J8.9 RETROSPECTIVE AND PROSPECTIVE VIEWS ON HOW AWIPS RELATES TO UNIDATA

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1. OPERATIONAL-ACADEMIC SYNERGIES

The interests of the National Weather Service (NWS) are linked in many ways to those of university departments of meteorology and related sciences. Many of the scientific underpinnings for NWS operations originated or have been advanced in academic settings, and much of the NWS workforce gains crucial skills in these settings. In turn, academia depends heavily on the NWS for observed and synthesized data that are employed in research and education. This mutually beneficial partnership is continually strengthened through collaborative research and through programs, such as COMET (the Cooperative Program for Operational Meteorology, Education and Training), which explicitly recognize the value of sophisticated, in-service learning as part of the operational forecasting environment.

Another area of operational-academic synergy is emerging from common needs for advanced information technology. This is evident in the relationship that has evolved between the Advanced Weather Information Processing System (AWIPS) program and the NSF-sponsored Unidata program, though they were formed for distinct constituents. Where AWIPS was targeted to operational forecasters in the NWS, with stringent demands for timeliness and reliability, Unidata (the name is derived from "university data") was intended to meet the needs of college-level instructors and researchers. Though these requirements led to a number of differences (e.g., Unidata has been an early adopter of the open Internet, where the NWS has relied more heavily on private networking), there are important commonalities and parallels between the AWIPS and Unidata experiences.

2. PUSH-STYLE DATA DISTRIBUTION

Needs for data from observing systems and, increasingly, from computer models and assimilation systems have long bound the academic and operational sectors. A common aspect of Unidata and AWIPS was their early emphasis on near-real-time delivery of data to multiple recipients. In fact the earliest tangible Unidata accomplishment (in 1985, partnering with a private firm) was to establish a data broadcast system utilizing C-band satellite transmission, similar to the primary AWIPS data delivery mechanism (also called NOAAport in some contexts). Though the Unidata broadcast had much lower bandwidth than the present NOAAport, it established the technical practice of disseminating large volumes of current data to distributed sites, each of which potential may retain all of the data, but typically skims off only the data of interest.

Widespread availability of Internet technology has altered the model, especially in Unidata, but the importance of push-style, one-to-many data dissemination remains high. In contrast to "pull" (i.e., request-based) systems, "push" systems are event-driven, and thus minimize the delay between data creation and data availability. Unidata's Internet-based implementation of push-style data delivery (where products are immediately relayed from one computer to another until all recipients have been served) is now being used experimentally in the AWIPS context to supplement NOAAport for disseminating high-resolution radar data and model outputs.

3. JUST-IN-TIME DATA ANALYSIS

One motivation for AWIPS was to shift from the delivery of graphical products (as manifest in AFOS and the earlier NWS reliance on facsimile maps) toward the delivery of primary data, which may be analyzed by increasingly powerful workstations in forecast offices and other end-user venues. A parallel transition has occurred in Unidata. Universities initially placed much value on Unidata support for acquiring DIFAX services and ready-to-view satellite images, but the interest in these capabilities has shifted steadily toward the greater flexibility afforded by systems that perform on-the-fly analysis of primary data, in response to the needs of end-users (i.e., faculty or students).

In fact, some of the NWS and Unidata tools for just-in-time data analysis are essentially identical. The NAWIPS software, known to Unidata users as GEMPAK, has long been a staple for university meteorologists. Used extensively in both research and instruction, a favorite aspect of GEMPAK is its capability for creating and displaying predefined and user-defined diagnostic variables.

4. SELF-DESCRIBING DATA SETS

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A major Unidata contribution to the data management world has been the netCDF library. This library, targeted for software developers, includes highly portable tools for the creation of machine-independent, self-describing files of scientific data. The system effectively handles most types of data, ranging from point observations to grids of arbitrary dimensionality. First released by Unidata in 1988, the netCDF file format remains unchanged from the original, even though there have been numerous advances in the associated access library, including an all-Java implementation that is genuinely "object oriented" in nature. NetCDF has become a de facto standard in many disciplines, and it is deeply embedded in the AWIPS software, as the internal representation for decoded data. The use of netCDF in AWIPS, and the schema employed, are outgrowths of interactions between developers at Unidata and at the Forecast Systems Laboratory (FSL), where much of the AWIPS software was designed.

The implications of netCDF in AWIPS are important. From an architectural perspective, it is an "open systems" approach, meaning that data are stored in a non-proprietary format and may be accessed via published, well-defined interfaces (i.e., via the netCDF library). The portable natures of the netCDF library and netCDF files imply that AWIPS can be re-implemented on a wide variety of hardware platforms without altering its underlying data access mechanisms. The mechanism for "self-description" embedded in netCDF files yields great flexibility for the evolution of AWIPS. For example, if a new variable is added to a netCDF data set, old programs will be unaffected, because they retrieve the data they need by name, not by position in the file. If a new type of processing is needed, programmers will find much of the information they require (such as units of measure, time stamps, and geolocations) to be embedded directly as "attributes" of the netCDF file, thus accelerating implementation and reducing errors.

5. REGIONAL SPECIFICITY IN DATA USE AND COMPUTATION

The aforementioned emphasis on primary data, rather than graphical products, has helped AWIPS achieve useful degrees of regional specificity, such as a "forecast funnel" focused on the area of direct concern to the local forecaster. This approach was reinforced by the design of the 88D radar network, in which real-time access to full-resolution (Level II) data has been available only on the nearest AWIPS workstation or--by special arrangement--to researchers, typically in a nearby university. Access to the 88D network as a nationwide "system" has been limited to less detailed (Level III) radar "products" or to retrospective views, assembled long after the fact from archival tapes of Level II data.

Recent experiments involving Unidata, Unidata universities (especially the University of Oklahoma), the National Climatic Data Center, the National Severe Storm Laboratories, and the AWIPS team are setting the stage for real-time access to all Level II data from the 88D network. These experiments are demonstrating the feasibility of this goal through the use of Unidata technology in conjunction with high-speed networking, as manifest in the Abilene Network (developed by the Internet2 community). Associated studies are detailing the forecast improvements that can be gained by incorporating Level II data *from multiple radars* into regional mesoscale models.

The results so far suggest that additional benefits from the NWS investment in AWIPS will be gained when the technology is in place to treat the 88D network as a truly integrated national system, providing input to high-resolution computer models and other systems. The potential gains include unprecedented accuracy, built on regional specificity, plus significant progress in difficult areas, such as quantitative precipitation.

6. A NEW ERA OF DATA USE, LINKED TO SOCIETAL NEEDS

The experimental merging of Unidata and AWIPS technologies in respect to the radar network is but one example of potential new synergies between the academic and operational communities. Similar progress is being made toward university access to outputs from the latest, highest-resolution models being run by the National Centers for Environmental Prediction. It is reasonable to speculate that--as companies worldwide increase their use of the Internet for crucial business transactions--the NWS will increase its reliance on that medium (push or pull) for data conveyance. To this end, additional merging of Unidata and AWIPS technologies may transpire.

Another shift in data usage patterns is taking place in Unidata: the software for analyzing and displaying information is increasingly capable of operating directly upon data sets that are maintained on *remote servers* rather than local files. More specifically, this functionality is built into the McIDAS software (which Unidata distributes through the good graces of the University of Wisconsin-Madison), and it is being designed into the new suite of Java-based software Unidata is planning for release in 2003. Though not part of the current AWIPS planning (to the authors' knowledge), this capability may be viable for some future version of the system.

The differing requirements of the AWIPS and Unidata communities almost certainly preclude a complete joining of technologies. However, it is equally certain that significant gains will continue to accrue through the cross-fertilization that arises from the common interests of these communities and from their parallel advances in the applications of Internet technology. One area of shared interest that seems ripe for additional exploration is the societal impact of weather and climate. This topic appears to be gaining importance in both the operational and academic communities, and both face similar challenges:

- Scientists and operations personnel must learn new terminologies and methodologies to allow effective interactions between the meteorological and hydrological fields and those pertaining to social impact, such as emergency management, hazard mitigation, and energy production.
- Pertinent data, such as demographics, are difficult to acquire and use in the conventional AWIPS and Unidata toolkits.
- Most potential partners in the social impact arena are avid users of Geographic Information Systems (GIS), so effective collaboration may require a variety of adaptations to AWIPS and Unidata toolkits, modes of data representation and transmission, forms of data access, etc.

These and other challenges facing the operations and academic communities can be lessened through collaboration and the sharing of technology. In particular, the positive relationships that have been developed between AWIPS and Unidata will continue to serve both communities well.