18.10   DEOS: The Delaware Environmental Observing System

David R. Legates[1†], Daniel J. Leathers[1], Tracy L. DeLiberty[1], Geoff E. Quelch[1],
Kevin Brinson[1], Jason Butke[1], Rezaul Mahmood[2], and Stuart A. Foster[2]
[1]Center for Climatic Research, University of Delaware, Newark, Delaware
[2]Kentucky Climate Center, Western Kentucky University, Bowling Green, Kentucky

1. Introduction

The Delaware Environmental Observing System (DEOS) is a tool for decision makers involved with emergency management, natural resource monitoring, transportation, and other activities throughout the State of Delaware and the Delmarva Peninsula. DEOS provides both State agencies and the citizens of Delaware immediate information as to environmental conditions in and around the State.

DEOS is a real-time system dedicated to monitoring environmental conditions. DEOS consists of three main components: (1) the DEOS Environmental Monitoring and Observing Network (DEMON), a network of approximately thirty meteorological observation sites coupled with existing weather observation stations in and around Delaware, (2) the DEOS Integrated Visualization and Analysis System (DIVAS), which integrates surface weather observations with National Weather Service WSR-88D radar estimates of precipitation, thereby providing estimates of meteorological and environmental variables over a high spatial resolution grid, and (3) DEOS Analysis Systems (DAS), designed to provide decision support in a variety of environmentally-sensitive areas. (see http://www.deos.udel.edu)

2.   The DEOS Environmental Monitoring and Observing Network (DEMON)

To make appropriate decisions regarding weather-related emergencies, decision makers must have meteorological data with the highest spatial and temporal resolution possible. But more importantly, these data must be of the highest quality, readily available, and easily applied to decision support applications. We address these issues through the DEOS Environmental Monitoring and Observing Network (DEMON). Primary components of the DEMON include (1) integration of existing station observations from federal, state, and local sources both within Delaware and from surrounding states, (2)

installation of between twenty and thirty additional meteorological observation sites in and around Delaware, (3) connection of the existing and new sites to a central data collection facility through use of existing telecommunications capabilities, (4) adoption of reliable data quality control and quality assurance procedures, (5) redundant computers for data ingest and processing, and (6) incorporation of adequate and timely data dissemination to all participating state agencies, the National Weather Service, and the public.

Existing station observations are incorporated into the DEMON to both enhance spatial coverage and to minimize redundancy. A number of state and federal agencies already have invested time and money to install observing sites. We have, where practical and with permission of the agency that owns existing sites, agreed to upgrade instrumentation and provide routine maintenance. Inclusion of data from outside Delaware is vitally important since the environment does not stop at the State boundary. Moreover, we have already installed eight and propose to install a total of twenty additional meteorological sites, reporting every five-minutes, to enhance the spatial resolution of data throughout the State. To provide real-time retrieval of station observations, we presently use telephone and Internet connections; ultimately, we propose to use the State's 800MHz microwave network to provide station connectivity to alleviate the potential problems associated with the loss of telephone lines and the Internet during emergency situations.

One of the fundamental components of DEOS will be the maintenance of existing observation sites, including the assessment of data quality control and timely replacement of defective sensors. Moreover, we propose redundant sites for data ingest and processing – at both the Center for Climatic Research at the University of Delaware and either the DEMA/DelDOT facility in Smyrna or the College of Marine Studies in Lewes (possibly both). Redundancy will provide a safeguard if one site should fail or need to be taken offline for routine maintenance. Finally, Internet access

---

[†]Corresponding author address: David R. Legates, Center for Climatic Research, University of Delaware, Newark, DE 19716: email: legates@udel.edu.

will be made available to all participating state agencies, the NWS, and the general public. Presently, we provide real-time data from DEOS directly to the NWS in Mt. Holly NJ via SHEF format. Special access by state agencies and the NWS will be afforded to ensure that public demand does not delay access to necessary agencies.

The USGS operates a network of 15 long-term streamflow-gaging stations, 6 tidal gages, and numerous water-level recorders in wells to collect data needed for assessing and evaluating hydrologic conditions. Most of these gages are operated in cooperation with the Delaware Geological Survey (DGS), Delaware Departments of Natural Resources and Environmental Control (DNREC) and Transportation (DelDOT), EPA, and the U.S. Army Corps of Engineers. DNREC also operates a number of water quality stations, which are incorporated into the DEMON. These data also are ingested into the DEMON as well and are monitored in real-time.

The processing and display system is a Linux-based workstation that affords both graphic and text visualization of station data for both real-time and historical analyses. Duplication of software at multiple sites will ensure continuous temporal coverage. An Oracle database is used to allow for easy data access and retrieval.

As of November 2004, DEOS has installed two weather stations in New Castle County, two in Kent County, and four in Sussex County in Delaware, as well as a station in Cecil County, Maryland and two stations in Chester County, Pennsylvania. We also have brought on-line ten additional stations in Delaware, through cooperation with existing sites supported by the Natural Estuarine Research Reserve, the Delaware Solid Waste Authority, and Christiana Care Hospitals. All sites feature research-quality instrumentation, purchased from Campbell Scientific Inc. and R.M. Young. Ultimately, we plan to install as many as ten additional sites, including coverage every five miles from the middle of Delaware Bay (Kitts Hummock in Kent County) to Assateague Island (in Maryland along the Atlantic Coast).

3. The DEOS Integrated Visualization and Analysis System (DIVAS)

While surface observations are a necessary component of any environmental observing system, meteorological fields vary considerably at spatial scales far below the resolution possible from any statewide network. Owing to the large spatial coherence that exists for nearly every meteorological variable, sophisticated spatial interpolation methods can be used to estimate data values between the observations. Incorporating the effects of topography and/or land cover can enhance estimates for many variables, such as air temperature and windspeed. In addition to presenting the surface observations, we utilize a system to provide both graphical and digital representations of the spatial distribution of the meteorological variables measured by the DEMON.

DIVAS is a real-time, operational system that provides high-resolution, spatially distributed, digital data products from both surface observing systems as well as the NWS's WSR-88D weather radars. This system produces both graphical and digital products that can be used for monitoring and analyzing meteorological or hydrological conditions for a particular location or a region. Moreover, this system will be comprehensive; that is, it will provide analysis capabilities by itself as well as provide output data that can be imported to a variety of other applications.

In addition to relying solely on surface observations to provide meteorological inputs, the advent of Doppler weather radar has allowed high spatial resolution estimates of precipitation to be made available from the national network of WSR-88D weather radars. One of the major advantages is that the DIVAS will be able to provide rainfall estimates from multiple WSR-88D weather radars – calibrated using raingage observations – at a spatial resolution of 16 km^2. The DIVAS system, when coupled with raingage observations from the DEMON, provides high-resolution (spatial and temporal) estimates of rainfall rates. The Spatial Meteorological Analysis in Real-Time System (SMARTS) is the component that provides the interaction with and maintenance of the Oracle database as well as the development of gridded products.

SMARTS is designed such that it can be easily tailored to suit most environmental applications. In particular, it is designed to function as a real-time weather analysis system in a stand-alone framework – without the need for constant user intervention or supervision. It is integrated within the DEOS to generate a suite of gridded meteorological products in real-time and processes data from multiple WSR-88D radars that cover Delmarva to provide a better coverage and multiple radar view angles than could be obtained simply from a single radar. These precipitation estimates from the WSR-88D weather radars are calibrated using raingage measurements to develop a calibrated radar precipitation product. Its calibration algorithms specifically address areas where over-estimates or under-estimates of precipitation can occur. Precipitation is obtained from four radars – KDOX in

Ellendale (DE), KDIX in Fort Dix (NJ), KLWX in Sterling (VA), and KAKQ in Wakefield (VA). Use of more than one radar is advantageous in that coverage is still afforded if one or more radars are unavailable and multiple views of storms are provided. SMARTS is currently under development, although the database storage and retrieval of data presently is functional.

Extensive diagnostic and informative information is produced by the DIVAS for processing control and to log all processing events, including exceptions encountered during processing. It also will be upgraded to notify appropriate individuals or groups when extreme conditions (*e.g.*, heavy rainfall, high winds, station outages, precipitation below freezing) are encountered through electronic mail, text paging, and/or other forms of communication. Text messages, watches, and warnings issued by the National Weather Service also will be available from the DIVAS system. Specific updates to other appropriate systems within various State agencies will be available. A graphical user interface also will be incorporated into the system for system initialization and changes and to control processing parameters.

DIVAS will be based on ESRI's ArcGIS 9.0, the latest and most feature-rich implementation of Geographic Information Science (GIS) available. The advantage of using ArcGIS is that it provides a powerful interface for presenting geographically distributed data using a server-side application to a client via a web browser. Other systems often require much software and computing power on the client side as the server simply downloads data to the client. Here, however, the server is responsible for processing and analysis based on user inputs and the results are distributed to the clients. Thus, data transfer is minimized and the presentation of results is not limited by the computing power of the client. This is particularly important in that many emergency managers in the field use handheld PDAs with limited computational power and bandwidth.

4. DEOS Analysis Systems (DAS)

A series of DASs provide decision support in a variety of environmentally sensitive areas. The data acquired by the DEMON and processed by the DIVAS can be extensive. Few applications require all of the products produced by DEOS – most depend primarily on a single variable or two. For example, we have proposed to develop a DAS to select information specifically tailored for mosquito control officials.

More pressing, however, is recent flooding resulting from heavy rainfall on the basins in upper New Castle County and along the coastal areas of Sussex County

during tropical storm and nor'easter passages. To assist in this area, DAS FLUSS is being developed – a DAS dedicated to the real-time monitoring and notification of stream and coastal flooding (Flooding of Land Under Storm and Surge). The system provides early warning when heavy rainfall may lead to significant flooding within specific watersheds or when specific conditions (wind speed and direction, rainfall, and astronomical conditions) may cause coastal flooding. Special "SMARTS Data Alerts" are Oracle database triggers that provide a predetermined system response when a specific event is detected. These "SMARTS Data Alerts" are configured to allow critical notification of emergency personnel of potential impending flooding conditions in the downstream portions of the basins that are susceptible to flood damage. DAS FLUSS provides DEOS with the capabilities needed to monitor and warn appropriate personnel of developing weather situations.
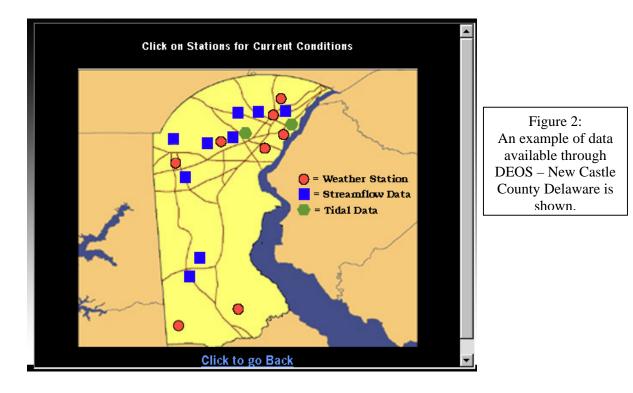
5. Extension of DEOS beyond Delaware and Delmarva

While much of the focus and early funding has focused on the development of DEOS to monitor environmental conditions across Delaware and Delmarva, DEOS has been designed to be transportable. DIVAS and various DAS systems are not designed specifically for Delaware, but can be expanded and extended to areas outside of Delmarva. As such, the Kentucky Climate Center at Western Kentucky University and other State Climate Offices have expressed interest in teaming with DEOS to extend its software and concepts to cover their respective areas. In Kentucky, for example, flash flooding is a serious concern. Collaboration with researchers at the development level is important so that DAS FLUSS is tailored with a number of flooding problems in mind – from heavy rain on rugged terrain to coastal flooding from strong storms to flooding of the Back Bays of Delaware when winds prevent heavy rainfall from draining through the narrow Indian River Inlet.

6. Summary and Future Outlook

DEOS is a work in progress and will take a number of years to fully reach its potential. At present, we are actively working to instrument Delaware with a high-resolution network of a number of environmental variables, not just weather – thus, completing the DEMON is our first goal. But concurrently, DIVAS and a number of DASs are being developed, which will provide a state-of-the-art environmental monitoring system. With the continued assistance and cooperation of a number of State and Federal Agencies, DEOS will hopefully become a useful tool for environmental monitoring and analysis.

Figure 1: The current DEOS homepage. See http://www.deos.udel.edu.

Figure 2:
An example of data available through DEOS – New Castle County Delaware is shown.

ODD-DIVAS Current Data - Microsoft Internet Explorer

Station: DAGF: Newark, DE

Elevation: 106 ft.

Latitude: 39° 40' N

Station Type: DEOS

Longitude: 75° 45' W

Date: November 8, 2004

Updated: 7:20 pm

Observations

Data Type	Measurement	Time	Chart	Data
Precipitation	0.00 in	7:20 pm		
24-hour Precipitation	0.00 in	7:20 pm		
Temperature	41.4 °F	7:20 pm		
Dewpoint Temperature	26.5 °F	7:20 pm		
Relative Humidity	45 %	7:20 pm		
Barometric Pressure	30.30 inHg	7:20 pm		
Solar Radiation	0.0 W/m^2	7:20 pm		
Wind Speed	Calm	7:20 pm		
Wind Gust (5)	Calm	7:20 pm		
Wind Direction	Calm	7:20 pm		
Volumetric Water Content	34.4 %	7:20 pm		

Change to SI units

Station updates every 5 minutes

Note: All observations were obtained from the Delaware Environmental Observing System network

Figure 3:
An example of the ODD-DIVAS (Operational Data Display) output available from each DEOS station. Users can retrieve both real-time observations as well as historical data from the DIVAS database.
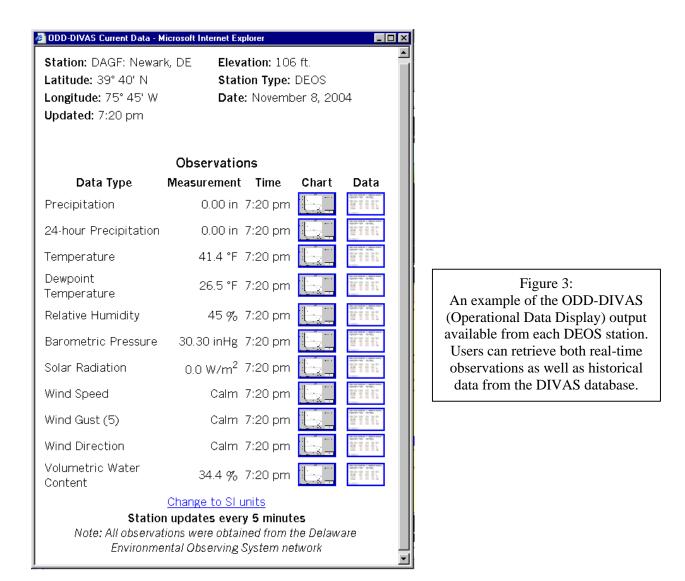
Figure 4:
Example of the graphical display available from the ODD-DIVAS system.

Temperature

Latest Values
Air: 41 F
Dew: 26 F
RH: 45 %

Air
Dew Point
Rel. Hum.

Time [hr]

SN: 1099959953-T