email: rmay@ucar.edu
Most Senior Project Role: Other Professional
Nearest Person Month Worked: 12

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

Funding Support: NSF Grant - AGS 1344155, NSF Grant 1901712, NSF Grant 1541031, NSF Grant 1740633, NSF Grant 1740315

International Collaboration: No
International Travel: Yes, Canada - 0 years, 0 months, 7 days

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Terry Mitchell-Sur
Email: tmitchel@ucar.edu
Most Senior Project Role: Other Professional
Nearest Person Month Worked: 12

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

Funding Support: NSF Grant - AGS 1344155, NSF Grant 1901712, NSF COOP R1623751

International Collaboration: No
International Travel: No

Matthew Perna
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Most Senior Project Role: Other Professional
Nearest Person Month Worked: 12

Contribution to the Project: Systems Administration

Funding Support: NSF Grant - AGS 1344155, NSF Grant 1901712

International Collaboration: No
International Travel: No

Inken Purvis
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Most Senior Project Role: Other Professional
Nearest Person Month Worked: 12

Contribution to the Project: Administrative Support

Funding Support: NSF Grant - AGS 1344155, NSF Grant 1901712, NSF COOP R1623751,

International Collaboration: No
International Travel: No

Sheri Ruscetta
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Most Senior Project Role: Other Professional
Nearest Person Month Worked: 12

Contribution to the Project: Administrative Support

Funding Support: NSF Grant - AGS 1344155, NSF Grant 1901712, NSF COOP R1623751, NOAA COOP 4620043B

International Collaboration: No
International Travel: No

Mike Schmidt
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Most Senior Project Role: Other Professional
Nearest Person Month Worked: 12

Contribution to the Project: Systems Administration

Funding Support: NSF Grant - AGS 1344155, NSF Grant 1901712

International Collaboration: No

International Travel: No

Howard Van Dam II

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Most Senior Project Role: Other Professional

Nearest Person Month Worked: 12

Contribution to the Project: Software Engineer - program development

Funding Support: NSF Grant - AGS 1344155, NSF Grant 1901712, NSF Grant 1450180, NSF Grant 1541031, NOAA - S0120157

International Collaboration: No

International Travel: No

Jeff Weber

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Most Senior Project Role: Other Professional

Nearest Person Month Worked: 12

Contribution to the Project: Project Manger - project management

Funding Support: NSF Grant - AGS 1344155, NSF Grant 1901712

International Collaboration: No

International Travel: No

Tom Yoksas

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Most Senior Project Role: Other Professional

Nearest Person Month Worked: 12

Contribution to the Project: Software Engineer - program development

Funding Support: NSF Grant - AGS 1344155, NSF Grant 1901712

International Collaboration: Yes, Brazil, Costa Rica

International Travel: No

Joshua Young

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Most Senior Project Role: Other Professional

Nearest Person Month Worked: 12

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

Funding Support: NSF Grant - AGS 1344155, NSF Grant 1901712

International Collaboration: No

International Travel: No

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

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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 2019 in journals of the American Meteorological Society shows 44 articles containing citations of Unidata software and data services. (Of these, 38 refer to Unidata software packages but make no mention of the Unidata program itself.) In the same period, an additional 135 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 2019 indicated that Unidata software and data services were cited 3079 times in the full range of scholarly literature encompassed by the search engine. Of these, 2669 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: 279
    Number of universities outside the U.S.: 747
    Number of attendees of 2018 training workshops: 360

What is the impact on physical resources that form infrastructure?

COVID-19 Related Hardware Loan to Metropolitan State University of Denver

The Unidata Program Center was able to loan six refurbished laptop computers to students in Dr. Keah Schuenemann's Advanced Synoptic Meteorology course at Metropolitan State University of Denver after courses went on-line as a result of the COVID-19 pandemic. The laptops were loaned to students whose personal computer equipment is not capable of running the IDV, which is used extensively in the course.

Says Dr. Schuenemann: "Without this hardware offer, the inequity among the students in my classroom would have kept me from using IDV for the remainder of the class. This worst case scenario would have involved me making lots of imagery for them to write about and students would have left the class having learned significantly less."

The loan, which lasts through the Spring 2020 term, came about after a student in Dr. Schuenemann's course who had spoken with Unidata staff at the 2020 American Meteorological Society meeting in Boston made contact with the UPC to ask about Unidata resources. UPC was able to repurpose the laptops, which had been taken out of service as development machines, for student use of the IDV.

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 2019 include:

University/PI	Project Title
Northern Illinois University Vittorio Gensini	Bringing Back Weather.NIU.edu: A Multifaceted Server at Northern Illinois 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. The Science Gateway JupyterHub server concept has been implemented for use during a semester-long data science class at Southern Arkansas University, several two-day workshops, and supported roughly 140 students during a short workshop at the AMS 2020 Student Conference. During the spring of 2020, when many universities have transitioned to remote-learning during the COVID-19 outbreak, Unidata offered to set up JupyterHub systems to support atmospheric and related science courses finishing out the spring term. As of this writing, two universities have already requested custom JupyterHubs for this purpose.

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.

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 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, and with a variety of collaborators on a project titled *Advancing netCDF-CF for the Geoscience Community*.

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 2019, the traffic handled by servers operated by the UPC itself -- a fraction of the total IDD system -- was more than 54 Tbytes/day, or an average of nearly 20 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 1.6 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 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 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 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 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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