A. Project Summary

Each year across the United States, floods, tornadoes, hail, strong winds, lightning, and winter storms – *so-called mesoscale weather events* -- cause hundreds of deaths, routinely disrupt transportation and commerce, and result in annual economic losses greater than $13B. Although mitigating the impacts of such events would yield enormous economic and societal benefits, the ability to do so is stifled by rigid information technology (IT) frameworks that cannot accommodate the *real time, on-demand, and dynamically-adaptive* needs of mesoscale weather research; its disparate, high volume data sets and streams; and its tremendous computational demands.

In response to this pressing need for a comprehensive national cyberinfrastructure in mesoscale meteorology, particularly one that can interoperate with those being developed in other cognate disciplines, we will address the fundamental IT research challenges needed to create an integrated, scalable framework – known as Linked Environments for Atmospheric Discovery (LEAD) – for identifying, accessing, preparing, assimilating, predicting, managing, analyzing, mining, and visualizing a broad array of meteorological data and model output, independent of format and physical location. A transforming element of LEAD is *dynamic workflow orchestration and data management*, which will allow use of analysis tools, forecast models, and data repositories as *dynamically adaptive, on-demand* systems that can a) change configuration rapidly and automatically in response to weather; b) continually be steered by new data; c) respond to decision-driven inputs from users; d) initiate other processes automatically; and e) steer remote observing technologies to optimize data collection for the problem at hand.

LEAD will create a series of interconnected, heterogeneous virtual IT "Grid environments" to provide a complete framework for mesoscale research. A set of Integrated Grid and Web Services Testbeds will maintain a rolling archive of several months of recent data, provide tools for operating on them, and serve as an infrastructure (i.e., a mini Grid) for developing distributed Web services capabilities. Education Testbeds will ensure that education and outreach are integrated throughout the entire LEAD program, and will help shape LEAD research into applications that are congruent with pedagogic requirements, national standards, and evaluation metrics.

Intellectual Merit: The LEAD core team consists of leading experts who have a long history of collaboration and proven track records in managing large interdisciplinary projects which yield breakthrough research and bring practical resources to the user community. Fundamental IT and CS advances include the development of scheduling and orchestration methodologies for multi-component applications that are driven by, and that drive, real-time sensors – with these same applications driving others in response to their own outputs or to the changing weather. Distributed monitoring and performance capabilities will enable real-time performance guarantees across the Grid, especially to deal with weather- or user-driven faults and interrupts. Other IT challenges addressed include data streaming and management, as well as semantic data representation and data mining, coupled via the My LEAD user portal. Fundamental meteorology advances include development of data assimilation, orchestration and fault tolerance capability for the national Weather Research and Forecast (WRF) system, enabling all users, especially at universities, to experiment with the WRF in sophisticated real time settings using local data. In addition, ensemble techniques applied at the storm scale, along with dynamic model updating and the application of data mining to assimilated data sets, will be studied to improve the forecasting of high-impact, local weather.

Broader Impacts: The LEAD environments will enable researchers, educators, and students to run atmospheric models and other tools in much more realistic, real time settings than is now possible, allowing students to analyze weather as it occurs and study related impacts. LEAD will be integrated into dozens of universities and operational research centers via Unidata, which includes 150 organizations, 21,000 university students, 1800 faculty, and hundreds of operational practitioners. Via the many linkages between LEAD investigators and Minority Serving Institutions, traditionally underrepresented groups will be included in all aspects of LEAD research and education. Education Testbeds will foster direct involvement of the education community, WRF workshops will engage minority students in using LEAD for discovery, and LEAD will directly fund 15 graduate students, 6 undergraduates, and 6 teachers. It will accelerate the transfer of WRF-based research results into operations, particularly via its links with the NOAA Forecast Systems Laboratory and National Center for Atmospheric Research. To facilitate a national dialog on geosciences cyberinfrastructure, and to engage broader elements of the IT and CS communities, LEAD will establish the *National Geosciences Technology Forum (GTF)*.

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C.1. The Vision: A Comprehensive IT Infrastructure for Mesoscale Meteorology

Each year across the United States, floods, tornadoes, hail, strong winds, lightning, and winter storms – *so-called mesoscale weather events* -- cause hundreds of deaths, routinely disrupt transportation and commerce, and result in annual economic losses greater than $13B [1]. Although mitigating the impacts of such events would yield enormous economic and societal benefits, the ability to do so is stifled by rigid information technology (IT) frameworks that cannot accommodate the *real time, on-demand, and dynamically-adaptive* needs of mesoscale weather research; its disparate, high volume data sets and streams; and the tremendous computational demands of its numerical models and data assimilation systems.

In response to this pressing need for a comprehensive national cyberinfrastructure in mesoscale meteorology, particularly one that can interoperate with those being developed in other relevant disciplines [e.g., ecology (NEON), solid Earth sciences (EarthScope and NEESgrid), and physics (GriPhyN)], **we will address the fundamental IT research challenges needed to create an integrated, scalable framework -- known as Linked Environments for Atmospheric Discovery (LEAD) -- for identifying, accessing, preparing, assimilating, predicting, managing, analyzing, mining, and visualizing a broad array of meteorological data and model output, independent of format and physical location.** A transforming element of LEAD is *dynamic workflow orchestration and data management*, which allows the use of analysis tools, forecast models, and data repositories not in fixed configurations or as static recipients of data, as is now the case, but rather as *dynamically adaptive, on-demand, Grid-enabled* systems that can a) change configuration rapidly and automatically in response to weather; b) continually be steered by new data; c) respond to decision-driven inputs from users; d) initiate other processes automatically; and e) steer remote observing technologies to optimize data collection for the problem at hand.

LEAD is designed for use principally by the meteorological higher education and operations research communities, and will be developed as a *phased set of prototypes* that embody an increasingly complete and sophisticated set of tools and capabilities. The starting point is the highly successful Internet data distribution (IDD) and thematic server (THREDDS) infrastructure of the University Corporation for Atmospheric Research (UCAR) Unidata Program. Atop this foundation we will conduct the basic research needed to support the unique requirements of mesoscale meteorology research and education.

The impacts of LEAD will be broad and sustained. As a virtual extension of the user's desktop, and via deployment through Unidata – which involves approximately 150 organizations encompassing 21,000 university students, 1800 faculty, and hundreds of operational practitioners – LEAD will enable researchers, users, educators, and students to use atmospheric models and other tools in more realistic, real time settings than is now possible. Through collaboration with the National Oceanic and Atmospheric Administration (NOAA) Forecast Systems Laboratory (FSL), the operations researchers will play an active role in developing LEAD components and will have full access to its resources. Prototype testing will occur at Education Testbeds, particularly with involvement of underrepresented groups, at NOAA collaborator facilities, and at the National Center for Atmospheric Research (NCAR). The *National Geosciences Technology Forum* (§C.10), to be established by LEAD, will serve as a mechanism for coordinating and sharing IT infrastructure development within the solid Earth, ocean, and atmospheric sciences. Finally, LEAD will directly fund 15 graduate students, 6 undergraduates and 6 teachers.

C.2. Qualifications of the Research Team and History of Collaboration

To meet the bold challenges of LEAD, we have assembled leading atmospheric and computer scientists with expertise in mesoscale modeling; remote sensing; Grid infrastructure, scheduling and monitoring; task orchestration; data access, management, distribution, analysis, mining, and visualization; and education and outreach. This team has a substantial portfolio of previous and ongoing collaboration on topics that underpin LEAD (§C.12), as well as extensive experience guiding large, physically distributed, multi-disciplinary projects that bring *practical, sustainable capabilities* to the user community. Additional collaborators include scientists from the NOAA FSL, NCAR, the National Climatic Data Center (NCDC), and IBM. An External Advisory Panel of renowned experts (§C.13.b), drawn from relevant topical areas and the NOAA operations research community, will provide overall direction.

C.3. Atmospheric Sciences Drivers

C.3.a. Directions in Mesoscale Research and Supporting Infrastructure

A significant component of today's knowledge base in mesoscale meteorology derives from numerical simulation, with computer models playing a central role in research, education and operational forecasting. Twenty-five years ago, only a few three-dimensional (3D) "hero simulations" of a severe thunderstorm in idealized settings, using a grid of order 10^5 points, could be performed at select high-performance computing sites. Each such simulation required laborious manual analysis. Today, sophisticated mesoscale forecast models, representing all relevant atmospheric processes and in some cases coupled with hydrologic and oceanographic models, are being operated *locally, in real time*[1], at dozens of universities, Federal research laboratories, and even private companies. This same technology, applied in a non-real time research framework, now can be used to generate hundreds of simulations for assessing complex atmospheric behavior in real or idealized settings. Such capability is particularly important for ensemble prediction, where multiple, concurrently valid forecasts are generated from slightly different initial conditions, from different models, or by using different options within the same model.

Unfortunately, these and other advances in mesoscale research have far outpaced the cyberinfrastructure needed to support them. The availability of increasingly sophisticated models, including the new Weather Research and Forecast system (hereafter WRF) being developed as a dual research-operational resource [2]; much broader access to affordable and extremely powerful computers; the proliferation of high-performance networks; and rapidly growing private sector interest in customized numerical weather prediction (NWP) all have catalyzed demand for flexible software frameworks for weather research, especially that conducted in real time. Cyberinfrastructure, while advancing, has notable limitations that, if left unaddressed, will widen the gap between mesoscale tools and their execution environments, stifling advances in research and education.

C.3.b. Real Time Weather Research Challenges

Most experimental *real time forecasts*, especially those created at universities, are initialized with pre-processed analyses from the National Weather Service (NWS) – with no real time observations added – owing to the complexity of managing data flows, dealing with multiple and changing data formats, and synchronizing complex data ingest, processing, and forecasting software. Consequently, the primary research benefit of local forecasts – namely, the use of much finer model grid spacings, and more sophisticated dynamical and physical frameworks, than those employed operationally by the NWS – is offset by an inability to assimilate observations, especially those *available locally* (e.g., from local highway, agricultural, and electric utility mesonetworks) and collected on *fine scales* (e.g., from Doppler radar).

This limitation has important scientific implications: the spacing between model grid points and observations used in model initialization should be reasonably similar; otherwise, the use of fine grids is unjustified, except in regions of significant orographic or coastal forcing, or for features represented within coarse models (e.g., fronts) that collapse nonlinearly on finer grids. Further, this inability to use both local and non-local *real time observations* may jeopardize the potential of the soon-to-be ubiquitous WRF because the research version contains none of the orchestration[2] components needed for real time data acquisition, assimilation and prediction. Because WRF will be used heavily within the research and education communities [2], where IT support to develop orchestration capabilities is scarce, the consequences are obvious and severe. LEAD also is giving special attention to on-demand, user-driven capability, and to scalability, so that models and other mesoscale research and education tools can be run *locally*, if resources allow, or be run *across the Grid* with automatic resource scheduling – all in a manner transparent to the user.

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[1] Real time is defined here as the transmission or receipt of information about an event nearly simultaneously with its occurrence, or the processing of data immediately upon receipt or request.
[2] Orchestration refers to the software needed to control and coordinate processes, data and workflows, and software components such as models, assimilation systems, and data mining engines.

The importance of *real time* functionality cannot be overstated. Although retrospective case study with models and analysis tools is an important methodology for research and education, real time execution is essential for studying many problems because of the need to use streaming data, complete with its frequent outages and quality control problems, and to evaluate model and algorithm output concurrently with other available information. Real time functionality also is vital so that students can analyze weather as it occurs and study the related impacts.

C.3.c. Non Real Time Weather Research Challenges

Non-real time "research mode" simulations needed to understand increasingly complex behaviors at the mesoscale, including ultra fine-scale experiments (domains of 10^7 or more points) that resolve both a tornado and its parent thunderstorm, produce enormous volumes of output, the analysis of which today proceeds as it did a quarter century ago – through the study of each run individually, even though parameter spaces may encompass hundreds of experiments. Tools are needed for end-to-end orchestration of workflows; to assimilate all available observations; to prepare initial and boundary conditions; and to mine massive amounts of resulting information to reveal complex physical relations, verify against observations, visualize four-dimensional behavior, and curate and catalog all results and their meta data for future use in digital libraries. Not surprisingly, the associated IT limitations are *not confined to computer modeling*, but extend to diagnostic case study analyses and the creation of climatological data bases, both of which require identifying, gathering, synthesizing, and managing vast quantities of information across a broad array of observing technologies and formats.

C.4. Computer Science (CS) and Information Technology (IT) Challenges

The nimble weather research relevant to LEAD involves highly nonlinear dependencies among filtering, analysis, pattern recognition, mining, and simulations that are *stream driven*, have complex feedback loops, and have dynamic structure. Indeed, the exact choice and sequencing, as well as the scale of the tasks, may change in response to the evolving weather or to user commands. Achieving these capabilities will require significant, fundamental computer science/information technology advances in *six key areas*, described below. Together, they must guarantee on-demand response, dynamic flexibility and autonomic behavior across the entire system.

Workflow orchestration and coordination must enable construction and scheduling of parameterized execution task graphs, with data sources drawn from real-time sensor streams and outputs – themselves forming streams for later use by either other computations or data mining and visualization tools. In turn, *data streaming* mechanisms must support robust, high bandwidth transmission of multi-sensor data to and from potentially large numbers of geographically distributed sites. A *distributed monitoring and performance evaluation* infrastructure is necessary to enable soft real-time performance guarantees for ensemble executions and data streams by providing estimates of resource behavior and performance for the workflow orchestration. Hints from the performance monitoring and prediction infrastructure must guide initial ensemble scheduling and trigger re-evaluation when execution does not satisfy expectations. *Data management* involves not only the storage and cataloging of observational data, but also of model output and results from data mining. The latter requires correlation of ensemble outputs, perhaps at multiple geographically dispersed sites. The dynamic processing environment of LEAD will impose additional requirements on *data mining* tools, including hazardous weather detection algorithms that identify and classify specific features being sensed in real-time. Because LEAD needs to adapt to changing conditions, the mining components must detect faults, allow incremental processing (interrupt / resume), and estimate run time and memory requirements based on properties of the data (e.g., number of samples, dimensionality). Finally, the resulting data must be *semantically rich*, enabling use by diverse tools and applications.

These daunting challenges can only be addressed via a long-term, integrated research program that leverages emerging industry and community standards while also exploring the basic research questions inherent in dynamic, adaptive Grid systems. On-demand meteorological exploration, coupled with large-scale data sources, provide a "driving problem" to focus research on key issues in workflow, scheduling, orchestration, and data management.

C.5. The Unifying Concept of Linked Environments

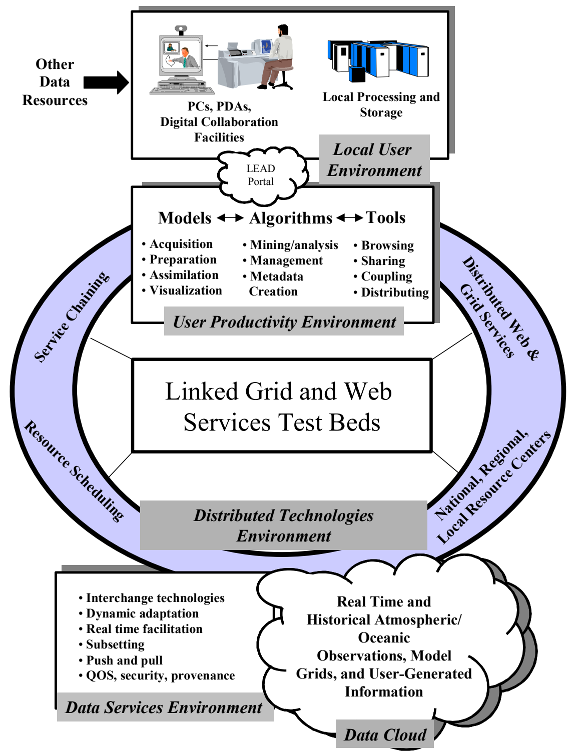

Figure 1. Functional concept of linked environments.

Our proposed research centers on creating a series of interconnected, heterogeneous virtual IT "Grid environments" that are linked at several levels to enable data transport, service chaining, interoperability, and distributed computation. These Grid environments, shown in Figure 1, will provide a complete, distributed framework within which users can identify, obtain, and work with observational and user-generated data where the problem being addressed, the relevant data, and the computational resources can change with time and be dependent upon or control one another. *From the user perspective*, these environments include a deployable system consisting of the LEAD *Toolkit* and "MyLEAD," both within the *Local User Environment*. MyLEAD represents a virtual information space for controlling information flows, posting results for access by others, and managing interconnected processes. The *User Productivity Environment* contains models, tools and algorithms for operating on data and other information available within the *LEAD Data Cloud* – a virtual space of existing servers that provides access to all types of geophysical data (§C.7.a). The *Data Services Environment* will handle the complexities of data transport, formatting and interoperability using interchange technologies. Users will be able to download and process data locally using *Productivity Environment* tools, or if the data are too large, operate on them remotely, using the *Distributed Technologies Environment* to schedule resources and distribute work across the Grid. In this environment, the proposed Grid workflow infrastructure will autonomously compute scheduling constraints, dynamically acquire resources, recover from component errors and adapt to changing plans. A set of *Linked Grid and Web Services Testbeds* (§C.7.a and §C.8) will maintain a rolling archive of several months of recent data (plus selected historical data); provide tools for operating on these data (e.g., mining engines, algorithms); and serve as a framework (i.e., a mini Grid) for developing distributed Web services capabilities (§C.3.e).

The LEAD software component architecture, shown in Figure 2, is our research and development framework for realizing the LEAD vision. LEAD will leverage and advance ongoing research in Grid infrastructure and middleware, augmented by advanced, distributed event monitoring and data stream management tools. Applications, models, and user tools will be based upon the Open Grid Service Architecture (OGSA) now being formulated in the Global Grid Forum [3]. As a component architecture extension of the Web Services standards now being adopted by industry, OGSA will allow us to leverage ongoing academic and industry software development and standards. Applications required for each environment will be layered upon this base, with the MyLEAD virtual environment providing the advanced information and services needed for dynamically orchestrating workflows of application services and data. Semantic descriptions of both data and software will facilitate interoperability, allowing these disparate components to be used together effectively and dynamically to solve user problems.

C.6. Empowering Mesoscale Research and Education: A Representative Scenario

Given the multiple ways LEAD can be utilized, the capabilities and benefits to be enabled are best illustrated by a use case scenario. Although this particular example touches all aspects of LEAD to demonstrate its full potential, *LEAD is not geared solely to the high-end user community, but rather will bring to all users practical, sustainable integrated Grid and Web Services.*

Suppose a graduate student wishes to understand why some severe thunderstorms produce a succession of mesocyclones[3] and multiple tornadoes, while others do not. The first step, involving capabilities to be made available during Phase I of LEAD (years 0-1.5; §C.13.a), requires establishing a climatology of observed storm behavior for comparison with numerical simulations. The Web-enabled LEAD portal, which is the access point to all of LEAD's capabilities, allows the student to search and locate, access, and decode all required data – including ten years[4] of NEXRAD Doppler radar data, along with upper air observations and NWS model forecasts, hourly surface observations, weekly land surface data, 6-minute precipitable water data from GPS satellites, and 15 minute satellite radiance data – all for the contiguous United States. Because the study concerns only intense thunderstorms, a mining engine within the LEAD toolkit is applied to the NEXRAD data to identify only those dates and times when severe thunderstorms were present. Using the LEAD portal, the student then accesses the appropriate subset of data, which are too voluminous to be stored locally and must be stored on a LEAD Testbed site. There, the disparate, asynchronous and distributed observations are combined via a data assimilation system to yield a set of dynamically consistent, gridded, three-dimensional fields of all principal meteorological variables at five minute intervals. Using feature detection and pattern recognition techniques, the student applies a data mining engine to the assimilated data sets to catalog all cyclic versus non-cyclic storms, the existence of tornadoes, and the surrounding environmental conditions associated with each. The resulting metadata, along with the assimilated data sets, are then automatically available on the student's MyLEAD virtual information space for use by the broader community, even though the data physically reside at the LEAD Testbed. [5]

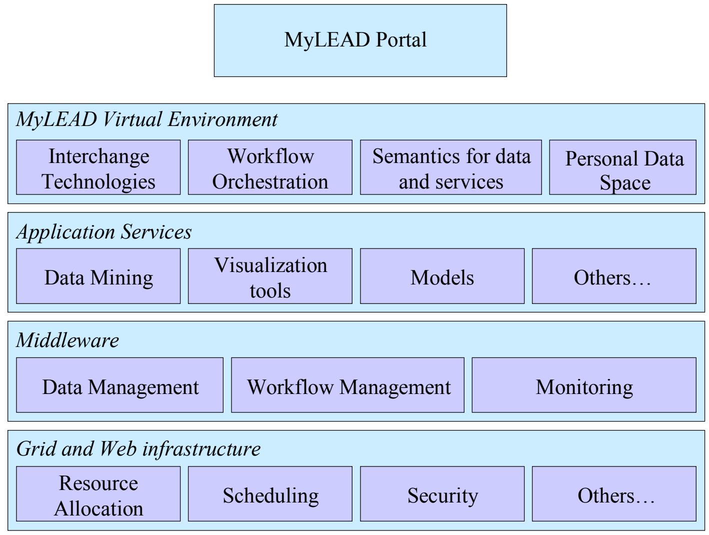

Figure 2. IT infrastructure of the linked environments.

Using capabilities to be made available during Phase II of LEAD (years 1.5-3.5; §C.13a), the student then develops a parameter space of 500 idealized numerical simulations designed to provide a physical-dynamical understanding of the storm cycling process. The simulations produce hundreds of terabytes of output, and mining techniques are used to correlate cyclic storm behavior with environmental characteristics and internal storm dynamics. The simulation output and its metadata again are accessible on the student's MyLEAD server and are automatically published to digital library catalogs [e.g., National Science Digital Library (NSDL) and Digital Library for Earth System Education (DLESE)]. To examine the predictability of cyclic storm behavior in an operational environment, the student, in collaboration with operational researchers at the NOAA/FSL, uses LEAD orchestration tools to configure a set of 50 real-time, high-resolution WRF ensemble forecasts. Because she wants to run the ensembles only when thunderstorms are actually forming, the student applies data mining tools to streaming real time feeds of NEXRAD data from all 142 radars in the U.S. to identify storm locations. With Phase III LEAD capabilities (years 3.5-5; §C.13a), mining tools trigger the WRF ensemble system over appropriate domains, which in turn automatically requests Grid computing resources with sufficient priority to provide results significantly faster than the weather unfolds. As storms form in new regions and intensify in others, additional ensemble forecasts are spawned and finer grids are emplaced to capture their evolution. This on-demand requirement for additional resources is handled automatically by the Grid.

[3] A vertically oriented vortex that precedes, and within which is embedded, all large tornadoes.
[4] The longest time for which all required data are available, and the shortest period for which meaningful statistics can be created.
[5] This sounds innocuous but is a major IT challenge.

In this example, data mining, atmospheric modeling, and computing systems were interoperating and responding to the weather, whereas the observing systems were providing data *independent of all other activities*. In contrast, arrays of dynamically adaptive, collaborating remote sensors – which reconfigure in real time to sense multiple phenomena – now are being developed to optimize the collection of atmospheric data. Examples include the phased array radar (PAR) being developed by the National Severe Storms Laboratory (NSSL) and the CHILL research radar at Colorado State University (CSU). LEAD will develop, in Phases II and III (§C.13a), the capability for algorithms and models to guide the collection of data by dynamically responsive remote sensors, beginning with CHILL. In the scenario above, once a data mining engine detected a severe thunderstorm, it could change the radar's mode of operation to scan only that storm at high time resolution, or with different polarization diversity, so as to optimally provide observations for hazardous weather detection and model initialization.

C.7. Proposed Research

The research components of LEAD consist of three distinct but highly synergistic elements: (1) basic IT and CS research driven by the unique needs of mesoscale meteorology to enable the linked environments system described above; (2) mesoscale meteorology research that utilizes these capabilities to address important scientific problems; and (3) the development, deployment, and refinement of tools and technologies by researchers, educators, and operational development technologists.

C.7.a. Enabling Technologies and the LEAD Data Cloud

The IT and meteorology research in LEAD is not *ab initio,* but rather builds upon several enabling technologies pioneered by the LEAD team. The first is the UCAR Unidata Local Data Manager (LDM) [4,5], a software package for event-driven data distribution within the Unidata Internet Data Distribution (IDD) network. The Collaborative Radar Acquisition Field Test (Project CRAFT) [6], which compresses and transmits, via the Internet, real time WSR-88D (NEXRAD) Level II radar data, uses LDM. The Unidata Thematic Real Time Environmental Data Distributed Services (THREDDS) [7,8] project is developing an extensible framework for distributed thematic data for a scientific data web, and Unidata's Integrated Data Viewer (IDV) provides analysis and visualization capabilities for data residing on THREDDS servers[6]. The Advanced Regional Prediction System (ARPS) [9-11] and the new Weather Research and Forecast (WRF) model [2] provide advanced tools for assimilation and modeling. With NASA funding, Unidata and NCSA are merging NetCDF and HDF so the former can be used in high performance computing environments, be more efficient, and work with parallel I/O interfaces and large arrays. These enhancements are being made with an eye toward implementation in WRF.

The Algorithm Development and Mining (ADaM) System at the University of Alabama in Huntsville (UAH) provides distributed data mining components that may be accessed across the Web or Grid for federated data analysis solutions. These components provide data mining capabilities, such as phenomena detection and feature extraction, for large scientific data sets [12-15]. OGSA work at Indiana [16,17] builds upon software component frameworks for Grid applications [18,19], and upon collaboration with IBM on its Business Process Execution Language for Web Services (BPEL4WS) workflow language [20]. The Earth Science Markup Language (ESML), developed at the UAH, encodes structural and semantic information required for data-to-application or model interchange [21-23]. The dQUOB project [24,25] at Indiana provides an advanced streaming technology for filtering data for applications requiring low latency. The LEAD monitoring architecture will be based in part upon the Illinois Autopilot Grid Toolkit [26], while the NOAA Operational Model Archive and Distribution System (NOMADS) [27] and Meteorological Assimilation Data Ingest System (MADIS) [28] represent options for accessing historical as well as real time gridded model output and observations (see letters of collaboration). Finally, the CHILL radar, operated by LEAD partner Colorado State University (CSU) and enabled as a remotely-controllable device (see CSU facilities description), will be used to develop and test observation system steering capabilities.

[6] For brevity, the phrase "THREDDS server" is used to describe a combination of OPeNDAP (Open-source Project for a Network Data Access Protocol) data services and THREDDS catalog services.

The enabling data technologies described above collectively create a "cloud" of distributed information resources we call the LEAD *Data Cloud*. Shown in Figure 3, it consists of the data, metadata, simulations, and other data-related services pertinent to mesoscale meteorology. Its foundation is a series of existing and future THREDDS servers, to which IDD provides a variety of real time data and metadata (over 35GB daily). IDD is an event-driven "push" system within which some 150 LDM sites relay data to one another using hierarchical distribution "trees" [29,30]. This non-centralized topology, coupled with multiple ingest sites, provides scalability and redundancy. LEAD will leverage the significant investments made to date in THREDDS servers located at the: NCDC; National Geophysical Data Center; Space Science and Engineering Center; Lamont Doherty Earth Observatory, Pacific Marine Environment Laboratory; National Center for Atmospheric Research, Climate Diagnostics Center; Fleet Numerical Meteorological and Oceanographic Center; George Mason University/Center for Oceans Land Atmosphere; UAH, and OU.

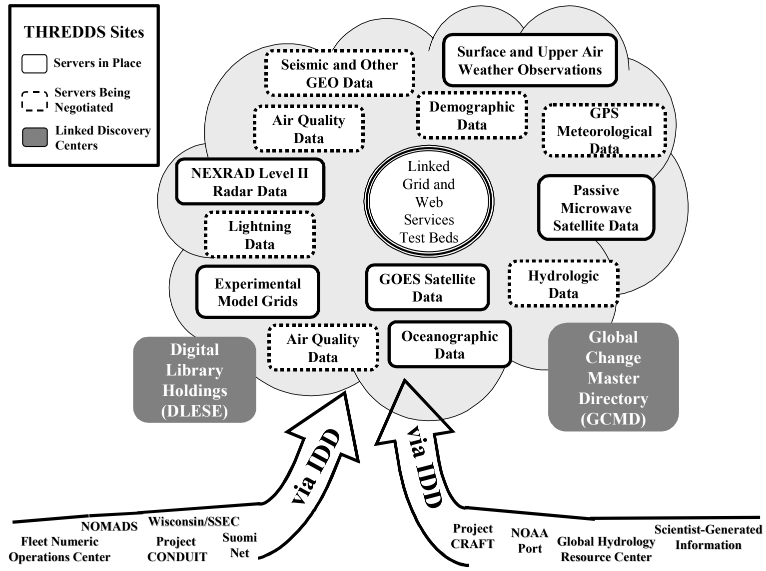

Figure 3. The LEAD Data Cloud.

The THREDDS infrastructure will be supplemented by four *Linked Grid and Web Services Testbeds* (see also §C.8), which will leverage their institution's particular expertise. For example, the data mining engine at one of the Testbed sites will monitor incoming data at another to detect specific weather events. Upon such detection, a high-resolution local model run can be initiated at another Testbed site, or across the Grid, with the output sent in real-time, via IDD, to another site for further mining and analysis. In this manner, the Testbeds serve both as development and production environments, and leverage the already significant investments made by the participating institutions in data ingest and analysis hardware.

C.7.b. Workflow Orchestration and Coordination

Orchestrating the dynamic, decentralized set of Grid activities associated with any of our LEAD scenarios is a first class IT challenge. Because the flow of work is driven by real-time user input, by output from simulations and data mining, and by the monitored load on resources, the problem is unlike that found in any other Grid applications. For existing Grid systems, several different workflow tools are available. For simple applications, workflow can often be programmed with simple scripting languages such as Python [31]. For others involving concurrent execution of many copies of the same program, Grid tools such as Condor's Dagman or Nimrod [32] are appropriate. Data and virtual data management in Grid systems is the specialty of the GriPhyN Chimera [33] workflow specification system. The most advanced workflow system for managing web services is the "Business Processing and Execution Language for Web Services" (BPEL4WS) that has been proposed by Microsoft and our IBM partners [20]. Unfortunately, these workflow specification systems are limited to relatively static workflow execution graphs.

In LEAD, we will work with our IBM colleagues to extend BPEL4WS to operate in the Grid Services Infrastructure where it can exploit the unique properties of Grid Services that are not available for "garden variety" web services. We will incorporate the useful features of Chimera and Dagman by allowing these tools to operate as a client process to our specification. However, we emphasize that our goal is not simply the definition of a new orchestration language. Rather, it is to build an experimental framework that will allow us to construct long-running, adaptive workflows capable of responding to radical changes in weather-driven data stream behaviors and available Grid resources. In general, we envision humans writing orchestration specifications in terms of the scientific tasks required when certain conditions arise. The "back end" of our workflow execution engine must map the individual tasks (which in OGSA terms are transient stateful service instances) to available Grid resources. However, when complex new scenarios emerge from sensors and data mining results, we must generate new workflow specifications dynamically at runtime. Our approach will be based upon use of semantic Web concepts, which are ideal for associating the data mining output with the workflow patterns most appropriate to the current conditions (see §C.7.f). Grid monitoring services (§C.7.c) will update available resources and their usage. The workflow execution must reorganize its own structure in response to dramatic changes in this Grid environment that are in turn driven by the real (i.e., atmospheric) environment.

C.7.c Distributed Monitoring and Performance Estimation

Monitoring is the watchdog of workflow and autonomic computing. Much has been accomplished in the monitoring and steering of scientific computations [34-36] that can be applied to LEAD. However, LEAD's distributed applications, and heterogeneous components and functionality, require monitoring advances well beyond the current state-of-the-art. Indeed, LEAD's dynamic characteristics make detection and understanding of application and middleware behavior both more critical and more difficult. Additionally, focus must extend beyond assessing performance, and monitoring progress, to include detection of vulnerabilities and opportunities, and recovery and self-healing given restarts and malfunctions.

After the orchestration and workflow tools create a task graph, the resulting graph must be mapped to a set of *physical resources* capable of meeting the associated soft real-time performance goals. Achieving the expected performance is dependent upon both the behavior of the application code and the resources on which it executes. *To identify resource classes capable of satisfying performance expectations, and to verify that the resources behave as expected during ensemble execution, we will develop an extended set of Grid monitoring and performance estimation tools suitable for use with real time weather data streams, Grid services and dynamic orchestrations.* Leveraging the Illinois Autopilot Grid toolkit [26], these tools will accept workflow specifications of task graph characteristics (e.g., input stream rates and nominal execution times on known hardware) and monitored resource availability, and produce estimates of graph execution time that can be verified during execution. To support these execution estimates, we will develop an extended set of monitoring tools that capture the performance of tasks and the multicast data streams (e.g., from IDD and THREDDS; see §C.7.a,d) used as inputs and outputs. This distributed measurement infrastructure will provide the raw data needed for intelligent tuning of application components and for resource selection.

Because the Grid is built from a wide variety of geographically distributed, network-connected components, it has the potential to be unreliable. When computations are launched and dispersed across the Grid, some may fail due to failed network links or because shared resources were reclaimed for other uses. *To increase the probability of success, we will develop a set of data stream bandwidth and resource reliability forecasting tools that monitor resource availability and predict the likelihood of successful execution or data stream connection and sustained bandwidth on a given resource set.* Finally, as a complement, we will develop a set of performability models that can be used to estimate the number of redundant copies of application components that must be launched to ensure timely completion of a given experiment. These models will exploit knowledge of the task structure of each application, as well as reliability and execution time estimates, to redundantly schedule selected tasks and ensure completion of the aggregate task graph.

C.7.d. Data Streaming

Due to the dynamic nature of LEAD, data routing will range from static, long-term routes to dynamic, temporary routes. New types of data will be asynchronously introduced, and large volumes of experimental output must be relayed to dynamically established data sinks. At any time, both real time and retrospective data must be available.

As some data volumes will be large, partitioning of data flows must be supported. *Above all, real time response latency (i.e., the latency between the occurrence of a possibly complex weather event and its subsequent detection at remote sources, must be minimized).*

Unidata recently improved the throughput of its LDM protocol by an order of magnitude when operated under high latency, high bandwidth conditions. Concurrently, it has been testing the Network News Transport Protocol (NNTP) for data relay. NNTP has the advantage of multiple relay modes, virtually unlimited number of hierarchically structured newsgroups, automated routing, network level automated control functionality, and backlog handling. As part of our proposed research, we will identify an essential set of relay functionality, and evaluate relevant protocols and technologies. We will explore existing research in peer-to-peer routing, which can route data efficiently within a dynamic node set, including location-independent routing, fault tolerance, and load balancing. Research in IP level improvements is also an area we will track and implement where needed.

LEAD's dynamic and real-time functionality will require more flexible content-based subscription approaches to data stream management and control. Dynamic subscription mechanisms allow users to modify their subscriptions at remote hosts without overburdening administrators or compromising or overloading remote sites. Also, methods for asynchronous pull-based retrieval will be needed. Batching methods also might be useful for relaying large volumes of archival data. Several fundamental research problems exist in these areas. For example, data streams are asynchronous and can exhibit event rates that vary widely with respect to one another and with respect to a particular model. Both data formats and logical notions of time may differ, forcing reconciliation before flow can be established. Further, synchronization between data streams and models must be resilient to application restarts, sensor restarts and other malfunctions. As data input sources are extended to include less reliable sources, such as battery-operated, limited range sensor networks, streams will contain data of questionable quality. *We will explore the issue of data quality by means of extended language support for temporal expressivity and by abstractions and algorithms for assigning a provenance, or "measure of goodness."* Finally, the varied data sources, including legacy sources, require solutions that operate over semi-structured data. Decision making over data streams must be sufficiently flexible to return results based on partial satisfaction of the decision-making criteria. This work will leverage the Indiana dQUOB toolkit [37], which imposes an abstract view on a data stream as a database table, over which database queries are continuously executed.

C.7.e. Data Management: Dissemination, Storage and MyLEAD

The three cornerstones of data movement and management are data dissemination, data storage, and user view maintenance. *Data dissemination* connotes the discovery, access, and dissemination of data to the broader community. Involvement of the Unidata team and the THREDDS system, which serve a large community and have strong links to other projects such as NSDL and DLESE, are significant strengths of LEAD. As noted above, THREDDS data dissemination research focuses on efficient relay through a large-scale network of servers, and the generation of metadata for transforming data streamed by IDD/LDM and storage in THREDDS catalogs and servers.

LEAD also must consider *data storage*, cataloguing, archival of processes, metadata, and ephemeral data. These products include experiment descriptions, data transformation processes, derived products from recent experimental runs, and intermediate files produced as part of a multi-phase process. The data may exist in various formats (i.e., text files, records in a database, binary files, and compressed data chunks). To this end, we are examining the Metadata Catalog Service (MCS) [38], NEESgrid [39], and Storage Resource Broker (SRB) [40] systems to support the cataloging of metadata associated with stored entities, and to provide container storage for the data themselves. These metadata systems support rich constructs and provide access to a catalog via a declarative query language for rapid retrieval of data based on complex conditions. Our work also will explore policies and mechanisms for persistence of ephemeral data and the processes and metadata descriptions required to understand and act on the data. This persistence and versioning will provide the community a rich resource allowing reproduction of experiments and experimentation using retrospective data.

Personalization (*user view maintenance*) of LEAD's computing and data-intensive research environment is a key need of LEAD data management. The *MyLEAD data space* is envisioned as an environment, accessible from the LEAD portal, that provides fast access to a user's private data and to data of interest to any user. Privacy of data is preserved (i.e., it is kept private until the user explicitly publishes it to the broader LEAD research community or beyond). Where the scientific portal provides customized access to the computing capability of LEAD, MyLEAD provides *personalized access* for developing index support for fast and transparent access to personal data from heterogeneous sources including inverted indexes for hierarchically organized content. It also provides a multi-key index [41] for augmented spatial data, that is, geospatial data augmented with time-based data such as storm developments. We will develop abstractions for data publication [42] from the private domain to the public domain, leveraging the publication efforts in GEON [43] as appropriate. Data publication will require collaboration with the THREDDS team to develop policies enabling an individual to publish data to the THREDDS server. Data publication and privacy issues involving the metacatalog system is also a key research issue. Policies and mechanisms that preserve the privacy of data that might include encryption of selected data and access mechanisms that subsequently operate over the encrypted data.

C.7.f. Data Mining

Data mining provides the tools that enable users to glean insights from data and model output. The LEAD research team developed ADaM [22], which will be used to build the mining and analysis infrastructure for LEAD. Our LEAD data mining capabilities will be implemented as sets of federated mining components capable of operating on multiple platforms as independent services. This approach serves to provide the integration of data mining functionality into the multiple LEAD analysis environments as Grid and Web resources, extensions to GIS, and visualization tools. Methods will be developed to dynamically link federated services for analysis tasks. In addition, the mining components will interface with Grid middleware technologies [44,45] so that mining tasks can be efficiently scheduled and distributed among the available processing resources. The extensive computing resources of the Grid also make possible the production of higher quality results by exploring more potential solutions. This is particularly true for feature selection and classifier training problems, where optimization techniques such as simulated annealing and genetic algorithms have been used to boost resulting classification accuracy [46]. In addition, ensemble classifiers have been shown to outperform the individual classifiers that compose them [47]. Optimization can also be used to facilitate the formulation of a classification process. LEAD will employ genetic algorithms and simulated annealing-based optimization methods for feature selection and parameter tuning and will facilitate creation of ensemble classifiers. We will enable ADaM mining components for Grid execution, and will explore the use of Grid technology to efficiently stage and schedule data mining jobs.

LEAD's dynamic processing environment will require adaptable data mining tools, such as hazardous weather detection algorithms. The mining components will provide feedback to scientists on the quality of the results being produced. We will develop data integrity components to check for missing or invalid data values, incorrect formats, and other potential problems. We will include in the LEAD mining environment neural networks that use cross validation [48] and fault detection [49] to ensure integrity of the mining process.

The foundation of LEAD *visualization* will be the Unidata IDV, which already operates on THREDDS servers. *We will expand the capabilities of IDV to function in the dynamic orchestration environment of LEAD, and in multi-user collaborative settings, working closely with NCAR (see accompanying letter), which is developing portals, visualization, and analysis tools for the WRF, and tying IDV to data mining and other tools within the LEAD environments.*

Other challenges presented by LEAD concern non-stationary phenomena and streaming data. Certain weather events are non-stationary phenomena, which have signatures that change over time or space, making it necessary to adapt the classifiers trained to recognize the phenomena to changing conditions. We will use incremental learning methods to construct an initial model for the phenomenon of interest, and then refine that model as new information or training samples become available. Both supervised [50,51] and unsupervised classification [52], can be used to address the issues that arise due to non-stationary phenomena and streaming data.

C.7.g. Semantic Data Representation

LEAD will allow scientists to orchestrate workflows involving both heterogeneous information from different data sources, and chains of disparate services, in a seamless, dynamic, automated fashion. To allow such capabilities, LEAD will incorporate ontologies, interchange technologies, and other concepts being explored in the Semantic Web [53] and Semantic Grid [54]. Ontologies provide a formal, explicit, specification of shared conceptualizations [55] and thus can be used to share ideas and information. Integration technologies facilitate the use of heterogeneous information, including data with different formats, interfaces, structures, spatio-temporal coverage, etc., not as a disparate collection of files and databases, but rather as a virtual single resource. Taken together, these semantics technologies can be a basis for workflow orchestration and data mapping.

By utilizing ESML [56] as an interchange technology, many different data formats can coexist, and applications within LEAD can achieve the required interoperability. This will be the basis of our common data model. ESML is a markup language based on XML [57] for describing the structure of sets of similar data files or streams. LEAD proposes to augment the existing capabilities of ESML by providing machine-understandable semantics for the automated linking of information and services. Coupled with various domain ontologies implemented as DAML [58], this semantics will describe what the data actually mean, and how they can be used by different services in LEAD.

These domain ontologies will provide for semantic mediation between data streams and repositories; for services input/output requirements; for constraining the parameters of services and inferring allowable configurations; and for checking the semantic validity of a workflow. By using these ontologies, knowledge-based functions will facilitate service discovery, service execution and workflow orchestration for LEAD. Considerable research has been conducted by the intelligent systems community [59,60] in linking Semantic Web resources, and interest continues to grow in semantic Grid services [45,61]. However, the differences between Grid and Web services offer challenges and research opportunities for LEAD. For instance, Grid services have a soft state of registration, long lived service configuration and typically involve a large number of processes interacting in a coordinated fashion [62]. *The proposed research in semantic services will be tightly integrated with the low level service workflow (BPEL4WS) to allow LEAD users more direct and automated access to the Grid's resources. Our research also will lead to better coordination between processes, both in terms of workflow orchestration and the sharing of data and information.* To build the domain ontologies, the research team will leverage the Earth Science ontology developed by JPL [63]. The domain ontology research for LEAD will initially focus on data mining services, and expand to include other data processing and analysis capabilities required by LEAD. Software agents utilizing inference engines will interface the ontologies with the LEAD portal to intelligently assist LEAD users in workflow orchestration and data mapping.

C.7.h. Mesoscale Meteorology Research and Technology Development

Our mesoscale meteorology research and technology development will focus on five key areas. First, we will investigate development of fault tolerance and the ability to respond to automated and user-prescribed interrupts in data flow and in the system execution stream of the WRF model. At present, the WRF only can save history and restart files at prescribed intervals. Fault tolerance and interrupt-driven capabilities are essential for operating WRF in the dynamic environment envisioned by LEAD. Second, we will study the detection of hazardous weather features by applying data mining tools to assimilated data sets. Today, most automated algorithms are applied to raw data collected by individual sensors (e.g., Doppler radar). When a new sensor is deployed, the algorithms need to be modified, or new ones developed, at considerable time and cost. We will apply advanced data assimilation and retrieval techniques, developed at Oklahoma, to generate for specific cases a set of complete, 3D, dynamically consistent gridded meteorological fields to which data mining tools can be applied. The signatures detected will be compared against those from operational algorithms used by the NEXRAD Doppler radar (all of which were developed and continue to be tested in Oklahoma) applied only to raw sensor data. An advantage of using assimilated data sets is that they contain all fundamental atmospheric variables, including (via retrieval) those that cannot be observed directly and thus which are not available to algorithms operating on sensor data alone.

Third, we will refine the interface between the CAPS data assimilation system (ADAS) [64-67] and WRF. ADAS is a complete environment for the real time ingest, quality control, and assimilation of virtually any type of meteorological observation. It is used operationally by the National Weather Service and NASA, and provides the capability for *any institution to run the WRF using real time local data*. An ADAS-to-WRF interface is now being developed and will be enhanced to allow community-wide deployment within the LEAD orchestration framework. Fourth, we will study the response of cloud-resolving models to continuous updating with observations. Today's operational NWP models operate in a batch environment and are initialized at fixed intervals, e.g. every 12 hours. Once the forecast is started, no additional observations are used. At the mesoscale and especially for individual thunderstorms, where evolution is extremely rapid, continuous updating of a model with streaming observations during the early part of a forecast may be essential for producing quality forecasts. This capability, however, poses notable challenges, particularly regarding the model's acceptance or rejection of new data in comparison with its own internal dynamics and time scales of adjustment. We will examine this topic using both idealized (simulated) and real observations, the latter in the context of case studies for which actual storm evolution is known. Ultimately we will incorporate this capability into the real time experimental forecast system at Oklahoma and work with NCAR and the FSL to do the same for WRF.

Finally, we will investigate storm-scale ensemble forecasting. The mesoscale meteorology community is unanimous in its belief that ensemble forecasting is the correct approach for predicting intense local weather such as severe thunderstorms. Yet, ensemble techniques developed for large-scale flows are likely not adequate for application to individual storms owing to inherent differences in dynamics and the growth of errors. We will study this problem using cloud model simulations to understand the basics of error structure and growth rates in convective storms. We then will conduct real data simulations that build off the idealized cases using various resolutions, ensemble methods, and verification strategies. The latter already is underway at Oklahoma but only for a single case with relatively coarse spatial resolution.

C.8. From Basic Research to Deployed Technologies: The LEAD Roadmap

Transforming basic research into useful, deployable, and maintainable technologies is a daunting task, but one that has been achieved consistently by LEAD organizations. The LEAD approach centers around four *Grid and Web Services Testbeds* (Oklahoma, Illinois, UCAR, and Alabama in Huntsville) as the LEAD-specific development environment for CS and meteorological experimentation. Unidata and the University of Illinois will have the primary responsibility for fusing research results into system components suitable for use by the environmental science communities that Unidata serves. As tools reach sufficient maturity, they will be rigorously tested in the crucible of Unidata's providers and academic users. Final products, improved by experimentation in the Testbed setting, will be subjected to Unidata's stringent release-engineering process that readies them for use in the large, diverse, demanding Unidata community. LEAD capabilities also will be tested within the operations research environment of the NOAA FSL (see accompanying letter). Education testbeds (§C.9) will play an integral role as well, and finally, WRF-related technologies to be developed by LEAD are envisioned to become part of the planned NOAA-NCAR Modeling Developmental Testbed Center (DTC; see accompanying letter). To be located at NCAR, the DTC is envisioned as a semi-virtual distributed environment for all WRF users.

C.9. Education and Outreach

Partnered as a collaborative Education Testbed, Millersville University (MU) will coordinate and manage a three-phase plan designed to assess the effectiveness of LEAD technologies for education, to provide critical input and feedback to IT developers, and to facilitate knowledge transfer to a community of users (educators, researchers and students). The *first phase* will establish education objectives to help shape the evolution and environment of LEAD, and fuse the goals and enabling technologies into applications that are scalable and especially congruent with educational requirements, specifications, and standards. During this phase, LEAD Education Testbeds (OU, Illinois, UAH, Millersville, and Howard) will engage successful national science and technology education initiatives (e.g., DLESE, NSDL, UCAR Windows to the Universe, DataStreme, and AMS Project ATMOSPHERE) to build on best practices that will help steer the development of an education-friendly LEAD *User Productivity Environment*. MU already has strong ties to several of these initiatives. A collaborative network of teacher-partners from pre-college schools (likely to be "thin" clients), each located near one of the LEAD partner institutions for person-to-person interaction, will be invited and trained to assist in the evaluation of LEAD prototypes. Education testbeds will initiate the development of tele-collaborative projects using LEAD technology with distinct goals tied to undergraduate and pre-college curricular improvements, including the NSF-funded Visual Geophysical Exploration Environment (VGEE) [68,69] developed at Illinois, which couples visualization (using Unidata's IDV) with data probes for inquiry-based exploration of the relationships between concepts and data.

The second phase commences with the flow of proto-tools and proto-technologies, including user documentation, for evaluation and refinement. Undergraduate and graduate students will join project participants to refine prototypes using assessment metrics that emphasize applicability, functionality, accessibility, scalability, and extensibility in the LEAD Educational Testbeds. In parallel, the MU Testbed will engage teacher-partners in evaluating prototypes for use in pre-college education, including a directed effort to align LEAD science and enabling technologies with National Science Education and National Educational Technology Standards, giving special attention to the need for the changing emphases on teaching, professional development, science content, and assessment. Outcomes from this collaborative assessment will provide critical feedback to the LEAD developers, resulting in progressive refinements to the tools and technologies as IT research proceeds toward deployable applications.

The third and culminating component focuses on deploying and integrating LEAD applications into higher education and pre-college learning environments to incite curricular changes as bold as the LEAD concept itself. Partner institutions have identified several curricular areas where LEAD capabilities will be integrated to drive innovation in meteorology and computer science courses (e.g., real time, dynamic experimentation in numerical weather prediction, computational fluid dynamics, algorithm design, networking, data management), and to other disciplines because of its inherent extensibility (e.g., oceanography, ecology). MU will assume a lead role for the integration of tools and services into undergraduate and pre-college curricula, while Howard University will coordinate graduate level WRF workshops (years 4 and 5) incorporating LEAD capabilities. The dissemination of LEAD to the education community will occur via national and regional workshops and short courses at professional venues. This will be supplemented by the distribution of tele-collaborative tutorials and learning materials designed initially by the LEAD participants, and later, leveraging Unidata's success in building communities, by contributions from the community of users. MU is experienced in developing and implementing workshops for in-service teachers, and will follow this path for bringing LEAD capabilities to the greater pre-college communities. Illinois, Indiana and Alabama in Huntsville will play key roles in brining LEAD developments into the CS/IT education environments.

C.10. Broader Impacts and Increasing the Involvement of Traditionally Underrepresented Groups

LEAD will establish an entirely new set of capabilities – and indeed promote discovery, as the acronym indicates – in atmospheric research and education by enabling students, scientists, and operational practitioners to utilize enormous volumes of streaming or historical data to drive models, analysis tools, data mining engines, and visualization systems. LEAD will remove the significant obstacles that now exist in working with diverse, multi-format data and will allow students and scientists to quickly locate, access, and begin using both observations and model results. Further, it will allow these same users to post their own results to virtual data spaces – including national digital libraries – for access by others. LEAD will be integrated into dozens of universities via Unidata, and the LEAD Education Testbeds will provide a framework for bringing the benefits of LEAD to secondary and high school teachers as well as higher education. WRF workshops for undergraduates and graduates will directly engage young scientists in the use of LEAD for discovery, and the potential benefits to society are extraordinary because LEAD will enable virtually any institution to run the WRF model in much more realistic settings than is now possible. Because WRF is being designed expressly as a dual research and operational model, LEAD will greatly accelerate the move of research results into an operational setting.

Careful attention has been given in LEAD to meaningful strategies for improving the involvement of traditionally underrepresented groups. Indeed, of the 20 PIs in LEAD, 4 are women, 16 are men, and 2 of the men are African American. The two WRF workshops, to be coordinated by Howard University (an HBCU and major participant in

WRF), will involve 10-15 students, half from Howard and the other half drawn from minority serving institutions (MSIs). Graduate and undergraduate student recruiting will leverage existing linkages at LEAD institutions, including Clark-Atlanta (3+2 program with OU), REUs (which themselves emphasize the issue), SOARS (operated by NCAR), and Howard's programs with Jackson State. The doctoral students at Howard most likely will be from underrepresented groups. The Education Testbeds coordinated by Millersville will recruit heavily from MSIs, including Hispanic and Tribal Colleges, and select pre-college teacher partners from a diverse demographic to participate in the development of the LEAD Portal and assessment of LEAD technologies. LEAD will collaborate with the Colorado Alliance for Minorities Program to enhance the participation of underrepresented groups, both at graduate and undergraduate level. LEAD Co-PI V. Chandra, a recipient of the " Distinguished Minority Services Award", has a long history of contribution toward this effort. Finally, the Unidata community of approximately 150 educational institutions, which represents the core user base for LEAD, includes 14 MSIs (3 of which are HBCUs) and several accredited minority postsecondary institutions, all of which will be targeted for early involvement in LEAD curriculum development.

Working with the NSF Geosciences Directorate, NASA, NOAA, professional societies and other appropriate agencies, LEAD will establish the *National Geosciences Technology Forum (GTF)*. Similar in concept and with strong ties to the OGF and similar groups, the GTF will serve as a focal point for national dialog on cyberinfrastructure in the geosciences with particular emphasis on the linking of IT systems and the sharing of knowledge and resources. The LEAD External Advisory Panel, with a few additional representatives, will guide the establishment of the GTF, which is expected to be funded separately from LEAD.

C.11. Differentiation from and Synergy with Other Projects

LEAD differs from other cyberinfrastrucuture efforts in its emphasis on *dynamically adaptive, on demand, real time, fault tolerant Grid computing*. LEAD personnel have close contact with a number of such other efforts from which we expect synergistic relationships to develop and/or continue. The Earth System Modeling Framework is developing tools to enhance ease of use, performance, portability, interoperability, and reuse in climate, numerical weather prediction, and data assimilation applications. It emphasizes code development and maintenance tools and not data transport, mining/analysis, or distributed computing. DOE's Earth System Grid (ESG) Project is focusing on access to *climate model output*. NOMADS and MADIS, discussed earlier, are very distinct from but also synergistic with LEAD, and as shown in the accompanying letters, LEAD will collaborate directly with them. The GriPhyN Project has many objectives similar to those of LEAD, though is focused on the physics community and does not address the real time challenges of LEAD. Considerable synergy exists between LEAD and the two-year MEAD (Modeling Environment for Atmospheric Discovery) effort funded by the NCSA Alliance. MEAD (its name derived from LEAD) is an early limited prototype focused on providing a research environment for idealized ensemble simulations using a coupled atmosphere/ocean system (WRF/ROMS). However, unlike LEAD, it is not focused on creating a real-time, dynamically adaptive, on-demand environment, nor does it have a real-time observational data component. Further, LEAD addresses IT research such as monitoring and performance, data streaming, orchestration, use of OGSA, service discovery ontology, and distributed data mining; MEAD does not.

C.12. Results from Prior NSF Support

V. Chandrasekar (ATM-9500108) "The CSU-CHILL Radar Facility." The Colorado State University operates, maintains and advances the CSU-CHILL Doppler weather radar through a Cooperative Agreement with the NSF. Recent upgrades include a new antenna system and a second transmitter and receiver. Virtual-CHILL, funded by DARPA, is an infrastructure that allows CHILL to be controlled remotely over the Internet.

Ben Domenico, Don Murray, Anne Wilson (ATM-0130792) "Unidata 2003" Implemented significant improvements to and expanded LDM, incorporated new data streams into IDD, and developed a new set of platform-independent data analysis and display tools (MetApps) that access data from a wide variety of distributed data sources. This work established the foundation for the NSDL THREDDS project.

Kelvin K. Droegemeier (ATM-9220009) “Science and Technology Center for the Analysis and Prediction of Storms” developed the Advanced Regional Prediction System (ARPS), which was the world’s first mesoscale model designed for highly parallel computers. It also developed techniques for assimilating Doppler radar and other fine-scale data into storm-resolving models, demonstrated the practical predictability of thunderstorms and related mesoscale phenomena, and studied numerous aspects of convective storm dynamics.

Dennis Gannon (EIA-9975020) “GrADS: Grid Advanced Development Systems” and related projects have focused on parallel computation, object oriented methods for distributed scientific applications, and problem solving environments for scientific computation. Work in Grid applications resulted in an award for heterogeneous distributed computation as part of the I-Way project at SC98 which was the first real Grid applications test bed.

Sara Graves (EPS-0091853) “Research Infrastructure Improvement Program Information Science and Technology: Internet2 Middleware Initiative” is focused on migrating research and education applications to high-performance networks and provides a middleware environment enabling a seamless interface to networking services, shared data files, videoconferencing, and remote access to computing, storage, and instrumentation resources using grid technology.

Everett Joseph (ATM-9909190) "Upgrading a Training and Research Lab for CSTEA and HUPAS". This support enabled the acquisition of a UNIX workstation to serve as the local host for the UNIDATA LDM. The workstation was added to a laboratory being developed as facility for student research and instructional applications in several areas of atmospheric sciences.

Beth Plale (EIA-9973834) "Applying Database Techniques to Management of Large Data Flows in Scientific Applications" explored the abstraction of data streams as database in the context of scientific, wide area parallel and distributed applications. The major outcome was successful performance of the prototype and discovery that certain well-established query optimization heuristics yield less than optimal queries in a data stream environment.

Mohan Ramamurthy (ATM-9730985) "Mesoscale Ensemble Forecasting and Predictability Studies.” Investigated the use of ensemble forecasting for mesoscale phenomena and developed a comprehensive multi-model, multi-analysis ensemble prediction system which includes (MM5, WRF, RSM and Eta) and analyses from multiple data assimilation systems (NCEP/Eta, NCEP/AVN, ECMWF, NOGAPS and GEMS).

Daniel Reed (EIA-9975020) “GrADS: Grid Advanced Development Systems," together with the NSF TeraGrid project, has focused on creation of a flexible infrastructure for adaptive Grid application execution. Real-time performance monitoring and software performance contracts allow Grid scheduling and management systems to adapt to changing execution contexts while attempting to maintain specified performance levels. Such flexible application runtime environments will be critical to full exploitation of the NSF TeraGrid's distributed computing, communication, and storage infrastructure.

Robert Wilhelmson and Mohan Ramamurthy (DUE-9972491). “Visualization Geophysical Exploration Environment (VGEE)” VGEE offers a framework for technology-mediated, inquiry-based approach to help students connect theoretical and abstract understanding to real world meteorological phenomena using state-of-the-art simulations, visualizations, interactive java tools, and tutorials.

Ming Xue (ATM-9909077) “A New Joint Weather Research and Prediction (WRF) Model” includes developing 3-D variational techniques for small-scale (unbalanced) flows with emphasis on the use of Doppler radar data, evaluating case studies for model verification, exploring optimal assimilation/forecast strategies, calibration and initialization of soil models, and developing and testing the dynamic and computational frameworks of WRF.

Sepideh Yalda and Richard Clark (ATM-9909711) “Workstations to Support Interactive Learning and Research in Atmospheric Science Using Unidata Applications” enabled the acquisition of workstations to complete the hardware configuration of the Synoptic/Dynamics Lab to facilitate full utilization of Unidata applications in several upper level meteorology and computer applications (Fortran, IDL) courses.

C.13. Project Milestones and Management

C.13.a. Milestones

The research in LEAD will be conducted in *three phases*, each striking a careful balance between basic inquiry and the development of practical tools and capabilities (see Table 1). The work will proceed via research and design, followed by prototyping, testing, re-design, and deployment.

Table 1. Yearly LEAD Milestones.

LEAD Research Component	Phase I (Years 0-1.5)	Phase II (Years 1.5-3.5)	Phase III (Years 3.5-5)
Workflow Orchestration and Coordination	Initial OGSA and orchestration of WRF with data mining; integrate BPEL4WS with other services for dynamic, long running workflows	Distributed monitoring and sensor input to drive workflow; compile semantic mediation and DAML specs into low-level adaptive workflow.	Workflow automatically derived from sensor input and predefined ontologies and patterns.
Data Streaming	Relay functionality analysis; protocol/technology survey and selection; initial classification definition; LDM and IDD on Testbed; NNTP evaluation.	Protocol and dynamic subscription with integrated workflow; NNTP, content-based subscription; SQL; application-level multicast routing.	Additional relay methods (e.g., batching); push dynamic subscription capability to broader community; refinement and deployment.
Distributed Monitoring and Performance Estimation	THREDDS/IDD instrumentation and measurement; workflow analysis	Grid services workflow instrumentation; reliability design and validation; workflow measurement and assessment.	End-to-end assessment and feedback to workflow orchestration; integrated performability support.
Data Management	THREDDS and metadata catalog on Testbed; initial policies for data publication, curation, MyLEAD data space index support.	Publication of private data to public in metacatalog; distributed metacatalog support in Testbed.	Publication of private data to THREDDS, broad access to curated data; seamless interaction among MyLEAD data space; THREDDS, and metacatalog.
Data Mining	Data mining for Grid and model data; integrate with Grid middleware; fault detection services for data input problems	Fault detection for problems with classifier training; Implement incremental learning algorithms.	Tools using streaming data; evaluate and improve incremental learning algorithms, Grid scheduling.
Semantic Data Representation	Ontology for mining; processing; interface w/ workflow orchestration; semantic descriptions; agents for mining ontology	Semantic validity checking of chained services; Extended agent software using services ontology; defined ontology for input/output requirements	Couple ontology efforts with workflow orchestration; improve ontology representations and agent system including automation for workflow orchestration.
Mesoscale Meteorology Research and Technology Development	Dynamic model updating with idealized forcings; detection algorithms for sensor data; data assimilation front-end for WRF	WRF fault tolerance; weather detection in assimilated data; dynamic updating w/real data; control of V-CHILL; ensembles	Dynamic orchestration within model execution streams; real time Grid forecasts on demand, including local forecasts using V-CHILL.
Education and Outreach	Objectives; pre-college teacher-partner sites; develop tele-collaborative projects & learning materials	Deploy proto-technologies; incorporate metrics; deploy applications; integrate tools.	Integrate into higher ed and pre-college environments; short courses and workshops; evaluation of metrics.
Deployable Tools and Capabilities	ADAS front-end to WRF users; establish test beds; prototype LEAD Portal and mining and orchestration tools on Test Beds	Dynamically adaptive experiments on Test Beds; WRF and orchestration at partner sites including NCAR/NOAA Developmental Test Bed Center	Tools deployed via Unidata and components operational at the NCAR/NOAA Developmental Test Bed Center

C.13.b. Project Leadership and Management

The governance of a project as large and physically distributed as LEAD requires an effective balance between the bureaucratic structure needed to manage a complex effort and the flexibility that is essential in an academic setting for accommodating new ideas or technological developments. The PI of the lead institution (K. Droegemeier), will serve as *Project Director* (Figure 2). He has extensive experience formulating and leading multi-institutional, multi-disciplinary collaborative projects, including one of the first NSF Science and Technology Centers, which, though graduated, remains in operation. As director he will have overall responsibility for ensuring the success of LEAD and will serve as its principal point of contact with the NSF. Droegemeier will be assisted by a full-time Project Coordinator, at OU, who will facilitate the day-to-day activities of the entire LEAD collaboration. This individual will be a scientist who also has strong skills in organization management, and every effort will be made to draw this hire from traditionally underrepresented groups.

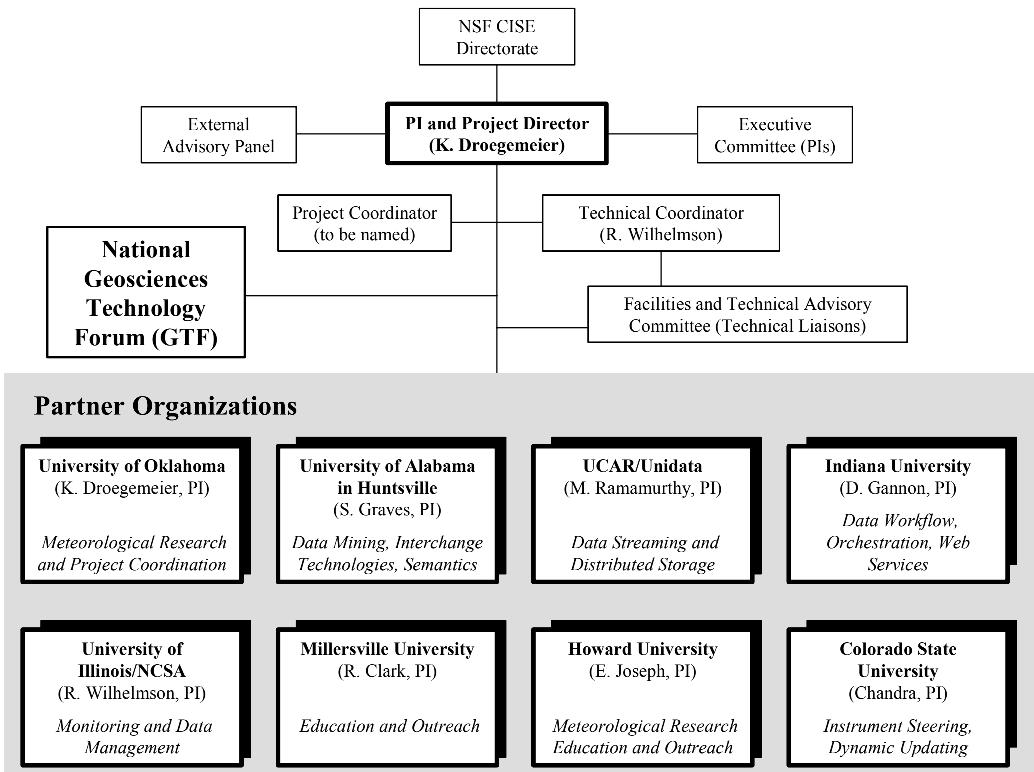

Figure 2. LEAD management structure and institutional areas of responsibility. The National Geosciences Technology Forum (GTF) is described in the Project Description.

Each of the principal scientific thrust areas in LEAD will be overseen by one of the institutional PIs (Figure 2). In this capacity they will have responsibility for helping set research directions, ensure timely progress, and identify problems and new opportunities. A *Technical Liaison*, drawn from among each institution's scientific participants, will assist with these duties. Collectively, the Liaisons will compose the *Facilities and Technical Advisory Committee*, which will be chaired by R. Wilhelmson (NCSA) as the project *Technical Coordinator*. In this role he will oversee technical development, testbed configuration and management, and software testing.

The PIs in LEAD will serve on an *Executive Committee* (EC) to advise the Director on all facets of the project (Figure 2). Chaired by the Director, it will meet monthly, via the Access Grid and desktop video conferencing, and will hold two face-to-face meetings per year. Every effort will be made to leverage PI attendance at national meetings so that most of the LEAD travel funding can be used for research interactions. Individual project researchers will collaborate regularly via the Access Grid and desktop video conferencing, and sufficient travel support has been requested to accommodate several face-to-face collaborations per year as well as attendance at conferences. The Technical Coordinator will facilitate monthly virtual meetings of the Technical Liaisons, and once each year, an "all hands" meeting will be held at one of the participating sites. Finally, an *External Advisory Panel (EAP)* will meet yearly, at one of the LEAD institutions, to advise the Director and EC on all aspects of the project (travel for these meetings has been requested in the form of participant support costs). We are pleased that outstanding leaders in computer science, information technology, and the geosciences have agreed to serve on the EAP, as shown in Table 2. This commitment reflects their view of the importance of LEAD and its potential for success.

Table 2. Members of the LEAD External Advisory Panel (EAP).

External Advisory Panel Member	Position and Affiliation	Roles or Areas of Expertise Relevant to LEAD
Guy Almes	Chief Engineer of Internet2 and Vice President, Advanced Network and Services, Inc.	Networking, data protocols, quality of service, meteorological data transport.
Peter Cornillon	Professor of Oceanography, University of Rhode Island	Principal Scientist for the National Virtual Ocean Data System (NVODS), with expertise in data management, protocols, and visualization
Ian Foster	Senior Scientist Argonne National Laboratory	Key developer of the national Grid concept and a visionary for Globus.
David Fulker	University Corporation for Atmospheric Research	Executive Director of the National Science Digital Library (NSDL) and former director of Unidata, with expertise in data management, real time data transport, visualization.
Tony Hey	Director e-Science Program of the UK Research Councils Professor of Computing University of Southampton	Co-developer of the Message Passing Interface (MPI) with expertise in parallel, Grid and quantum computing.
John Horel	Professor of Meteorology University of Utah Director NOAA Cooperative Institute for Regional Prediction	Expertise in real time analysis and numerical weather prediction, especially at regional and local scales.
Roberta Johnson	Director of Education and Outreach National Center for Atmospheric Research	Developer of "Windows to the Universe" Web site with expertise in education and outreach at all levels including the general public.
Williams E. (Bill) Johnston	Manager NASA Information Power Grid NASA Ames Research Center	Senior scientist in Lawrence Berkeley National Laboratory's Information and Computing Sciences Division, with expertise in Grid and high performance computing and communications.
Joseph Klemp	Senior Scientist National Center for Atmospheric Research Project Coordinator, WRF Model	Expertise in atmospheric numerical modeling, convective dynamics, and computational fluid dynamics.
A.E. "Sandy" MacDonald	Director NOAA Forecast Systems Laboratory	Expertise in atmospheric modeling and data assimilation, observing systems, operations research and development, and high-level project management and administration.

During the past two decades, Unidata has been the focal point for delivering meteorological and related information to the academic community. To effectively integrate LEAD into this community and to obtain feedback from it, the LEAD senior leadership will continue its long-standing close interaction with the national Unidata governance structure. At the present time, LEAD PIs play key roles in two Unidata governance bodies: User Committee (R. Clark, Chair) and THREDDS Technical Task Force (B. Domenico, Chair). In addition, close ties will be maintained between LEAD and NSDL (headquartered at UCAR and led by former Unidata Director D. Fulker, who is serving on the LEAD EAP), and DLESE (Program Center headquartered at UCAR, with LEAD Co-PI R. Wilhelmson serving on its Steering Committee).

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OU Associates Foundation Presidential Professor, University of Oklahoma, 1998-2002
Founder and Director, Environmental Computing Applications System,1996-2002
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Associate Professor, School of Meteorology, University of Oklahoma, 1991-1998
Director of Model Development Program, Center for Analysis and Prediction of Storms, University of Oklahoma, 1989-1994
Visiting Senior Fellow, Army High Performance Computing Research Center, University of Minnesota (Sabbatical) 1 January - 30 June 1992
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5 Publications Relevant to this Proposal

Droegemeier, K.K., 1997: The numerical prediction of thunderstorms: Challenges, potential benefits, and results from realtime operational tests. *WMO Bulletin*, **46**, 324-336.

Xue, M., D.-H. Wang, J.-D. Gao, K. Brewster, and K. K. Droegemeier, 2002: The Advanced Regional Prediction System (ARPS), storm-scale numerical weather prediction and data assimilation. In press for *Meteor. and Atmos. Physics*.

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5 Other Significant Publications

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Hou, D., E. Kalnay, and K.K. Droegemeier, 2001: Objective verification of the SAMEX '98 ensemble forecasts. *Mon. Wea. Rev*., **129**, 73-91.

Synergistic Activities

- Co-founder and Director, NSF Science and Technology Center for Analysis and Prediction of Storms (graduated in 2000)
- Founder and director of the Collaborative Radar Acquisition Field Test (Project CRAFT)
- Member of the NSF Blue Ribbon Panel on Cyber Infrastructure and NSF Geosciences Directorate Advisory Committee

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Graduate Advisor

Dr. Robert Wilhelmson, University of Illinois at Urbana-Champaign

Graduate Students and Post-Docs Supervised

Graduate Students (21 degrees completed, 7 students in progress): Students Completed: Richard Carpenter (M.S., Ph.D.), Kimberly Carver (M.S.), Steven Lazarus (M.S., Ph.D), Kriste Lyon Paine (M.S.), William McPherson (M.S.), Renee McPherson (M.S.), James T. Johnson (M.S.), Michael Babcock (M.S.), Yong Li (Ph.D.), Hao Jin (M.S.), David Jahn (M.S.), Seon-Ki Park (Ph.D.), Stephen Weygandt (Ph.D), Edwin Adlerman (M.S), Jason Levit (M.S.),Yvette Richardson (Ph.D.), DeWayne Mitchell (M.S.), Xuechao Yu (M.S.), Matthew Miller (M.S.) Current Students: Edwin Adlerman (Ph.D), Hee-Dong Yoo (Ph.D.), Ernani Nascimento (Ph.D.), Gary Foulks (M.S.), Nicki Hickmon (M.S.), Janelle Janish (M.S.), Xuechao Yu (Ph.D.). Post-Docs (9 total to date): Gary Dietachmayer, Shian-Jiann Lin, Miodrag Rancic, Alan Shapiro, Ming Xue, Vince Wong, Gene Bassett, David Zhi Wang, Donghai Wang.

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    TS Infosystems, under contract to NOAA/Forecast Systems Lab,
    MAPS (RUC) model development group
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5 Publications Relevant to this Proposal

Brewster, K., 2002: Recent advances in the diabatic initialization of a non-hydrostatic numerical model. *Preprints, 21st Conf. on Severe Local Storms*, and *Preprints, 15th Conf. Num. Wea. Pred. and 19th Conf. Wea. Anal. Forecasting*, San Antonio, TX, Amer. Meteor. Soc., J51-54.

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Xue, M., D.-H. Wang, J.-D. Gao, K. Brewster, and K. K. Droegemeier, 2001: The Advanced Regional Prediction System (ARPS), storm-scale numerical weather prediction and data assimilation. *Meteor. Atmos. Physics*, **76**, submitted.

5 Other Significant Publications

Gao, J., M. Xue, K. Brewster, F. Carr, and K.K. Droegemeier, 2002: New developments in a 3DVAR system for a non-hydrostatic NWP model. *Preprints, 14th Conf. on Num. Wea. Pred.*, San Antonio, Texas, Amer. Meteor. Soc. 339-341.

Shapiro, A., L. Zhao, S. Weygandt, K. Brewster, S. Lazarus, and K. K. Droegemeier, 1996: Initial forecast fields from single-Doppler wind retrieval, thermodynamic retrieval and ADAS. *Preprints, 11th Conference on Numerical Weather Prediction*. Amer. Meteor. Soc., Norfolk, VA, 119-121.

Souto, M. J., C. F. Balseiro,V. Pérez-Muñuzuri, M. Xue, and K. Brewster, 2002: Impact of cloud analysis on numerical weather prediction in the Galician region of Spain, *J. App. Meteor.*, In Press.

Benjamin, S.G., K.A. Brewster, R. Brummer, B.F. Jewett, T.S. Schlatter, T.L. Smith and P.A. Stamus, 1991: An isentropic three-hourly data assimilation system using ACARS aircraft observations. *Mon. Wea. Rev*., **119**, 888-906.

Synergistic Activities

Developer of ADAS analysis software used as part of ARPS modeling system or as a stand-alone analysis package.

WRF Model Working Groups on Standard Initialization Procedures and Data Handling and Archiving.

President, Central Oklahoma Chapters of the America Meteorological Society and National Weather Association, 2000-2001.

Planning Committee, National Severe Weather Workshops-2001, 2002, 2003, Norman, OK, 2000-2002.

Reviews for Weather and Forecasting, Journal of Hydrometeorology, J of Oceanic and Atmospheric Technology, and Monthly Weather Review.

Collaborators & Other Affiliations

-Collaborators

Dr. Frederick Carr, University of Oklahoma School of Meteorology
Dr. Jidong Gao, Center for Analysis and Prediction of Storms
Dr. Alan Shapiro, University of Oklahoma School of Meteorology
Dr. Ming Xue, University of Oklahoma School of Meteorology

-Graduate and Postdoctoral Advisors

Dr. Frederick Carr, University of Oklahoma School of Meteorology (Ph.D. Advisor)
Dr. Dusan Zrnić, NOAA/National Severe Storms Laboratory (M.S. Advisor)

Daniel B. Weber
Senior Research Scientist
Center for Analysis and Prediction of Storms
Sarkeys Energy Center, Room 1110, 100 East Boyd Street.
Norman, OK 73072-0470
Phone: (405) 325-1932 Fax: (405) 325-7614 E-mail: dweber@ou.edu

Education

Institution and Location	Subject	Degree	Year
University of Utah, Salt Lake City	Geology	B.S.	1983
University of Utah, Salt Lake City	Meteorology	B.S.	1984
University of Utah, Salt Lake City	Meteorology	M.S.	1987
University of Oklahoma, Norman	Meteorology	Ph.D.	1997

Professional Experience

2001-Present Senior Research Scientist, Center for Analysis and Prediction of Storms (CAPS), University of Oklahoma
1997-2001 Research Scientist, Center for Analysis and Prediction of Storms (CAPS), University of Oklahoma
1992-Present ARPS Model Development Team, CAPS, University of Oklahoma
1991-1997 Graduate Assistant, School of Meteorology, University of Oklahoma
1989-1991 Consulting Meteorologist/Geologist, Harding Lawson Associates, Oak Brook, IL
1989-1992 Meteorologist/Environmental Analyst, Kennecott Copper Corporation, Salt Lake City, Utah
1986-1987 Meteorologist Intern, National Weather Service, Salt Lake City, Utah
1984-1986 Teaching Assistant, Department of Meteorology, University of Utah

Publications Relevant to this Proposal

Brotzge, J.A., and D. Weber, 2002: Land-surface scheme validation using the Oklahoma Atmospheric Surface-layer Instrumentation system (OASIS) and Oklahoma Mesonet data: Preliminary results. Meteor. Atmos. Phy., 80, 189-206.

Xue, M., K. K. Droegemeier, V. Wong, A. Shapiro, K. Brewster, F. Carr, D. Weber, Y. Liu, and D.-H. Wang, 2001: The Advanced Regional Prediction System (ARPS) - A multiscale nonhydrostatic atmospheric simulation and prediction tool. Part II: Model physics and applications. *Meteor. Atmos. Phys.*, 75, 161-193.

Other Publications

Weber, D.B., D.K. Lilly, and M. Xue, 2002: The effects of surface heat flux on the mountain wave environment. In preparation for submittal to *J. Atmos. Sci.*.

Doyle, J.D.. et. al., 2000: An intercomparison of model predicted wave breaking for the 11 January Boulder Windstorm. *Mon. Wea. Rev.*, Vol. 128, No. 3, 901-914.

Weber, D.B. 1998: An investigation of the diurnal variability of the Central Colorado Downslope Windstorm. 8th AMS conference on Mountain Wave Meteorology. Flagstaff, AZ. (http://www.caps.ou.edu/~dweber)

Durran, D.R., and D.B., Weber, 1988: An investigation of the sharp poleward edge of cirrus clouds associated with midlatitude jet streams. *Mon. Wea. Rev.*, Vol. 116, No. 3.

Synergistic Activities

- Board of Directors, OU Supercomputing Center for Educational Research, University of Oklahoma
- Research Experiences for Undergraduates, Clark-Atlanta University, technology transfer (ARPS)

Collaborators & Other Affiliations

Bob Wilhelmson, Jay Alameda, Bruce Loftis, Shawn Hampton, Henry Neeman, Suresh Marru, Charles Doswell III, Douglas Lilly, David Jahn, Eric Kemp, Gene Bassett, Lucy Zheng, David Montroy, Kevin Thomas, Keith Brewster, Ming Xue, Caren Marzban, Jerry Brotzge, Steve Tracton, Jun Du, Rob Pennington, Sirpa Saarinen, David O'Neal, Seon-Yong Lee, Hee-Dong Yoo, Frank Gallagher, Scott Richardson, Ken Howard, Lucian Banitz, Jason Levit

Graduate and Post Doctoral Advisors

Dr. Dale Durran, M.S. Advisor, Department of Atmospheric Sciences, University of Washington, Seattle, WA
Dr. Douglas Lilly Ph.D. Advisor, School of Meteorology, University of Oklahoma, Norman, OK

Graduate Students Supervised

Current Students: Suresh Marru, Geoffrey Stano

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PROFESSIONAL PREPARATION

Nanjing University, P. R. of China	Atmospheric Sciences	B.Sc.,1984
Nanjing University, P. R. of China	Atmospheric Sciences	Master's program 1984-85
University of Reading, U.K.	Meteorology	Ph.D.,1989

APPOINTMENTS

Mar. 2001 – Present	Scientific Director, CAPS, U. of Okla.
Oct. 1999 – Present.	Assistant Professor, School of Meteorology, U. of Okla.
Jan. 1999 – Oct. 1999	Research Assistant Professor, School of Meteorology, U. of Okla.
Jan.1997 – Dec. 1998	Adjunct Assistant Professor, School of Meteorology, U. of Okla.
July 1994 – Oct. 1999	Director, ARPS Model Development Project, CAPS
Aug. 1993 – Oct. 1999	Senior Research Scientist, CAPS, University of Oklahoma
Aug. 1992 – July 1993	Research Scientist, CAPS, University of Oklahoma
July 1991 – June 1994	Co-director, ARPS Model Development Project, CAPS
Oct. 1989 – Aug. 1992	Post-doctoral Fellow, CAPS, U. of Okla.

5 Publications Relevant to this Proposal

Xue, M., K. K. Droegemeier, and V. Wong, 2000: The Advanced Regional Prediction System (ARPS) - A multiscale nonhydrostatic atmospheric simulation and prediction tool. Part I: Model dynamics and verification. Meteor. Atmos. Physics. **75**, 161-193.

Gao, J., M. Xue, A. Shapiro, and K.K. Droegemeier, 1999: A variational method for the retrieval of three-dimensional wind fields from dual-Doppler radars. *Mon. Wea. Rev.*, **127**, 2128-2142.

Gao, J., M. Xue, A. Shapiro, Q. Xu, and K. K. Droegemeier, 2001: Three-dimensional simple adjoint velocity retrievals from single Doppler radar, *J. Atmos. Oceanic Tech.,* **18**, 26-38.

Droegemeier, K. K., M. Xue, K. Johnson, M. O'Keefe, A. Sawdey, G. Sabot, S. Wholey, N. T. Lin, and K. Mills, 1995: Weather prediction: A scalable storm-scale model. *High Performance Computing*, G. Sabot, Ed., Addison-Wesley, 45-92.

5 Other Significant Publications

Xue, M. and A. J. Thorpe, 1991: A mesoscale numerical model using the nonhydrostatic sigma-coordinate equations: Model experiments with dry mountain flows, **119**, *Mon. Wea Rev.,* 1168-1185.

Xue, M., 2000: High-order monotonic numerical diffusion and smoothing, *Mon. Wea. Rev.* **128**, 2853-2864.

Xue, M., 2000: Density currents in two-layer shear flows. *Quart. J. Roy. Met. Soc.*, **126**, 1301-1320.

Xue, M., K. K. Droegemeier, V. Wong, A. Shapiro, K. Brewster, F. Carr, D. Weber, Y. Liu, and D.-H. Wang, 2001: The Advanced Regional Prediction System (ARPS) - A multiscale nonhydrostatic atmospheric simulation and prediction tool. Part II: Model physics and applications. *Meteor. Atmos. Physics*, **76**, 143-165.

Xue, M., D.-H. Wang, J.-D. Gao, K. Brewster, and K. K. Droegemeier, 2002: The Advanced Regional Prediction System (ARPS), storm-scale numerical weather prediction and data assimilation. *Meteor. Atmos. Physics*, In press.

Synergistic Activities

Member, Weather Research and Forecast (WRF) Model Development Science Board, 1999 –

Member, WRF Model Dynamics, Model Physics, Software Architecture, 4DVAR working groups. Active participant of WRF 3DVAR working group. Participant of WRF model design activities since the early stage.

Elected member, WMO/WGNE COMPARE (International Comparison of Mesoscale Prediction and Research Experiment) Scientific Steering Committee. 1997 – 1999.

Invited speaker, Seminar on Mesoscale NWP and its Applications, Japan Meteorological Agency and Japan Ocean Foundation, 1999.

Principal developer of the Advanced Regional Prediction System.

Graduate Advisor

Dr. Alan J. Thorpe, University of Reading, England, U.K.

Collaborators

Kelvin Droegemeier, Frederick Carr, Alan Shapiro, Jidong Gao, William Martin, Brewster, Dan Weber, Donghai Wang (NASA Langley), Dingchen Hou (George Mason Univ.), Vince Wong (NCEP), Richard Carpenter, Gene Bassett (WDT Inc.), Eugenia Kalnay (U. Maryland), Jim Doyle (NRL, Monterey), Qin Xu (NSSL), Carl Hane (NSSL), Joe Klemp (NCAR), Bill Skamarock (NCAR), Jim Dudhia (NCAR), Jim Purser (NCEP), Geoff DiMego (NCEP), Stan Benjamin (FSL), John Brown (FSL), Thomas Schlatter (FSL), Steve Weygandt (FSL), Shouting Gao (IAP, China), Zhemin Tan, Rongsheng Wu (Nanjing Univ., China).

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CSU CHILL Radar Facility
Colorado State University
1373 Campus Delivery, Ft. Collins, CO 80523-1373
E-mail: chandra@engr.colostate.edu

Professional Preparation

Colorado State University	Ph.D., 1986
Colorado State University	M.S., 1983
Indian Institute of Technology (India)	B. Tech., 1981

Academic Appointments

1998 – Current Professor, Colorado State University
1993-1998: Associate Professor, Colorado State University
1990-1993: Assistant Professor, Colorado State University
1989-1990: Assistant Professor, University of Alabama in Huntsville
1986-1989: Research Assistant Professor, Colorado State University

PUBLICATIONS:

Text Books

i) Co-author "***Polarimetric Doppler Weather Radar***", Cambridge University Press, ISBN 0 -521-62384-7, 2000.
i) Co-author of undergraduate textbook, "***Probability and Random Processes****" McGraw-Hill,* ISBN 0-07-001563-5, 1997.

Articles Author/co-author of over 80 Journal articles and 130 Conference papers.

Publications Relevant to this Proposal

1. S. Bangolae, A.P. Jayasumana and V. Chandrasekar, "TCP-friendly Congestion Control Mechanism for a UDP-based High-Speed Radar Application and Characterization of its Fariness," Proc. 8th IEEE International Conference on Communication Systems (ICCS), Singapore, Nov. 2002, pp.163-167
2. H. Liu and V. Chandrasekar, 2000: "Classification of Hydrometeors based on Polarimetric Radar Measurements: Development of A Fuzzy Logic System and In-situ Verification". *J. Atmos. Ocean. Tech.,* Vol. 17, pp. 140-164.
3. V. Chandrasekar, D. Brunkow and A. Jayasumana, 2001: CSU-CHILL Operation Over the Internet, THE Virtual CSU-CHILL, Preprints, 30th International Radar Conference, AMS, Boston, pp 58-60.
4. V. Chandrasekar and A. Jayasumana, 2001: Radar Design and Management in a Networked Radar Environment, 2001, Protocols and Services for Next-Generation Internet, Proceedings of SPIE, Vol.4527, pp142-147.
5. A. Mudukatore, V. Chandrasekar and R.J. Keeler, 1998: "Pulse Compression for Weather Radars", *IEEE Trans GRSS*, Vol. 36, No. 1, pp. 125-142.
6. E. Gorgucci, G. Scarchilli and V. Chandrasekar, 1992: "Calibration of Radars Using Polarimetric Techniques", *IEEE Transaction of Geoscience and Remote Sensing,* Vol. 30, No. 5, pp. 853-858.

Five Other Publications

1. V. Chandrasekar and V.N. Bringi, 1987: "Simulation of Radar Reflectivity and Surface Measurements of Rainfall", *J. Atmos. Ocean. Tech.,* Vol. 4, No. 3, pp. 464-478.
2. V. Chandrasekar and R.J. Keeler, 1993: "Antenna Pattern Analysis and Measurements for a Multiparameter Radar", *J. Tech.,* Vol. 10, No. 5, pp. 673-683.
3. V. Chandrasekar. G.R. Gray, V.N. Bringi, and R.J. Keeler, 1988: "Efficient Differential Reflectivity Processing from Logarithmic Receivers", *J. Atmos, Ocean. Tech.,* Vol. 6, No. 4, pp. 663-670.
4. V. Chandrasekar, W.A. Cooper and V.N. Bringi, "Axis Ratios and Oscillations of Raindrops", *JAS*, Vol. 45, No. 8, pp. 1323-1333.
5. V. Chandrasekar, G.R. Gray and J. Caylor, 1993: "Auxiliary Signal Processing System for a Multiparameter Radar" *J. Atmos. Ocean. Tech.,* Vol. 1, No. 2, pp. 586-592.

Synergistic Activities

Dr. Chandrasekar (Chandra) has made pioneering contributions in the area of "Polarimetric Radar Observations of the Atmosphere". Dr. Chandra has extensive experience in Radar System Design, Radar Network Development, DSP Design as well as RF Communication Systems. He has contributed significantly to the area of Networking radar systems as well as radar and applications to Atmospheric Sciences. He also conducts research on related topics including Image Processing, Neural Network Applications and Large Scale System Simulation. He has organized and participated in six large multi-agency, national level experiments involving many radars, aircraft and ground instrumentation. He was a Co-PI on the Advanced Communication Technology Satellite (ACTS) program at CSU and the Co-PI on the CSU-CHILL radar facility. He has served on design review panels of major development projects such as the NCAR ELDORA Airborne Doppler Radar Systems. He is a Science Team Member of the NASA TRMM mission. He is a member of the National Academy of Sciences panel on "Future Radar Systems beyond NEXRAD". He has won numerous awards including, *the NASA Technical Innovation Award, 2002, Cermak Outstanding Advisor Award, 2001, Abell Outstanding Researcher Award, 2001, Distinguished Minority Service Award, 1999, Deans Council Award for Excellence in Teaching and Research, 1996, Halliburton Foundation Young Faculty Research Excellence Award, 1993.*

Dr. Chandra has served as the REU Director for over 10 years, promoting undergraduate research participation. He has actively participated in educational outreach efforts by offering distance education courses as well as building online educational programs associated with the CSU-CHILL radar. He was a founding member of the "Undergraduate research initiative" at CSU. Dr. Chandra has served as the associate editor of J. Atmospheric and Oceanic Technology as well as *JAM*. He is a member of the IEEE ADCOM, AMS Commission on radar meteorology and has served on AGU committee on precipitation and NSF panels. Dr. Chandra serves as the departmental advisor for the honors program. He has advised 19 Masters and 14 Ph.D. students. He is a long standing member of the Technical Program Committees of AMS Conference on Radar Meteorology as well as the IEEE Conference on Geoscience and Remote Sensing.

List of Recent Collaborators

1) Dr. W. Krajewski, University of Iowa, 2) Dr. J. Smith, Princeton University, 3) Dr. V.N. Bringi, Colorado State University, 4) Dr. Steven Rutledge, Colorado State University, 5) Dr. K. Knupp, University of Alabama in Huntsville, 6) Dr. R. Doviak, National Severe Storms Laboratory

Dr. Sara J. Graves
Director, Information Technology & Systems Center
University Professor, Computer Science Department
Director, Information Technology Research Center
National Space Science and Technology Center
The University of Alabama in Huntsville, Technology Hall S339A, Huntsville, AL 35899
E-mail: sgraves@itsc.uah.edu

Professional Preparation

University of Alabama, Tuscaloosa	Mathematics	B.S., 1967
University of Alabama, Tuscaloosa	Institutional Analysis	M.A., 1971
University of Alabama in Huntsville	Computer Science	M.S., 1981
University of Alabama in Huntsville	Computer Science	Ph.D., 1984

Academic and Professional Appointment

The University of Alabama in Huntsville, Director of Information Technology & Systems Center, University Professor of Computer Science, Vice President for University Advancement, Executive Director of UAH Foundation, Huntsville, AL.

National Space Science and Technology Center, Director of Information Technology Research Center, Huntsville, AL.

California Institute of Technology, Jet Propulsion Laboratory, Visiting Senior Scientist with Office of Space Science and Applications, NASA Headquarters, Code SE, Washington, D.C.

Nichols Research Corporation, Senior Scientist and Consultant, Huntsville, AL.

The University of Alabama, Research Associate, Sr. Systems Analyst, Instructor in Computer Science, Tuscaloosa, AL.

BELLCOMM, Inc., Systems Analyst/Programmer, Washington, D.C.

5 Publications Relevant to this Proposal

Rushing, J., H. Ranganath, T. Hinke, and S. Graves, August, 2001: Using Association Rules as Texture Features, IEEE Transactions on Pattern Analysis and Machine Intelligence, Vol. 23, No. 8, pp. 845-858.

Ramachandran, R., H. Conover, S. J. Graves, K. Keiser, S. Movva, and S. Tanner, August 26-29, 2001: Flexible Earth Science Data Mining System Architecture, Fourth Workshop on Mining Scientific Datasets, Seventh ACM SigKDD International Conference on Knowledge Discovery and Data Mining, San Francisco, CA.

Tanner, S., S. J. Graves, R. Ramachandran, M. Alshayeb, E. Criswell, A. McDowell, M. McEniry, and K. Regner, November 1-3, 2002: On-Board Mining in the Sensor Web, NSF Data Mining Workshop, Baltimore, MD.

Hinke, T. H., J.Rushing, H. Ranganath and S. J. Graves, 2001: Techniques and Experience in Mining Remotely Sensed Satellite Data, Artificial Intelligence Review (AIRE, S4): Issues on the Application of Data Mining, pp. 503-531.

Yubin, H., R. Ramachandran, U. S. Nair, K. Keiser, H. Conover, S. Graves, Earth Science Data Mining and Knowledge Discovery Framework, SIAM International Conference on Data Mining, April 11-13, 2002, Arlington, VA.

5 Other Significant Publications

Conover, H., M. Alshayeb, B. Beaumont, S. Graves, K. Keiser, X. Li, S. Movva, A. McDowell, R. Ramachandran, M. Smith and S. Tanner, May 29 - June 2, 2001: Promoting Science Data through Innovative Information Systems, 2001 Spring Meeting of American Geophysical Union, Boston, MA.

Ramachandran, R., J. A. Rushing, U. S. Nair, S. J. Graves, S. Tanner, and R. M. Welch, 2001: Comparing Texture Feature Characterization Methods for Cumulus Cloud Classification in GOES Images, Third Workshop on Mining Scientific Datasets held in conjunction with the First SIAM Conference on Data Mining on April 7, 2001 in Chicago.

Ramachandran, R., H. Conover, S. Graves and K. Keiser, January 2000: Algorithm Development and Mining (ADaM) System for Earth Science Applications, Second Conference on Artificial Intelligence, 80th American Meteorological Society (AMS) Annual Meeting, Long Beach.

Ramachandran, R., M. Alshayeb, B. Beaumont, H. Conover, S. Graves, N. Hanish, X. Li, S. Movva, A. McDowell, and M. Smith, January 2001: Earth Science Markup Language, 17th Conference on Interactive Information and Processing Systems for Meteorology, Oceanography, and Hydrology, 81st American Meteorological Society (AMS) Annual Meeting, Albuquerque, NM, January.

Rushing, J., H. Ranganath, T. H. Hinke, and S. J. Graves, December 2001: Image Segmentation Using Association Rule Features, IEEE Signal Processing Society.

Synergistic Activities

- Earth Systems Science Applications Advisory Committee (ESSAAC) and Chair, ESSAAC Subcommittee on Information Systems and Services, NASA Headquarters, 1999-2003.
- "Data Fusion in a Data Mining Framework," Invited Talk, S. J. Graves, Combating Uncertainty with Fusion Workshop, Woods Hole, MA, April 22-24, 2002.
- "Creating a Data Mining Environment for Geoscience Data"- Invited Talk and "Geoinformatics" - Invited Session Chair, S. J. Graves. Interface 2002 - Theme of 34th Symposium is Geoscience and Remote Sensing, Montreal, Canada, April 17-20, 2002.
- "Creating an Environment for Scientific Data Mining," S. J. Graves. Keynote address for the Society for Industrial and Applied Mathematics (SIAM) - Third Workshop on Mining Scientific Datasets, Chicago, April 7, 2001.
- Coordinator and Host, NASA Workshop on Issues in the Application of Data Mining to Scientific Data, October 19 - 21, 1999.

Recent Non-UAH Collaborators:

J. Alameda (NCSA), R. Atlas (NASA/GSFC), R. Clark (Millersville), L. DeLucas (UAB), B. Domenico (UCAR), K. Droegemeier (OU), D. Emmitt (Simpson Weather Assoc.), R. Fikes (Stanford), I. Foster (U. Chicago), P. Fox (NCAR), D. Gannon (IU), M. Ghil (UCLA), S. Goodman (NASA/MSFC), D. Haidvogel (Rutgers), R. Harriss (NCAR), T. Hinke (NASA/ARC), E. Joseph (Howard), C. Kamath (LLNL), W. Liatsky (AAMU), T. Killeen (NCAR), D. McGuiness (Stanford), D. Middleton (NCAR), S. Pulasani (AAMU), M. Ramamurthy (UCAR), D. Reed (NCSA), B. Rock (UNH), R. Stevens (Argonne), A. Tan (Alabama A&M), M.
Welge (NCSA), B. Wilhelmson (UIUC)

Advisors

Dr. F. Lee Cook, Dr. James D. Johannes, Dr. James W. Hooper and Dr. Sajjan A. Shiva

Recent Graduate Students Supervised

Mohammad Alshayeb, Edward Bosworth, Evans Criswell, J. Ronald O.Guin, Rahul Ramachandran, John Rushing, Joel Sherrill, Bradley Vinz

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Professional Preparation

Jamia Millia Islamia University, New Delhi	Mechanical Engineering	B.E.,	1991
South Dakota School of Mines and Technology	Meteorology	M.S.,	1994
University of Alabama in Huntsville	Atmospheric Science	M.S.,	1996
University of Alabama in Huntsville	Computer Science	M.S.,	1997
University of Alabama in Huntsville	Atmospheric Science	Ph.D.,	2002

Academic and Professional Appointments

Research Scientist and Director- Data Mining Laboratory, The University of Alabama in Huntsville, 2001-Present
Senior Research Associate, The University of Alabama in Huntsville, 1998-2001
Graduate Research Assistant, The University of Alabama in Huntsville, 1994-98
Graduate Research Assistant, South Dakota School of Mines and Technology, 1991-94

5 Publications Relevant to this Proposal:

R. Ramachandran, S. Graves, H. Conover and K. Moe, Earth Science Markup Language, Submitted to Computers & Geosciences Journal, Submitted August 2002

S. Tanner, S. Graves, R. Ramachandran, M. Alshayeb, E. Criswell, A. McDowell, M. McEniry, and K. Regner, On-Board Mining in the Sensor Web, National Science Foundation Workshop on Next Generation Data Mining, Baltimore, MD, November 1-3, 2002

R. Ramachandran, M. Alshayeb, B. Beaumont, H. Conover, S. Graves, X. Li, S. Movva, A. McDowell and M. Smith, Interchange Technology for applications to facilitate generic access to heterogenous data formats, International Geoscience and Remote Sensing Symposium, Toronto, Canada, June 24-28, 2002

R. Ramachandran, H. Conover, S. Graves, K. Keiser, S. and S. Tanner: Flexible Earth Science Data Mining System Architecture, Fourth Workshop on Mining Scientific Datasets in conjunction with the 7th ACM SGGKDD International Conference on Knowledge Discovery and Data Mining, San Francisco, CA, August 26, 2001.

R. Ramachandran, H. Conover, S. Graves and K. Keiser: Algorithm Development and Mining (ADaM) System for Earth Science Applications, Second Conference on Artificial Intelligence, 80th AMS Annual Meeting, Long Beach, January, 2000

5 Other Significant Publications:

Y. He, R. Ramachandran, X. Li, J. Rushing, H. Conover, S. Graves, W. Lyatsky, A. Tan and G. Germany, Framework for Mining and Analysis of Space Science Data, Submitted to SIAM International Conference on Data Mining, San Francisco, CA, May 1-3, 2003

Nair, U., J. Rushing, R. Ramachandran, R. Welch, and S. J. Graves: Detection of boundary layer cumulus cloud fields in GOES satellite imagery, submitted to Journal of Applied Meteorology, September, 2001

R. Ramachandran, U. S. Nair, S. Graves, S. Tanner, R. Welch and J. A. Rushing: Comparing Texture Feature Characterization Methods for Cumulus Cloud Classification in GOES Images, Third Workshop on Mining Scientific Datasets, First SIAM International Conference on Data Mining, Chicago, IL, April 5-4, 2001.

P. Smith, D. Musil, A. Detwiler and R. Ramachandran, Observations of Mixed-Phase Precipitation Within a CaPE Thunderstorm, Journal of Applied Meteorology, 1999

R. Ramachandran, A. Detwiler, J. Helsdon, V. Bringi and P. Smith: Precipitation Development and Electrification in Florida Thunderstorms During Convection and Precipitation/Electrification Project, Journal of Geophysical Research, 1996.

Synergistic Activities

- "Data mining in Earth Science", Presentation made at the Mathematical Challenges in Scientific Data Mining, Institute for Pure and Applied Mathematics, UCLA, January 14-18, 2002
- "ADaM System Architecture" Presentation made at the Mathematical Challenges in Scientific Data Mining, Institute for Pure and Applied Mathematics, UCLA, January 14-18, 2002
- "Earth Science Markup Language", Presentation made at the OGC's 39th Technical Committee and OGC Planning Committee Meeting WWW Mapping SIG, Columbia University, NY,
- Coordinator and Host, Earth Science Markup Language Workshop, March 21-22, 2001.
- "Earth Science Markup Language", Presentation made at the XML Workshop, Goddard Space Flight Center, NASA, MD, February 28, 2001
- "Data mining: Atmospheric Science Case Studies", Presentation made at the NASA Workshop on Issues in the Application of Data Mining to Scientific Data, October 19 – 21, 1999.

Recent Non-UAH Collaborators

Richard Clark(Millersville), Larry DeLucas (UAB), Ben Domenico(Unidata), Kelvin Droegemeier(OU), Richard Fikes(Stanford) Peter Fox(NCAR), Dennis Gannon(IU), Michael Ghil(UCLA), Steve Goodman(NASA/MSFC), Robert Harriss(NCAR), Thomas H. Hinke(NASA/ARC), Everitt Joseph(Howard), Wladislaw Liatsky(Alabama A&M), Timothy Killeen(NCAR), Don Middleton(NCAR), Roger Pielke, Jr(UC), Rick Stevens(Argonne), Ajrun Tan(Alabama A&M), Bob Wilhelmson(UI), Rob Raskin(JPL)

Graduate Advisors

Dr. Ron Welch, Dr. Sara Graves, Dr. Sundar Christopher, Dr. Richard McNider and Dr. Q. Han

Dr. John A. Rushing
Senior Research Scientist, Information Technology & Systems Center
The University of Alabama in Huntsville, Technology Hall S347, Huntsville, AL 35899
E-mail: jrushing@itsc.uah.edu

Professional Preparation

Rensselaer Polytechnic Institute, Troy NY	Computer & Systems Engr.	B.S., 1988
University of Alabama in Huntsville	Computer Science	M.S., 1995
University of Alabama in Huntsville	Computer Science	Ph.D., 1999

Academic and Professional Appointments

The University of Alabama in Huntsville, Senior Research Scientist, Research Scientist, Huntsville, AL.
Intel Corporation, Senior CAD Engineer, Santa Clara, CA.
Intergraph Corporation, Software Consultant, Senior Software Analyst, Software Analyst, Huntsville, AL.

5 Publications Relevant to this Proposal

Rushing, J., H. Ranganath, T. H. Hinke, and S. J. Graves, December 2001: Image Segmentation Using Association Rule Features, IEEE Tranactions on Image Processing, Vol. 11. No. 5, pp. 558-567.

Rushing, J., H. Ranganath, T. H. Hinke, and S. J. Graves, August 2001: Using Association Rules as Texture Features, IEEE Transactions on Pattern Analysis and Machine Intelligence, Vol. 23, No. 8, pp. 845-858.

Ramachandran, R., J. A. Rushing, U. S. Nair, S. J. Graves, S. Tanner, and R. M. Welch, 2001: Comparing Texture Feature Characterization Methods for Cumulus Cloud Classification in GOES Images, Third Workshop on Mining Scientific Datasets held in conjunction with the First SIAM Conference on Data Mining on April 7, 2001 in Chicago.

Hinke, T. H., J. Rushing, H. Ranganath and S. J. Graves, 2001: Techniques and Experience in Mining Remotely Sensed Satellite Data, Artificial Intelligence Review (AIRE, S4): Issues on the Application of Data Mining, pp. 503-531.

Hinke, T. H., J. Rushing, H. Ranganath and S. J. Graves, August 1997: Target-Independent Mining for Scientific Data, Third International Conference on Knowledge Discovery and Data Mining, Newport Beach, CA.

5 Other Significant Publications

Ramachandran, R., J. Rushing, H. Conover, S. Graves and K. Keiser, February 9-13 2003: Flexible Framework for Mining Meteorological Data, 19th Conference on Interactive

Information and Processing Systems for Meteorology, Oceanography, and Hydrology, 83st AMS Annual Meeting, Long Beach, CA.

Ramachandran, R., H. Conover, S. Graves, K. Keiser and J. Rushing, 1999: The Role of Data Mining in Earth Science Data Interoperability, American Society for Photogrammetry and Remote Sensing Annual Conference, Portland, OR.

Nair, U. S., J. Rushing, R. Ramachandran, K. Kuo, S. Graves and R. Welch, 1999: Detection of Cumulus Cloud Fields in Satellite Imagery, The International Symposium on Optical Science, Engineering and Instrumentation, Denver, CO.

Hinke T. H., J. Rushing, S. Kansal, S. Graves and H. Ranganath, August 1997: For Scientific Data Discovery: Why Can't the Archive be More Like the Web, Ninth International Conference on Scientific Database Management, Evergreen State College, Olympia, Washington.

Hinke, T. H., J. Rushing, S. Kansal, S. Graves, H. Ranganath and E. Criswell, February 2-7, 1997: Eureka Phenomena Discovery and Phenomena Mining System, American Meteorological Society 13th International Conference on Interactive Information and Processing Systems (IIPS) for Meteorology, Oceanography and Hydrology,.

Recent Non-UAH Collaborators:
Steve Goodman, Thomas H. Hinke, Vinoo Srinivasan, Nagbhushan Veerapaneeni, Artour Levin, Bharat Krishna, Sabyasachi Das, William Halpin, Khartik Rajagopal, Narayanan Thondugulam.

Advisors
Dr. Heggere Ranganath, Dr. Sara Graves, Dr. Thomas Hinke, Dr. Tim Newman, Dr. Peter Slater

Robert B. Wilhelmson
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Senior Research Scientist - National Center for Supercomputing Applications (NCSA)
National Center for Supercomputing Applications
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Professional Preparation

Wheaton College, Illinois	Mathematics	B.S., 1966
University of Illinois at Urbana-Champaign	Computer Science	M.S., 1969
University of Illinois at Urbana-Champaign	Computer Science	Ph.D., 1972

Academic and Professional Appointments

1966–69	Research Assistant, Computer Science Department, U. of Illinois
1969–72	Research Assistant, Laboratory for Atmospheric Research, U. of Illinois
1972–74	Research Assistant Professor, Laboratory for Atmospheric Research & Center for Advanced Computation, U. of Illinois
1974–78	Assistant Professor, Laboratory for Atmospheric Research & Center for Advanced Computation, U. of Illinois
1978–83	Associate Professor, Laboratory for Atmospheric Research, U. of Illinois
1983–present	Professor, Department of Atmospheric Sciences, U. of Illinois
1985–86	Assistant Director, NCSA, U. of Illinois
1986–87	Associate Director, NCSA, U. of Illinois
1987–present	Senior Research Scientist, NCSA
1993–94	Department Head, Department of Atmospheric Sciences
1996–99	Department Head, Department of Atmospheric Sciences
1996–2000	Co-lead of the Environmental Hydrology Team at NCSA
2000–2002	Lead for the Environmental Hydrology Team at NCSA
2002–present	CoLead for Alliance Expedition entitled "Modeling Environment for Atmospheric Discovery"

Selected Publications

Wicker, L. J., and R. B. Wilhelmson, 1995: Simulation and analysis of tornado development and decay within a three-dimensional supercell thunderstorm. *J. Atmos. Sci.,* 52, 2675-2703.

Wilhelmson, R. B., M. Arrott, L. Wicker, D. Wojtowicz, C. Shaw, B. Lee, B. Jewett, M. Bajuk, M. McNeill, J. Terstriep, and V. Jaswel, 1996: Visualization of storm and tornado development for an OMNIMAX film and for the CAVE. *Preprints*, 12th International Conference on Interactive Information and Processing Systems (IIPS) for Meteorology, Oceanography and Hydrology, Atlanta, Georgia, AMS, 135–138.

Wilhelmson, R. B., B. Jewett, C. Shaw, L. Wicker, M. Arrott, M. Bajuk, C. Bushell, J. Thingvold, and J. Yost, 1990: A study of the evolution of a numerically modeled severe storm. *International Journal of Supercomputing Applications,* 4, Summer, 20–36.

Wilhelmson, R. B., and L. J. Wicker, 2001: Severe storm modeling. *Severe Convective Storms, Meteor. Monogr.,* **28**, No. 50, Amer. Meteor. Soc., 123-166.

Wilhelmson, R. B., D. P. Wojtowicz, C. Shaw, J. Hagedorn, and S. Koch, 1995: NCSA PATHFINDER: Probing ATmospHeric Flows in an INtegrated and Distributed EnviRonment. Visualization Techniques in Space and Atmospheric Sciences, E. P. Szuszczewicz and J. H. Bredekamp, Ed., NASA SP-519, 289-296.

Bramer, D. J., T. Scheitlin, R. Deardorff, D. Elliott, K. Hay, M. R. Marlino, D. Middleton, R. Pandya, M. K. Ramamurthy, M. Weingroff, and R. B. Wilhelmson, 2002: Using an Interactive Java-Based Environment to Facilitate Visualization Comprehension 18th Conference on IIPS, Amer. Meteor. Soc., Orlando, FL.

Wilhelmson, R. B., M. Arrott, L. Wicker, D. Wojtowicz, C. Shaw, B. Lee, B. Jewett, M. Bajuk, M. McNeill, J. Terstriep, and V. Jaswel, 1996: Visualization of storm and tornado development for an OMNIMAX film and for the CAVE. *Preprints*, 12th International Conference on Interactive Information and Processing Systems (IIPS) for Meteorology, Oceanography and Hydrology, Atlanta, Georgia, AMS, 135–138.

Wilhelmson R., M. Folk, M. Ramamurthy, B. Schatz, N. Yeager, R. Crutcher, and M. Winslett, 1996: HORIZON: A Digital Library Project for Earth and Space Data Serving the Public. NASA Newsletter.

Wilhelmson, R. B., B. Jewett, L. Auvil, D. Tcheng, J. Alameda, A. Rossi, M. Welge, 2001: Weather Research and Forecasting Environment, Alliance Supercomputing Conference Booth to Feature Interactive Weather Modeling (Release by Karen Green), Denver, CO.

Wilhelmson, R. B., R. Woodward, S. Anderson, D. Porter, S. Peckham, C. Shaw, and L. Wicker, 2002: Breaking the Billion Zone Barrier – Simulation, Data Handling and Visualization: An Example. Proc. 18th International Conf. On Interactive Information and Processing Systems for Meteorology, Oceanography, and Hydrology, *Orlando,* Amer. Meteor. Soc., J291-J293.

Synergistic Activities

- National Center for Atmospheric Research (NCAR) Outstanding Publication Award (1979) and AMS Meisinger Award (1983) in collaboration with Dr. Klemp.
- Co-founder of the National Center for Supercomputing Applications (NCSA - 1985)
- "Study of a Numerically Modeled Severe Storm" video production. This collaborative venture received the First Place Visualization Award at "The Computer Graphics Film Festival 1989" held in London, England and subsequently was submitted for an Academy Award. It has been widely used in television and video productions.
- Collaborative development of the VGEE (Virtual Geophysical Exploration Environment) designed for inquiry based learning in a simplified research environment. Faculty and staff from NCAR, UIUC, Westchester U., and Georgia Tech (1999 to present).
- Digital Library for Earth System Science (DLESE) Steering Committee (1999 to present). DLESE serves the national earth science education community.
- Environmental Hydrology Team member and lead for the NCSA Alliance involving members from Iowa State U., U. of Maryland, U. of Oklahoma, Rutgers U., U. of Wisconsin, and UIUC (1995 - 2002).
- MEAD co-lead within the NCSA Alliance involving participants from Rutgers U., U. of Oklahoma, U. of Alabama at Huntsville, NCAR, NCSA, U. of Minnesota, Portland State U., Georgia Tech, LLNL, and ANL (2002 – present).

Collaborators: J. Alameda, S. Anderson, P. Baker, D. Bock, D. Cox, D. Crutcher, T. Defanti, C. Doswell, M. Folk, I. Foster, J. Klemp, D. Gannon, S. Graves, D. Haidvogel, K. Hay, Shawn Hampton, R. Heiland, B. Hibbard, D. Johnston, J. Klemp, J. Leigh, T. Maxwell, M. Marlino, J. Michalakes, D. Middleton, V. Nefedova, L. Orf, B. Plale, R. Pandya, B. Patterson, D. Porter, M. Ramamurthy, D. Reed, A. Rossi, C. Shaw, R. Stein, R. Stevens, D. Tafti, S. Tanner, D. Tcheng, B. Vieux, D. Weber, F. Weirich, M. Welge, L. Wicker, P. Woodward; **Graduate and Postdoctoral Advisors:** Y. Ogura, University of Illinois at Urbana-Champaign (retired); **Thesis Advisor and Postgraduate-Scholar Sponsor:** Total Graduate Students (14) and Post-Docs (3): M. Bradley, H. Brooks, C-S Chen, S. Chin, Lee Cronce, K. Droegemeier, A. Houston, B. Lee, B. Jewett, E. Mlodzik, L. Muñoz, G. Romine, S. Peckham, L. Wicker, B. Zhou

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Professional Preparation

University of Missouri at Rolla	Computer Science	B.S. (*summa cum laude*), 1978
Purdue University	Computer Science	M.S., 1980
Purdue University	Computer Science	Ph.D., 1983

Appointments

Director, National Center for Supercomputing Applications (NCSA), 2000-
Director, National Computational Science Alliance, 2000-
Edward William and Jane Marr Gutgsell Professor, Department of Computer Science,
University of Illinois at Urbana-Champaign, 2000-
Head, Department of Computer Science, University of Illinois at Urbana-Champaign, 1997-2001
Assistant, Associate, and Professor, Department of Computer Science, University of Illinois 1984-
Senior Research Scientist, National Center for Supercomputing Applications, 1995-2000
Visiting Scientist, IBM T. J. Watson Research Center, 1990
Assistant Professor, Department of Computer Science, University of North Carolina, 1983-1984

5 Publications Relevant to this Proposal (Available at www-pablo.cs.uiuc.edu)

[1] C-D. Lu and D. A. Reed, "Compact Application Signatures for Parallel and Distributed Scientific Codes," SC02, November 2002.

[2] N. Tran and D. A. Reed, "ARIMA Time Series Modeling and Forecasting for Adaptive I/O Prefetching," *Proceedings of the 15th ACM International Conference on Supercomputing*, June 2001, pp. 473-485.

[3] R. L. Ribler, H. Simitci, and D. A. Reed, "The Autopilot Performance-Directed Adaptive Control System," *Future Generation Computer Systems*, special issue (Performance Data Mining), 18 (1) pp. 175-187, September 2001

[4] F. Vraalsen, R. A. Aydt, C. L. Mendes, and D. A. Reed, "Performance Contracts: Prediction and Monitoring Grid Application Behavior," *Proceedings of the 2nd International Workshop on Grid Computing/LNCS (GRID 2001)*, *Springer-Verlag Lecture Notes in Computer Science*, Nov. 2001

[5] J. S. Vetter and D. A. Reed, "Real-time Performance Monitoring, Adaptive Control and Interactive Steering of Computational Grids," *International Journal of Supercomputer Applications and High Performance Computing (IJSAHPC),* 2000

5 Other Significant Publications

[1] D. A. Reed and R. A. Aydt, "Performance Analysis and Measurement," in High-Performance Computing, K. Kennedy (ed.), *to appear*

[2] L. DeRose, M. Pantano, and D. A. Reed, "An Approach to Immersive Performance Visualization of Parallel and Wide-Area Distributed Applications", *Eighth IEEE Symposium on High-Performance Distributed Computing*, August 1999.

[3] C. L. Mendes and D. A. Reed, "Integrated Compilation and Scalability Analysis for Parallel Systems," *Parallel Architectures and Compilation Techniques (PACT '98),* October 1998

[4] D. A. Reed, R. A. Aydt, L. DeRose, C. L. Mendes, R. L. Ribler, E. Shaffer, H. Simitci, J. Vetter, D. R. Wells, S. Whitmore, and Y. Zhang, "Performance Analysis of Parallel Systems: Approaches and Open Problems," *Japan JSPP*, pp. 239--256, June 1998

[5] D. A. Reed and R. L. Ribler, "Performance Analysis and Visualization," in The Grid: Blueprint for a New Computing Infrastructure, Ian Foster and Carl Kesselman (eds), Morgan-Kaufmann, 1998

Synergistic Activities

- *Advisory Boards and Committees.* NSF CISE Advisory Committee (1997-2000), State of Illinois VentureTECH Committee (2000-2003), Argonne/University of Chicago Computation Institute External Advisory Council (2000-), Supercomputing XY Steering Committee (1999-), Board of Directors, Computing Research Association (1998-), Los Alamos Computer Science Institute Steering Committee (1999-), AAAS Member at Large, Section on Information, Computing, and Communication (2001-), DOE NERSC Policy Board (2001-)
- *Recent Program and Conference Chairs: IOPADS (1999), SC02 Technical Program (2002)*
- *Current Editorial Boards. Concurrency: Practice and Experience*, *Performance Evaluation and Modeling for Computer Systems, Parallel Computing (North American editor)*
- *Awards and Honors.* NSF Presidential Young Investigator Award (1987), University Scholar, University of Illinois (1989), Edward William and Jane Marr Gutgsell Professor (2000-)

Dr. Reed is the author of over one hundred research papers and monographs on algorithms, architectures, and performance evaluation techniques for high-performance computing and virtual environments. His Pablo project has developed portable performance data capture and presentation tools for scalable parallel systems, exploring the integration of high-level languages and data reduction techniques to relate dynamic performance data to application code. The Pablo toolkit has also been the basis for I/O characterization on HPC systems and was the springboard for creating the Virtue performance visualization system and the Autopilot Grid performance monitoring system. These tools are available at www-pablo.cs.uiuc.edu

As Director of NCSA and the Alliance, as well as Chief Architect for the NSF TeraGrid, he leads a national team of computing and application researchers developing computational grids, scalable PC clusters, and distributed collaboration tools in support of 21st century computational science. He is a member of the GrADS project, an eight institution effort (led by Ken Kennedy) to develop software tools and programming environments for computational Grids. Dr. Reed has also participated in two DOE ASCI/ASAP centers, the Illinois Center for Simulation of Advanced Rockets (CSAR), where he is a past member of the steering committee, and the Caltech Facility for Simulating the Dynamic Response of Materials. Finally, he is the principal investigator and leader of NEESgrid, the system integration project for NSF's George E. Brown Jr. Network for Earthquake Engineering Simulation (NEES).

Collaborators and Other Affiliations

R. Aydt (UIUC), A. Chien (UCSD), A. Choudhary (Northwestern), D. Bailey (LBL) F. Berman (UCSD), J. Dongarra (Tennessee), D. Gannon (Indiana) G. Gibson (CMU), K. Kennedy (Rice), R. Lucas (LBL), K. Li (Princeton), V. McKoy (Caltech), J. Mellor-Crummey (Rice), P. Messina (Caltech), B. Miller (Wisconsin), L. Peterson (Princeton), J. Pool (Caltech), J. Saltz (Ohio State), R. Sugar (UCSB), R. Stevens (ANL), R. Wolski (UCSB) (*Hundreds of PACI and ASCI collaborators omitted for brevity*.)

Graduate Advisor: Herbert D. Schwetman, Purdue University (now a private consultant)

Recent Graduate Student and Postdoctoral Advisees

P. E. Crandall (LANL), C. L. Mendes (UIUC), T. M. Madhyastha (UCSC), C. L. Elford (Intel), T. Kwan (McKinsey), R. Ribler (Lynchburg College), H. Simitci (Seagate), E. Smirni (William and Mary), L. Tavera (Inktomi), N. Tran (NCSA), L. DeRose (IBM), J. Vetter (LLNL)

Everette Joseph
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Co-Investigator NOAA-Howard University Cooperative Center in Atmospheric Sciences
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Professional Preparation

State University of New York, College at Cortland	Physics	B.S., 1985
State University of New York, University at Albany	Physics	Ph.D., 1997
State University of New York, University at Albany	Atmos Sci	1997- 1998

Academic and Professional Appointments

Co-Director Howard University Program in Atmospheric Sciences	2001 – Present
Co-Investigator NOAA-Howard University Cooperative Center	2001 – Present
Assistant Professor Dept. of Physics and Astronomy Howard Univ.	1998 – Present
Graduate Research Assistant, ASRC, SUNY at Albany	1991 – 1997
Graduate Teaching Assistant, Department of Physics, SUNY Albany	1991 – 1996
Research Assistant NY State Legislative Comm. on Sci. and Tech.	1989 – 1991
President SASU Inc	1986 – 1987

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5 Publications Relevant to this Proposal

Everette Joseph and Qilong Min: Assessment of IR Multiple Scattering Using Model Calculations and Observations from ARM Fall 1997 IOP, *J. Geophys. Res* (under review)

X-Z Liang, M-D Chou, E. Joseph, and Q. Min 2002, Development of the Regional Climate-Weather Research and Forecasting Model (CWRF). Part 1: Cloud-Radiation Interaction, Annual WRF Workshop, NCAR, Boulder Co, July, 02

G Jenkins, A. Kamga, A. Garba, A. Diedhiou, V. Morris, and E. Joseph, 2002: Investigating the West African Climate System Using Global/Regional Climate Models. *BAM* Vol 43, 583–595

Everette Joseph and W.-C. Wang 1999: An Interactive Cirrus Radiative Parameterization for Global Climate Models. *J. Geophys. Res.*104, 9501-9515.

Everette Joseph and W-C Wang 1997: Using ARM Data to Validate an Interactive Cirrus Cloud Parameteriz.ation for GCMs. *Preprints, Ninth Conference on Atmospheric Radiation*, Amer. Meteor. Soc. 165 – 169.

Synergistic Activities

- Co-Organizer, Workshop on Modeling the West African Climate System with Global and Regional Scale Climate Models: Relevance to Understanding Climate Variability, Land-Use, and Climate Change, July 2000
- Co-Organizer and Co-Chair, Celebrating 20th Century Pioneers in Atmospheric Sciences, Examining 21st Century Challenges and Opportunities Workshop, March 2000
- Co-Founder and Co-Director, NOAA-Howard University Center for Atmospheric Sciences Weather Camp
- Developed the Howard University 3+2 Program in Physics and Atmospheric Sciences
- Panelist, Congressional Briefing: Increasing Diversity in the Sciences: What Works, Sept 2002
- Developer, the Howard University Program in Atmospheric Sciences Laboratory for Atmospheric Analysis and Computation

Recent Non-Howard Collaborators

Xin-Zhong Liang	Illinois State Water Survey, University of Illinois at Urbana-Champaign
Wei-Chung Wang	SUNY, University at Albany
Anthony Reynolds	Embry-Riddle University
Qilong Min	SUNY, University at Albany
Chung-Hsuan Lu	NCEP, NOAA
Volker Mohnen	SUNY, University at Albany
Glenn Yue	NASA, Langley
Walter Hoegy	NASA Goddard Space Flight Center
P. K. Bhartia	NASA Goddard Space Flight Center
Ernest Hilsenrath	NASA Goddard Space Flight Center
Author Akin	NASA Goddard Space Flight Center
Paul Ginoux	Georgia Institute of Technology
Mian Chin	Georgia Institute of Technology
Robert Curran	University of Maryland Baltimore County
Henry Platkin	University of Maryland Baltimore County
Patrick McCormick	Hampton University
Ray Hoff	University of Maryland Baltimore County
Gregory Jenkins	Penn State University
Lee Harrison	SUNY Albany
M-D Chou	NASA Goddard Space Flight Center
Lisa Slone	University of California at Santa Cruz
Jose Fuentes	University of Virginia
Roy Armstrong	University of Puerto Rico
Paul Croft	Jackson State University
Ramon Lopez	University Texas El Paso

Graduate Advisor

Walter Gibson	Department of Physics, SUNY, University at Albany
Wei-Chung Wang	Atmospheric Sciences Research Center, SUNY, University at Albany

Graduate Students and Post-Docs Supervised

Graduate Students (1 degree completed, and 6 students in progress)
Students completed: Johnny Seymore (M.S.)
Students in progress: Francis Mensah (Ph.D.), Fonya Nzeffe (Ph.D.), Miliaritiana Robjhon (M.S.), Andrea Sealy (Ph.D.), Johnny Seymore (Ph.D.), Segayle Walford (M.S.).

Dr. Vernon R. Morris
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Howard University
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Professional Preparation

Morehouse College, Atlanta, GA Chemistry and Mathematics B.S., 1985
Georgia Institute of Technology, Atlanta, GA Geophysical Sciences Ph.D., 1990

Academic and Professional Appointments

1996- present, Deputy Director, Center for the Study of Terrestrial and Extraterrestrial Atmospheres

1998 – present Associate Professor, Department of Chemistry & Graduate Program in Atmospheric Sciences, Howard University, Washington, DC

1999-2001, Visiting Scientist, NASA Goddard Space Flight Center, Atmospheric Chemistry and Dynamics Branch

2000 – present, Director of Howard University Component of the NASA Goddard Earth Sciences and Technology Center www.umbc.edu/GEST

2001 – present, Co-Director, Howard University Graduate Program in Atmospheric Sciences (HUPAS), www.cstea.howard.edu

2001-present Director, NOAA Center for Atmospheric Sciences (NCAS)

Doctoral Thesis

An Investigation of Transient Peroxides: A Theoretical and Experimental Study

Relevant Publications

G. S. Jenkins, K. Devlin, and V. R. Morris The Role of Convective Processes Over the Zaire and Congo Basins in the Southern Hemispheric Ozone Maximum. ***JGR Vol 102, 18963(1997).***

V. R. Morris The CSTEA Howard Oxidants and Air Quality Experiment (CHOAQE): Preliminary Results from Summer 1997 ***Proceedings of the 26th Annual Meeting of the NOBCChE (1998)***.

Cassandra Williams, C. B. Peterson, and V. R. Morris "Calibration of the QCM/SAW Cascade Impactor For Measurement of Ozone" In **Technical Advances in Education, Aeronautics, Space, Autonomy, Earth, and Environment**. M. Jamshidi, R. Lumia, E. Tunstel, Jr., B. White, J. Malone, and P. Sakimoto, Eds. ACE Center Press: Albuquerque, NM **1997**.

V. R. Morris and A. N. Thorpe The Center for the Study of Terrestrial and Extraterrestrial Atmospheres: Cutting Edge Research and Training at Howard University ***The Journal of the NTA Vol 70, 1 (1996).***

V. R. Morris, S. C. Bhatia, T. S. Dibble, J. S. Francisco Evaluating the Accuracy of Density Functional Methods for ClOO. ***J. Chem. Phys. 104, 5345 (1996*).**

Collaborators in last 48 months
Gregory S. Jenkins, Pennsylvania State University
Roy Armstrong, University of Puerto Rico at Mayagüez
Daniel Bacelo, Universidad Metropolitana, San Juan
Arthur Aikin, NASA GSFC
Walter Hoegy, NASA GSFC
Garba Amadou, EAMAC School of Meteorology, Niamey, Niger
Arona Diedhou, IRD-LTHE-ENSHMG, Grenoble, France
Oludapo Bakare, Howard University

Graduate and Postdoctoral Advisors
Ph.D. Advisors – Drs. John H. Hall, Jr. and Doug Davis
1992 – 1994 UC Presidential Postdoctoral Fellow, University of California, Davis, CA
Postdoctoral Advisor – Dr. William M. Jackson
1991 – 1992 Postdoctoral Fellow, Lawrence Livermore National Laboratories, Livermore, CA
Postdoctoral Advisor – Dr. William M. Jackson
1990—1991 Advanced Study Institute, Erice, Sicily

Richard D. Clark
Professor of Meteorology
Director, Millersville University Environmental Institute
Department of Earth Sciences, Millersville University
STB-409, P.O. Box 1002, Millersville, PA 17551-0302
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Professional Preparation

University of Wyoming, Laramie, WY	Atmospheric Science	Ph.D.,	1987
University of Wyoming, Laramie, WY	Atmospheric Science	M.S.,	1985
Point Park College – Pittsburgh, PA	Chemistry	B.S.,	1975
Point Park College – Pittsburgh, PA	Mathematics	B.S.,	1975

Academic and Professional Appointments

Chair, Department of Earth Sciences, Millersville University, May 2002 - present
Professor of Meteorology, Dept of Earth Sciences, Millersville University, August 1997-present
Director, Millersville University Environmental Institute, Millersville University, Fall 1999-present
Associate Professor of Meteorology, Dept of Earth Sciences, Millersville University, 1992-1997
Assistant Professor of Meteorology, Dept of Earth Sciences, Millersville University, 1987-1992
Graduate Research Assistant, University of Wyoming, Laramie, WY, 1983-1987
Senior textile chemist, Woolrich Woolen Mills, Inc., Woolrich, PA, 1977-1983

Selected Publications and Presentations

Mihailovic, D. T., S. T. Rao, C. Hogrefe, and R. D. Clark, 2002: An approach for the aggregation of aerodynamic surface parameters in calculating the turbulent fluxes over heterogeneous surfaces in atmospheric models. *Environmental Fluid Mechanics*, **2**, 315-337.

Athanassiadis, G. A., S. T. Rao, J-Y Ku, and R. D. Clark, 2002: Boundary layer evolution and its influence on ground level ozone concentration. *Environmental Fluid Mechanics*, **2**, 339-357.

Clark, R.D., 2002: Using GEMPAK/GARP in Undergraduate Research. *Bull. Amer. Meteor. Soc.* **83**, 178-180.

Clark,R.D., C.R. Philbrick, W.F. Ryan, B.G. Doddridge, and J.W. Stehr, 2002: The effects of local and regional scale circulations on air pollutants during NARSTO-NE-OPS 1999-2001. (Preprints). *Fourth Conference on Atmospheric Chemistry*, American Meteorological Society, 125-132.

Ware, R.H., D.W. Fulker, S.A. Stein, D.N. Anderson, S.K. Avery, R.D. Clark, K.K. Droegemeier, J. P. Kuettner, J.B. Minster, S. Sorooshian, 2001: Real-time national GPS networks for atmospheric sensing. *Journal of Atmospheric and Solar-Terrestrial Physics*, **63**, 1315-1330.

Zhang, K., H. Mao, K. Civerolo, S. Berman, J-Y. Ku, S.T. Rao, B. Doddridge, C. R. Philbrick, and R. D. Clark, 2001: Numerical investigation of boundary layer evolution and nocturnal low-level jets: local verses non-local PBL schemes. *Environmental Fluid Mechanics*, 1, 171-208.

Ku, J-Y, H. Mao, K. Zhang, K. Civerolo, S.T. Rao, C.R. Philbrick, B.Doddridge, and R. D. Clark, 2001: Numerical investigation of the effects of boundary-layer evolution on the predictions of ozone and the efficacy of emission control options in the Northeast United States. *Environmental Fluid Mechanics*, **1**, 209-233.

Clark, R.D., C.R. Philbrick, B.G. Doddridge, G.A. Allen, 2001: Investigations of ozone and fine particles in the Northeast. (Preprints). *Symposium on Atmospheric Chemistry: Past, Present, and Future*, American Meteorological Society, 133-140.

Clark, R.D., C.K. Scharnberger, S. Yalda, 2001: SuomiNet: a report from a beta site-Millersville University. (Preprints). Fifth Symposium on Integrated Observing Systems, American Meteorological Society, 143-145.

Ware, R.H., D. W. Fulker, S.A. Stein, D.N. Anderson, S.K. Avery, R. D. Clark, K.K. Droegemeier, J.P. Kuettner, J.B. Minster, and S. Sorooshian, 2000: SuomiNet: A real-time national GPS network for atmospheric research and education. *Bull. Amer. Meteor. Soc.*, **81**, 677-694.

Professional and Synergistic Activities

- Director, Millersville University Environmental Institute, Millersville University
- Chair, UCAR Unidata Users Committee, Second term, 2000-2003
- Unidata Workshop, "Shaping the Future: Unidata Users and Leaders
- Partner and beta-test site for SuomiNet: A real-time GPS network
- Program Chair, First AMS Student Conference and Career Fair, Orlando, FL 2002
- Millersville University representative to the UCAR Academic Affiliates Program
- Member, American Meteorological Society Board of Higher Education, 1998-2004
- Member, American Meteorological Society and American Geophysical Union

Recent Non-Millersville Collaborators:

C. Russell Philbrick (PSU), William Ryan (PSU), Bruce Doddridge (UMD), Larry Kleinman (BNL), Peter Mueller (EPRI), Randolph Ware (GST-UNAVCO), S. T. Rao (U-Albany), Kenneth Gilbert (UMiss), Steve McDow (Drexel), Petros Koutrakis (HSPH), George Allen (HSPH), Georgios Athanassiadis (NY-DEC), K. H. Zhang (NY-DEC), J. Ku (NY-DEC), Jerome Fast (ANL), Dragutin T. Mihailovic, Jia-Yeong Ku, Chris Hogrefe.

Graduate Advisor:

Dr. Thomas R. Parish, Professor of Atmospheric Sciences, University of Wyoming, Laramie, WY

Selected Courses, Workshops and Learning Activities Developed and Taught:

Undergraduate Education

- Boundary Layer Meteorology
- Statistical Meteorology
- Chemistry of the Atmosphere
- Storm and Cloud Dynamics
- Atmospheric Dynamics I & II
- Physical Meteorology
- Atmospheric Thermodynamics
- Mesoscale Meteorology
- Meteorological Instruments, Measurement, and Observing Systems

General and Pre-college Education

- Earth in Space
- The Atmosphere (traditional)
- The Atmosphere (Web-based)
- Origin and Evolution of the Earth
- The Atmosphere (traditional)
- Education Workshop: Meteorology and Astronomy for Pre-College Teachers: Grades 6-12.

Sepideh Yalda
Associate Professor of Meteorology
Department of Earth Sciences, Millersville University of Pennsylvania
STB 405, P.O. Box 1002, Millersville, PA 17551-0302
E-mail: Sepi.Yalda@millersville.edu

Professional Preparation:

Saint Louis University	Meteorology	Ph.D.,	1997
Saint Louis University	Meteorology	M.S.,	1993
Saint Louis University	Meteorology	B.S.,	1991

Academic and Professional Appointments:
Associate Professor, Department of Earth Sciences, Millersville University, July 2002 - Present.
Assistant Professor, Department of Earth Sciences, Millersville University, August 1997-June 2002.
Adjunct Faculty, Harris-Stowe State College, 1993-1994
Instructor/Graduate Teaching Assistant, 1991-1997

Recent Publications and Presentations:
Yalda, S., A. Muller, and T.D. Marcoe, 2002: The effect of large-scale global atmosphere-ocean interactions on local weather conditions. A case study: Lancaster, Pennsylvania. Accepted for publication in the *Journal of The Pennsylvania Academy of Science*.
Yalda, S., C. E. Graves, and J. W. Zack, 2001: A validation technique for the assessment of numerical models. Submitted to the *Journal of Atmospheric and Oceanic Technology*.
Yalda, S., 2001: A Web-based introductory meteorology course. Digital Library for Earth System Education (DLESE) Annual Conference. Flagstaff, AZ.
L. West, M. Wismer, S. Yalda, D. Blum, and J. Ward, 2001: Teaming content and education faculty. Second meeting of the Collaborative for Excellence in Teacher Preparation in Pennsylvania. Bloomsburg, PA.
Marcoe, T. D., S. Yalda, and A. Muller, 2001: The effect of the large-scale global atmosphere-ocean interactions on local weather conditions. A case study: Lancaster, Pennsylvania. Fifth Annual Council on Undergraduate Research Posters on Capitol Hill. Washington, DC.
Clark, R. D., C. K. Scharnberger, S. Yalda, 2000: SuomiNet: A report from a Beta site-Millersville University. Proceedings of the Fifth Symposium on Integrated Observing Systems. Amer. Meteor. Soc. Albuquerque, NM.

Professional and Synergistic Activities:
- Community member: Digital Library for Earth System Education (DLESE) for the development of Earth System Science vocabulary
- Steering committee member: Pennsylvania Consortium on Energy and Climate Change Committee
- Member: UCAR University Relations Committee, 2002-2005
- Team member: SSHE-NSF Collaborative for Excellence in Teacher Preparation in Pennsylvania (CETP-PA)
- Steering committee member: Millersville University Environmental Institute
- Team member: NASA-CAPE Program (in collaboration with the Indiana University of Pennsylvania)
- Team member: Millersville University NASA-CAPE Program
- Member, American Meteorological Society and American Geophysical Union

Recent Non-Millersville Collaborators:
Charles Graves (SLU), John Zack (Meso Inc.), Adam Rose (PSU), Ann Fisher (PSU), Bud Rawlings (Pitt).

Graduate Advisor:
Dr. Charles E. Graves, Associate Professor of Meteorology, Saint Louis University, St. Louis, MO.

Selected Courses, Workshops and Learning Activities Developed and Taught:
<u>Undergraduate, General, and Pre-College Education</u>

- Satellite Meteorology
- Radar Meteorology
- Applied Climatology
- Atmospheric Dynamics I & II
- Introduction to Meteorology
- Introduction to Earth Sciences
- Environmental Meteorology
- Pedagogy Seminar in Earth Sciences
- The Atmosphere (traditional and Web-based)
- Investigations in Meteorology (Teacher Education Workshop)
- History of Meteorology (a perspectives course)

Dennis Gannon
Professor and Chair, Department of Computer Science
Indiana University
Email: gannon@cs.indiana.edu Web: http://www.cs.indiana.edu/~gannon

Professional Preparation

B.S., University of California, Davis, 1969 (Mathematics)
M.S., University of California, Davis, 1971 (Mathematics)
Ph.D., University of California, Davis, 1974 (Mathematics)
Ph.D., University of Illinois, 1980 (Computer Science)

Academic and Professional Appointments

Professor and Department Chair, Computer Science, Indiana University (1985-present, 1997-present).
Science Director, Indiana Pervasive Technology Labs, (1999-present.)
Chief Computer Scientist, NCSA Alliance (2001-present)
Visiting Scientist, NASA Ames Research Center, IPG project, 1998-2000.
Assistant,Associate Professor, Computer Science, Purdue University, 1980-1984,1985.
Senior Visiting Research Scientist, Center for Supercomputer Research and Development, University of Illinois, 1985-90.

5 Publications Relevant to this Proposal

1. S. Krishnan, R. Bramley, M. Govindaraju, R. Indurkar, A. Slominski, D. Gannon, J. Alameda, D. Alkaire, "The XCAT Science Portal, " Proceedings SC2001.
2. R. Bramley, K. Chiu, S. Diwan, D. Gannon, M. Govindaraju, N. Mukhi, B. Temko, M. Yechuri, "A Component Based Services Architecture for Building Distributed Applications," *Proceedings of HPDC*, 2000
3. W. Johnston, D. Gannon, B. Nitzberg, A. Woo, B. Thigpen, L. Tanner, "Computing and Data Grids for Science and Engineering," Proceedings of SC2000.
4. M. Norman, P. Beckman, G. Bryan, J Dubinski, D. Gannon, L. Hernquist, K. Keahey, J.P. Ostriker, J. Shalf, J. Welling, S. Yang, "Galaxies Collide on the I-WAY: An Example of Heterogeneous Wide-Area Collaborative Supercomputing", *Journal of Supercomputing Applications*, MIT Press, 1996.
5. D. Gannon, and A. Grimshaw, "Object-Based Approaches", (*The Grid: A Blueprint for a New Computing Infrastructure*}, Ian Foster and Carl Kesselman (Eds.), pp. 205--236, Morgan-Kaufman, 1998.

5 Other Significant Publications

1. D Gannon, R. Bramley, G. Fox, Ss Smallen, A. Rossi, R. Ananthakrishnan, F. Bertrand, K. Chiu, M. Farrellee, M. Govindaraju, S. Krishnan, L. Ramakrishnan, Y, Simmhan, A. Slominski, Y. Ma, C. Olariu, N. Rey-Cenvaz, "Programming the Grid: Distributed Software Components, P2P and Grid Web Services for Scientific Applications," Journal of Cluster Computing, 5(3): 325-336 (2002).
2. W. Johnston, D. Gannon, B. Nitzberg, "Grids as Production Computing Environments: The Engineering Aspects of NASAs Information Power Grid," Proceedings, High Performance Distributed Computing Conference 1999.
3. R. Armstrong, D. Gannon, A. Geist, K. Keahey, S. Kohn, L. McInnes, S. Parker, B. Smolinski, "Toward a Common Component Architecture for High-Performance Scientific Computing," Proceedings, High Performance Distributed Computing Conference 1999.

4. J. Villacis, M.Govindaraju, D. Stern, A. Whitaker, F. Breg, P. Deuskar, B. Temko, D. Gannon, R. Bramley, "CAT: A High Performance, Distributed Component Architecture Toolkit for the Grid," Proceedings High Performance Distributed Computing Conference 1999.
5. Kate Keahey and D. Gannon, "PARDIS: A Parallel Approach to CORBA", Proceedings 6th IEEE International Symposium on High Performance Distributed Computation, August 1997, Portland.

Synergistic Activities

Dr. Gannon's research interests include programming systems and tools, distributed computing, computer networks, parallel programming, computational science, problem solving environments and performance analysis of Grid and MPP systems. He is principal author of the Sage++ compiler toolkit used in many high performance computing compiler research projects. Most recently he has been involved with the Department of Energy SciDAC Common Component Architecture (CCA) project. This work has led to a framework for building component-based scientific applications called the Common Component Architecture Toolkit which uses C++ and Java to encapsulate and reuse Fortran-based scientific code in distributed applications. In addition, he was a partner in the NSF Computational Cosmology Grand Challenge project and the NCSA Alliance where he is helping to lead an effort to design Grid "Portals" which are desktop frameworks for Grid access. He also co-founded the Java Grande Forum, the co-chair of the Global Grid Forum research group on Grid Computing Environments and co-chair of the Global Grid Forum working group on the Open Grid Service Architecture. He was recently appointed Chief Computer Scientist of the NCSA Alliance.

Dr. Gannon is the Program Chair for the IEEE 2002 High Performance Distributed Computing Conference. He has served as General Chair of the 1998 International Symposium on Scientific Object Oriented Programming Environments (ISCOPE) and the 2000 ACM Java Grande Conference, and Program Chair for the 1997 ACM International Conference on Supercomputing as well as the 1995 IEEE Frontiers of Massively Parallel Processing. He has also been on the program committee for a dozen other conferences.

In the area of education, he chaired the committee that made the initial design for Indiana University's new School of Informatics. This school extends education in information technology to areas that are well beyond the traditional computer science/engineering curriculum. He is also the co-architect (with Michael McRobbie) of the Indiana Pervasive Technologies Labs. While at Purdue University, Dr. Gannon was awarded the Outstanding Teacher in the School of Science from 1981-1984.

Collaborators

Randall Bramley (Indiana), K. Mani Chandy (Caltech), Dan Reed (UIUC), Ken Kennedy (Rice), Carl Kesselman (USC), Ian Foster(ANL), Jack Dongarra (UTK), John Reynders (Celera), Andrew Grimshaw (Virginia), David Padua (Illinois), Allen Malony (Oregon), Joel Saltz (Maryland), J.P. Ostriker (Princeton), Mike Norman (UCSD), Dirk Grunwald (Colorado), Bart Miller (Wisconsin), C. Johnson (Utah), S. Parker (Utah) Geoffrey Fox (Florida), Bill Johnston (LBL/NASA), Bill Nitzberg (NASA), R. Armstrong (Sandia), Scott Kohn (LLNL), Fran Berman (UCSD), Andrew Chien (UCSD) and the other PIs on this proposal.

Graduate Students and Postdocs

Peter Beckman (Post Doc), Shelby Yang (Post Doc), Francois Bodin (Post Doc), Aart Bik (Post Doc), Madhusudhan Govindaraju (Post Doc)
Ph.D. Students: S. Diwan (HP), J. Villacis (Intel), Kate Keahey (Argonne), Suresh Srinivas (SGI), Neel Sundaresan (IBM), S. R. Sarukkai (HP), J. K. Lee (NTHU), Jacob Gotwals (Intel), Larry Tenny (IU-UCS), Daya Atapattu, A. Kapauan, Ko-Yang Wang (IBM), Elizabeth Johnson (Xavier U), Mann-Ho Lee, Jairo Panneta, S. Bechtolsheim and four current Ph.D. students.

Beth A. Plale

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Lindley Hall, Rm. 215
Indiana University
Bloomington, Indiana 47405-7104
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(812) 855-4373

Professional Preparation

Georgia Institute of Technology.	Computer Science	Postdoctoral	2001
SUNY at Binghamton	Computer Science.	Ph.D.	1998
Temple University.	Computer and Information Science	M.Sc.	1992
University of La Verne.	Business Administration	MBA	1986
University of Southern Mississippi.	Computer Science	B.Sc.	1984

Academic and Professional Appointments

Assistant Professor, Indiana University, Bloomington, IN, 2001-present
Lead Research Scientist**,** Georgia Institute of Technology, College of Computing. 1998-2001
Instructor, Georgia Institute of Technology. Undergraduate Advanced Operating Systems. 2000-2001
Graduate Research Assistant, Georgia Institute of Technology. 1995-1998
Adjunct Faculty, Perimeter College, DeKalb Georgia. 1994-1996.
Graduate Research Assistant, Instructor, Continuing Education Faculty, Graduate Teaching Assistant, State University of New York Binghamton. 1991-1994
Graduate Teaching Assistant, Temple University. 1990-1992.
Lead Software Engineer, GTE Federal Systems, Westlake Village, CA. DoD Air Force Intelligence. 1986-1989
Programmer, Vitro Corporation, Oxnard, CA. DoD Navy contract. 1984-1986

5 Publications Relevant to this Proposal

Plale, B. and K. Schwan, "Dynamic Querying of Streaming Data with the dQUOB System", accepted for publication in *IEEE Transactions on Parallel and Distributed Systems*.

Plale, B. and G. Turner, and Akshay Sharma, "Real time response to streaming data on Linux Clusters" LCI Linux Clusters: the HPC Revolution, October 2002.

Plale, B., "Leveraging Run Time Knowledge About Event Rates to Improve Memory Utilization in Wide Area Stream Filtering", *IEEE High Performance Distributed Computing (HPDC)*, August 2002.

Plale, B. and Karsten Schwan, "dQUOB: Managing Large Data Flows by Dynamic Embedded Queries", *IEEE High Performance Distributed Computing (HPDC)*, August

2000. Extended version available as Georgia Institute of Technology Technical Report GIT-TR-00-07.

Plale, B. and K. Schwan, "Run-time Detection in Parallel and Distributed Systems: Application to Safety-Critical Systems", *19th IEEE International Conference on Distributed Computing Systems (ICDCS)*, June 1999.

Other Significant Publications

Plale, B. and K. Schwan, "Optimizations Enabled by Relational Data Model View of Querying Streaming Data", *IEEE International Parallel and Distributed Processing Symposium (IPDPS),* April 2001.

Plale, B., P. Widener and K. Schwan, "Taking the Step from Meta-information to Communication Middleware in Computational Data Streams", *IEEE Heterogeneous Computing Workshop (HCW),* April 2001.

Plale, B., V. Elling, G. Eisenhauer, K. Schwan, D. King, and V. Martin, "Realizing Distributed Computational Laboratories", *International Journal of Parallel and Distributed Systems and Networks*, Vol. 2, No. 3, 1999.

Eisenhauer, G., B. Plale, K. Schwan, "DataExchange: High Performance Communications in Distributed Laboratories", *Journal of Parallel Computing*, Vol. 24, 1998.

Synergistic Activities

- Working group chair for Global Grid Forum (GGF). Specifically, founding member of Relational Database Information Services research group.
- Member NCSA Alliance Teragrid.

Collaborators & Other Affiliations

Dennis Gannon, Indiana University; Sudhir Aggarwal, Lucent Technologies; Peter Dinda, Northwestern University; Greg Eisenhauer, Georgia Institute of Technology; Karsten Schwan, Georgia Institute of Technology.

Thesis Advisors: Sudhir Aggarwal, formerly of State University of New York Binghamton; and Karsten Schwan, Georgia Institute of Technology.

Mohan K. Ramamurthy
Director, Unidata Program Center
University Corporation for Atmospheric Research
Boulder, CO 80307-3000
Tel: (303) 497-8661; e-mail: mohan@ucar.edu

Professional Preparation

B.S., Physics	University of Poona, India	1977
M.S., Physics	University of Poona, India	1980
Ph.D., Meteorology	University of Oklahoma, Norman, OK	1986

Academic and Professional Appointments

Director, Unidata, UCAR Office of Programs, UCAR, 2003-present
Associate Professor, Department of Atmospheric Sciences, University of Illinois, 1994 – 2003
Assistant Professor, Department of Atmospheric Sciences, University of Illinois, 1989 - 1994
Visiting Assistant Professor, Department of Atmospheric Sciences, University of Illinois, 1987 - 1989
Post-doctoral Research Assistant, Florida State University, Tallahassee, 1986 – 1987
Graduate Research Assistant, University of Oklahoma, Norman, 1980-1986.

Five relevant publications

Ramamurthy, M. K., K. P. Bowman, B. F. Jewett, J. G. Kemp, and C. Kline, 1992: A Networked Desktop Synoptic Laboratory. *Bull. Amer. Meteor. Soc.*, **73**, Cover and 944–950.

Bramer, D. J., D. P. Wojtowicz, J. Plutchak, R. B. Wilhelmson, and M. K. Ramamurthy, 1999: Integrating of Real-Time Weather into an Internet Learning Environment: WW2010 Current Weather Products. *Proceedings* of the Eighth Symposium on Education. Dallas, Texas, American Meteorological Society.

Ramamurthy, M. K., and B. Cui, 2001: Mesoscale ensemble prediction of mid-latitude cyclones. *Preprints*, Ninth Conference on Mesoscale Processes, Amer. Meteor. Soc., Fort Lauderdale, FL.

Jewett, B. F., M. K. Ramamurthy and H. Liu, 2001: Ensemble methods applied to hurricane track forecasting. *Preprints*, 14th Conference on Numerical Weather Prediction. Amer. Meteor. Soc., Fort Lauderdale, FL.

Pandya, R., D. Bramer, K. Ginger, K. Hay, M. Marlino, D. Middleton, M. Ramamurthy, T. Scheitlin, and R. Wilhelmson, 2001: Using the Virtual Exploratorium to support inquiry-based learning in introductory Geoscience courses: An ENSO example. *Preprints* , 10th Symposium on Education, Albuquerque, NM.

Five other publications

Jewett, B. J., R. M. Ramamurthy, and R. M. Rauber, 2002: Origin, maintenance and fine scale structure of the St. Valentine's Day gravity wave observed during STORM-FEST. Part III: MM5 modeling study of gravity wave genesis and evolution. *Mon. Wea. Rev.,* (In press)

Rauber, R. M., L. S. Olthoff, M. K. Ramamurthy, D. Miller and K. E. Kunkel, 2000: A synoptic weather pattern and sounding based climatology of freezing precipitation in the United States east of the Rocky Mountains. J. Appl. Meteor. , **40,** 1724-1747.

Rauber, R. M., M. Yang, M. K. Ramamurthy, and B. F. Jewett, 2000: Origin, evolution, and fine scale structure of the St. Valentine's Day gravity wave observed during STORM-FEST. Part I: Origin and maintenance. *Mon. Wea. Rev*., **129,** 198-217.

Yang, M., R. M. Rauber and M. K. Ramamurthy 2000: Origin, evolution, and fine scale structure of the St. Valentine's Day gravity wave observed during STORM-FEST. Part II: Fine scale structure. Mon. Wea. Rev. **129,** 218-236.

Ramamurthy, M. K., and T.-Y. Xu, 1993: Continuous data assimilation experiments with the NMC Eta Model: A GALE IOP-1 Case Study. *Mon. Wea. Rev.*, **121**, 3082-3105.

Synergistic Activities

Member, UNIDATA Users Committee, 1989-1992
Chairperson, UNIDATA Users Committee, 1991-1998
Member, AMS Committee on Weather Analysis and Forecasting, 1992-1995
Member, STORM Working Group on Mesoscale Numerical Prediction
Member, AMS Committee on Intelligent Transportation Systems, 1994-1998
Member, PAGE Executive Board Member, 1997-2000
Member, Unidata Policy Committee, 1999-present
Member, AMS Board of Higher Education, 2000-2002
Chairperson, DLESE Services Committee, 2000-present
Associate Editor, Monthly Weather Review, 2001-2002
Member, UCAR University Relations Committee, 2001-present
Chairperson, AMS Board of Higher Education, 2002-present
Member, JESSE Editorial Board, 2001-present

Recent Collaborators: Robert Rauber, Brian Jewett, David Smith, Rajul Pandya, Robert Wilhelmson, Dan Bramer, Greg McFarquahar, Mary Marlino, Don Middleton, Tim Scheitlin, Ken Hay

Ph. D. advisor: Prof. Fred Carr, University of Oklahoma, Norman, OK

Post-doctoral supervisor: Prof. Peter S. Ray, Florida State University, Tallahassee, FL

Graduate students supervised or co-supervised:

Name	Degree	Status
Michael Shields	M Sc.	National Weather Service
Brian Collins	M. Sc.	Private Industry
Meng Li	M. Sc.	Private Industry
David Christensen	M. Sc.	Private Industry
Naresh Malhotra	M.Sc.	Private Industry
Liho Chen	M. Sc.	National Taiwan University
Qizhou Guo	M. Sc.	Private Industry
Taiyi Xu	Ph. D (ABD)	Climate Diagnostics Center, NOAA
Guangming Zhou	Ph.D	Private Industry
Geoffrey Manikin	M. Sc.	National Centers for Environmental Prediction/EMC
Tom Grzelak	M.Sc.	Rutgers University
Steve Hall	M.Sc.	Private Industry
Muqun Yang	Ph.D., Post Doc	NCSA, Univ. of Illinois
Jingjun Shu	M. Sc.	Private Industry
Daniel Bramer	M. Sc.	University of Illinoiis
Scott Olthoff	M.Sc.	Private Industry
Noah Nigg	M. Sc.	Private Industry
Mei Han	Ph. D.	Student
Bo Cui	Ph. D.	Student

Benedict A. Domenico
University Corporation for Atmospheric Research (UCAR)
Post Office Box 3000
Boulder, Colorado 80307-3000
(303) 497-8631
ben@unidata.ucar.edu
http://www.unidata.ucar.edu/staff/ben/bad.html

Professional Preparation

Georgetown University	Physics	B. S.
Yale University	Physics	M.S.
University of Colorado	Astrophysics	Ph. D.

Professional Appointments

Acting Director, Unidata Program Center
Deputy Director, Unidata Program Center
Deputy Director Program for the Advancement of Geosciences Education (PAGE)
Manager, Data Display Division at Science Horizons, Inc.
Manager, Software and Libraries Group (SLG) SCD/National Center for Atmospheric Research (NCAR)

Publications Relevant to this Proposal

Hankin, D., P. Cornillon, M.Clancy, B. Domenico, B. Doty, D. Glover, 2002: Providing a service: ocean data systems. *Symposium on the Global Ocean Data Assimilation Experiment*, 13-15 June, Biarritz France.

Domenico, D., J. Caron, E. Davis, R. Kambic, S. and Nativi, 2002: Thematic Real-time Environmental Distributed Data Services (THREDDS): Incorporating Real-time Environmental Data and Interactive Analysis Tools Into NSDL. *Journal of Digital Information*, **2,** issue 4.

Ginger, K., M. Marlino, and B. Domenico, 2000: Digital Library for Earth System Education. Proceedings, *8th Conference on Education*, American Meteorological Society.

B. Domenico, 1995: Unidata Internet Data Distribution: Real-time Data on the Desktop. Proceedings, *Science Information Systems Interoperability Conference (SISIC).*

B. Domenico, 1986: The Supercomputer as an Experimental Apparatus. Proceedings, *Cray User Group Conference*.

Other Significant Publications

Marlino, M. and B. Domenico, 1999: A Geosciences Community Resource Discovery System. Proceedings, *15th International Conference on Interactive Information and Processing Systems***,** Jan., Amer. Meteor. Soc.

Domenico, B. and M. Marlino, 1997: Program for the Advancement of Geosciences Education:

Initial Steps. Preprints, *Fall Meeting,* 8-12 December, American Geophysical Union**,** San Francisco, CA.

Ahern, T. and B. Domenico, 1996: Using the Unidata Internet Data Distribution System for Disseminating IRIS Seismic Data. Preprints, *Fall Meeting,* 15-19 December, American Geophysical Union, San Francisco, CA,

Domenico, B., 1989: Real Time Atmospheric Data Management. Preprints, *US West Technology Symposium on Mass Database Communications and Management*, January.

Synergistic Activities

- Unidata Representative to ESIP (Federation of Earth Science Information Partners) which provides support for systems that disseminate, capture, and analyze real-time environmental data, including satellite and radar imagery, conventional bulletins, and computer model output.
- Formed the coalition of data providers, tool builders and metadata experts that comprise the THREDDS (THematic Real-time Environmental Distributed Data Services) team. Principal Investigator on THREDDS project, funded as a National Science Digital Library collections project.
- Co-PI on Geosciences Resource Discovery System project.
- Led a series of focus groups that led to the formation of the Program for the Advancement of Geosciences Education (PAGE), precursor to the DLESE (Digital Library for Earth System Education) program at UCAR whose mission is to enhance teaching and learning in undergraduate geosciences education through the application of contemporary pedagogies and educational technologies.
- Manager of the graphics project at NCAR which developed the widely-used NCAR Graphics package.

Recent Collaborators

Steve Ackerman (Wisconsin-Madison), Tim Ahern (IRIS), Benno Blumenthal (LDEO), Peter Cornillon (University of Rhode Island), David Dimitriou , Kelvin Droegemeier, Sarah Graves, Ted Habermann (NGDC), Steve Hankin (PMEL), Menas Kafatos (GMU), Kris Klaus (Argonne), Tamara Shapiro Ledley (TERC) Don Middleton (NCAR/SCD), Stefano Nativi (University of Florence), Rahul Ramachandran (UAH), Glenn Rutledge (NCDC), Phil Sharfstein (FNMOC) Roland Schweitzer (CDC), Michael R. Taber (Northern Colorado University), Ben Watkins (NCDC), Tom Whittaker (U of Wisconsin-Madison), Ruixin Yang (GMU)

Graduate Advisor

Andrew Skumanich, University of Colorado (Presently NCAR/HAO [ret])

Recent Awards

Member of team judged as semifinalist for Global Internet Infrastructure Award, 1998
USENIX Association Lifetime Achievement Award, 1996
UCAR Outstanding Achievement Award in Science Education, Honorable Mention, 1995

Donald R. Murray
MetApps Team Leader
UCAR/Unidata, 3300 Mitchell Lane, Boulder, CO 80301
E-mail: dmurray@ucar.edu

Professional Preparation

Lyndon State College	Meteorology, Mathematics	B.S., 1981
Montana State University	Earth Science	M.S., 1990

Academic and Professional Appointments

Software Engineer, UCAR/Unidata 1994-present
Administrative Computer Director, Lyndon State College, 1993-1994
Meteorological Technician, Lyndon State College, 1989-1994
Graduate Teaching Assistant, Montana State University, 1987-1989
Project Manager – Weather Network, Oceanroutes, Inc, 1983-1986
Meteorological Technician, Oceanroutes, Inc., 1981-1983

5 Publications Relevant to this Proposal

Hibbard, W., C. Rueden, S. Emmerson, T. Rink, D. Glowacki, T. Whittaker, D. Murray, D. Fulker, and J. Anderson, 2002: Java Distributed Objects for Numerical Visualization in VisAD, *Communications of the ACM*, **45**, (4), April 2002.

Murray, D., R. Rew, S. Emmerson, J. Caron, S. Wier, D. Fulker, 2001: "Unidata's MetApps Project - New ways, in Java, of Exploring Remotely Sensed Data," *2001 IEEE International Geoscience and Remote Sensing Proceedings*, Sydney, AU, 9-13 July.

Murray, D., B. Hibbard, T. Whittaker, J. Kelly, 2001: "Using VisAD to Build Tools for Visualizing and Analyzing Remotely Sensed Data," *2001 IEEE International Geoscience and Remote Sensing Proceedings*, Sydney, AU, 9-13 July.

Murray, D. and D. Fulker, 2000: "New Ways, in Java, of Visualizing the Same Old Data", Eos, *Transactions, American Geophysical Union*, **81**, (48), F300.

Murray, D, T. Whittaker, J. Kelly, 2001: "Accessing remote data servers through Java", Preprints, *17th Int. Conf. on Interactive Information Processing Systems (IIPS) for Meteorology, Oceanography and Hydrology*, 178-181.

Other Significant Publications

Murray, D.L. and W.W. Locke, 1989: Dynamics of the Late Pleistocene Big Timber Glacier, Crazy Mountains, Montana, USA. *J Glac.*, **35**, 183-190.

Recent Non-Unidata Collaborators

Bill Hibbard, Tom Rink, Tom Whittaker (U of WI-Madison); Andrew Donaldson, James Kelly (Australian Bureau of Meteorology); Chris Burghart, Mike Daniels, Susan Stringer (NCAR/ATD), Tim Schietlin (NCAR/SCD)

Graduate Advisor

Dr. William W. Locke, Professor of Geology, Montana State University

Anne E. Wilson
Software Engineer III
Unidata, University Corporation for Atmospheric Research (UCAR)
P.O. Box 3000, Boulder, CO 80307
Email: anne@unidata.ucar.edu

Professional Preparation

Humboldt State University	Theater Arts	B.A., 1979
University of California, San Diego	Computer Science	M.S., 1984
University of Maryland	Computer Science	Ph.D., 1993

Academic and Professional Appointments

Software Engineer III, University Corporation for Atmospheric Research, October 1999 - present

Research Associate, Systems Development Division, Forecast Systems Lab, October 1996 – October 1999

Assistant Professor, Department of Computer Science and Information Systems, The American University, 1994 – 1995

Faculty Research Associate, Computer Science Department, University of Maryland, 1994

Graduate/Faculty Research Assistant, Computer Science Department, University of Maryland, 1988 – 1993

Research Assistant, University of California, San Diego, 1986 – 1987

Publications Relevant to this Proposal

Wilson, A., Rew, R., 2001: Exploring an Alternative Architecture for Uidata's Internet Data Distribution. Preprints, *18th International Conference on Interactive Information and Processing Systems for Meteorology, Oceanography, and hydrology*, American Meteorological Society, Orlando, FL.

Rew, R., Wilson, A., 2000: The Unidata LDM System: Recent Improvements for Scalability. Preprints, *17th International Conference on Interactive Information and Processing Systems for Meteorology, Oceanography, and hydrology*, American Meteorological Society, Albuquerque, NM.

5 Other Significant Publications

Wilson, A. and Rodgers, D., Grote, H., 1999: Adding Productivity Tools to the WFO-Advanced Meteorological Workstation. Preprints, *15th International Conference on Interactive Information and Processing Systems (IIPS) for Meteorology, Oceanograhy, and Hydrology*, Dallas, TX.

Wilson A., and J. Hendler, 1993: Linking Symbolic and Subsymbolic Computing, *Connection Science*, Volume 5, Nos. 2 & 4.

Wilson, A., and J. Hendler, Y., Cui, 1993: Chemical Tank Control System, in Hybrid Neural Network and Expert Systems, L. Medsker, Kluwer Academic Publishers.

Wilson, A., and J. Hendler, R., Belew: Conncert: A Modular approach to the Design of Connectionist Architectures, in Progress in Neural Networks, Omidvar, Wilson (eds.), Ablex.

Wilson, A., Reducing Dependencies in Neural Computing, 1993: *15th International Conference on Software Engineering*, Baltimore, Maryland, May (poster).

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Synergistic Activities

- Sponsor, University of Colorado at Boulder Senior Software Engineering Poject. Project is to develop LDM Lite, recieve-only DM client based on the NNTP protocol and written in Java for platform independence.
- Science Fair Judge, local elementary and middle schools

Recent non-UCAR Collaborators

Dr. Joe St Sauver, University of Oregon

Graduate Advisor

Dr. James Hendler, Computer Science Department, University of Maryland