FINAL REPORT

PROJECT HWY-2005-26

Multi-sensor Precipitation Estimates in Support of NC DOT's Stormwater Quality Monitoring

by

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May 1, 2006

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Technical Report Documentation Page

1. Report No. **FHWA/NC/2006-04**	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle **Final Report on Multi-sensor Precipitation Estimates in Support of NC DOT's Stormwater Quality Monitoring.**		5. Report Date **May 1, 2006** 6. Performing Organization Code
7. Author(s) **Mark Brooks, Ryan Boyles, Aaron Sims, Sethu Raman**		8. Performing Organization Report No.
9. Performing Organization Name and Address **State Climate Office of North Carolina** **North Carolina State University** **Raleigh, NC 27695-7236**		10. Work Unit No. (TRAIS) 11. Contract or Grant No.
12. Sponsoring Agency Name and Address **North Carolina Department of Transportation** **Division of Highways, Roadside Environmental Unit** **1 South Wilmington Street** **Raleigh, North Carolina 27699-1557**		13. Type of Report and Period Covered **Final Report** **January 1, 2005 – December 31, 2005** 14. Sponsoring Agency Code **HWY-2005-26**
Supplementary Notes: **Supported by the North Carolina Department of Transportation through North Carolina State University.**		

16. Abstract

This project was undertaken to develop an Internet resource to monitor local precipitation at DOT work sites. A website was developed for NCDOT staff to login, define locations of interest and be notified if precipitation at those locations exceeds a defined threshold. The website also enables the user to view precipitation estimates spatially and in tabular format.

17. Key Words **Precipitation, estimates, monitoring, stormwater quality**	18. Distribution Statement		
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages **16**	22. Price

Form DOT F 1700.7 (8-72) **Reproduction of completed page authorized**

Acknowledgements

Support for this project was provided by the North Carolina Department of Transportation in cooperation with North Carolina State University.

The project team is grateful to Bob Holman, Matt Lauffer, and all other NCDOT staff who helped test the initial deployment of the system.

Raw data is provided by the National Centers for Environmental Prediction (NCEP) and the National Weather Service (NWS) River Forecast Centers.

Disclaimer

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1.0 INTRODUCTION

The State Climate Office of North Carolina (SCO) developed a Multi-sensor Precipitation Estimates (MPE) website for the North Carolina Department of Transportation Highway Stormwater Program. This website enables engineers to closely monitor estimated precipitation amounts at user-defined locations. Users can define their own latitude/longitude monitoring sites and receive an e-mail alert when precipitation at that location has exceeded a particular threshold. Additionally, a map interface was developed, which allows for spatial visualization of precipitation estimates. Future work should include enhancements to the map interface and overall maintenance of the system.

1.1 Background

Development of this project is in response to a general requirement in NCDOT's Stormwater NPDES Permit for rainfall monitoring. DOT engineers need to know when rainfall amounts at each road construction site have exceeded one-half inch in a 24-hour period.

A conventional approach would be to deploy automated rain gages and dataloggers to record precipitation at each construction site. This would be very accurate but requires on-site staff, regular maintenance to ensure accuracy, and redeployment of gages as construction sites move. The logistics of implementing this would be difficult and costly. The project between the SCO and NCDOT employs a more sophisticated approach using Doppler radar precipitation estimates and the Internet.

The National Weather Service operates a network of Doppler radars across the nation. One of the standard products from these radars is hourly-precipitation estimates. When corrected with ground-truth rain gages, an innovative multi-sensor precipitation estimate is produced. Accuracy of the estimates over the Carolinas is described in section 1.5 of this document.

The State Climate Office of North Carolina is a public service center housed at NC State University. Part of its mission is to support state agencies with local weather and climate data and expertise. The SCO has a team of meteorologists with expertise in radar meteorology and applications development.

1.2 Project Objectives and Deliverables

The purpose of the project was to develop an Internet resource to monitor local precipitation at DOT work sites.

The two deliverables required in the contract were:

1. A webpage accessible by DOT staff with daily updated graphical and tabular estimates of 24-hour precipitation (12-hour precipitation if data is available).
2. Software to send e-mail alerts to DOT staff when rainfall exceeds 0.5 inches at specified work sites.

Both products were fully developed and delivered on schedule.

1.3 Project Challenges and Achievements

Development of the interface could not begin until software was written to obtain and process the digital gage-corrected radar precipitation data. Doing so consumed about nine months of the project time. Several different methods were attempted to archive the data locally before ultimately devising the most efficient method.

One challenge that still remains is the timeliness of obtaining new data from NCEP. The data files contain precipitation estimates ending at 1am, 7am, 1pm, and 7pm EST. The actual files however are typically not available until 3-9 hours later. Fortunately, this issue is generally not a problem for this project.

Another challenge is the quality of the data. The SCO is downloading three types of files: accumulated hourly precipitation estimates in 1-hour increments, 6-hour estimates in 6-hour increments, and daily estimates in 24-hour increments. The 1-hour data files are suspect to inaccuracies and errors, and were not used for this project.

Towards the end of the project timeline, progress was going well and SCO staff began to experiment with new technologies to visualize the precipitation estimates. This resulted in the development and delivery of the map interface, which enables spatial visualization of the data overlaid with county lines, city names, DOT primary and secondary roads, and water features.

The SCO went beyond the requirements of the contract and developed additional tools for the webpage:

1. User-defined thresholds. Rather than a site having a default precipitation alert threshold of one-half inch in 24-hours, the user can define their own precipitation amount in 6, 12, 24, or 48 hours.
2. Hourly and daily precipitation accumulated estimates for a user-defined location and date range (starting in 2002). This enables engineers to look at historical data and graph it on-the-fly.
3. Map interface. This enables the user to spatially see accumulated precipitation amounts over the last 6, 12, 24, 48, 72 hours, and 7, 30, and 90 days. The user can zoom-in on an area and turn on/off

interstates, primary and secondary roads, shaded relief, water features, and their user-defined construction sites for reference.

1.4 Methodology

The SCO identified and obtained digital precipitation estimates from NCEP at a resolution of 4.765 kilometers. Software was written to archive the data locally in NETCDF format, which allows for rapid retrieval and manipulation. Software was also written to automatically download new data from NCEP when it becomes available.

The user-defined locations are stored in a MySQL database and linked with their unique website login credentials. When new data are downloaded, a program is run to compare the 6-hour precipitation estimates with all user-defined locations and thresholds. If the estimated precipitation amount at a particular site exceeds the threshold set for that site, another program is automatically executed to generate e-mail alerts. The local date and time of when the alert e-mails were generated for each site are saved for reference and system debugging.

A “My Projects” webpage was developed to show precipitation estimates in tabular format for the previous 6, 12, 24, and 48 hour time periods. Sites are grouped by Project. A project can have an unlimited number of sites. By default, the user only sees the projects that s/he is subscribed to. A link at the top of the page lets the user see all projects and subscribe to receive alerts from them. If the user created a project, they can add or delete sites from it. Otherwise, the user can only (un)subscribe to it. If an alert has been issued for a particular site, it is highlighted for recognition. Links beside each site let the user view a NWS forecast or retrieve past data.

The map interface employs several different scripting languages and libraries. The map is built by PHP interfacing with an open-source GIS called MapServer. When a map is requested by the webpage, a perl script is run that gets the data from local NETCDF archives and generates a GIS shapefile. The shapefile is then read by MapServer, which is manipulated by PHP to produce a webpage. Because web pages are stateless, meaning that each request to the server is treated as new, the map images are uniquely generated on-the-fly with random filenames. This ensures that each user’s request for a map is processed individually and that what the user asked for is what they get, regardless of how many concurrent users are requesting a map.

1.5 Comparisons with Observed Data

There are possible errors associated with these radar-based precipitation estimates. Regional seasonally averaged RMSE for 24-hour totals range from

0.019 inches in the winter to 0.028 inches in the summer. The annual regional average RMSE is 0.023 inches over a 24-hour period. Additional details on the evaluation of MPE are available online in a conference abstract: *http://www.nc-climate.ncsu.edu/rpboyles/ams_hydrology_conf_2006_complete.pdf*

2.0 INTERFACE

Screenshots of the interface are provided below in Figures 1 – 7. Features of each aspect of the interface are described in the Figure captions.

2.1 Map

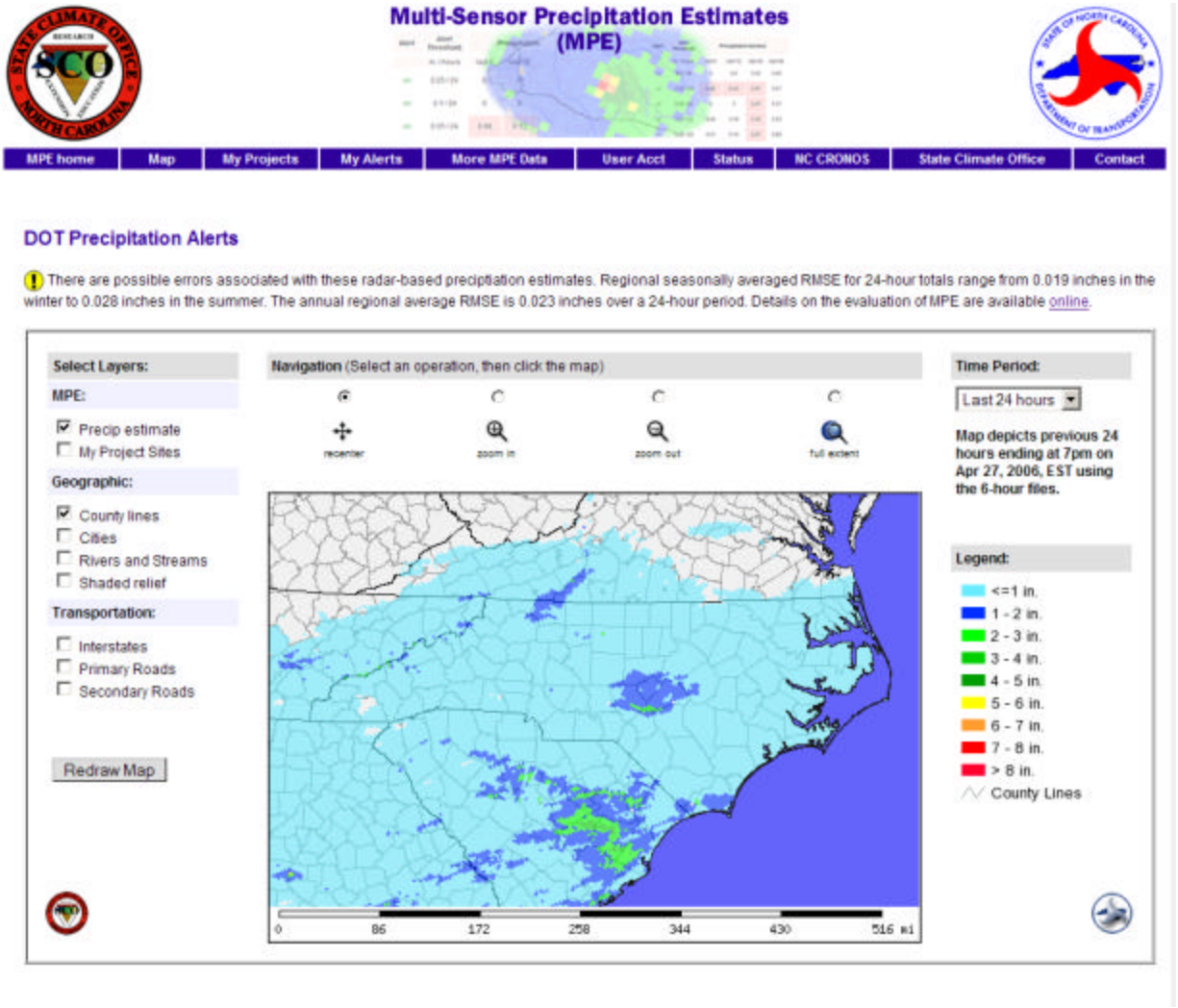


Figure 1. The map interface enables the user to spatially visualize precipitation estimates. The interface is a simplified GIS via the web. On the left, the user can turn on and off various layers. At the top right, the user can change the time period of data to plot.

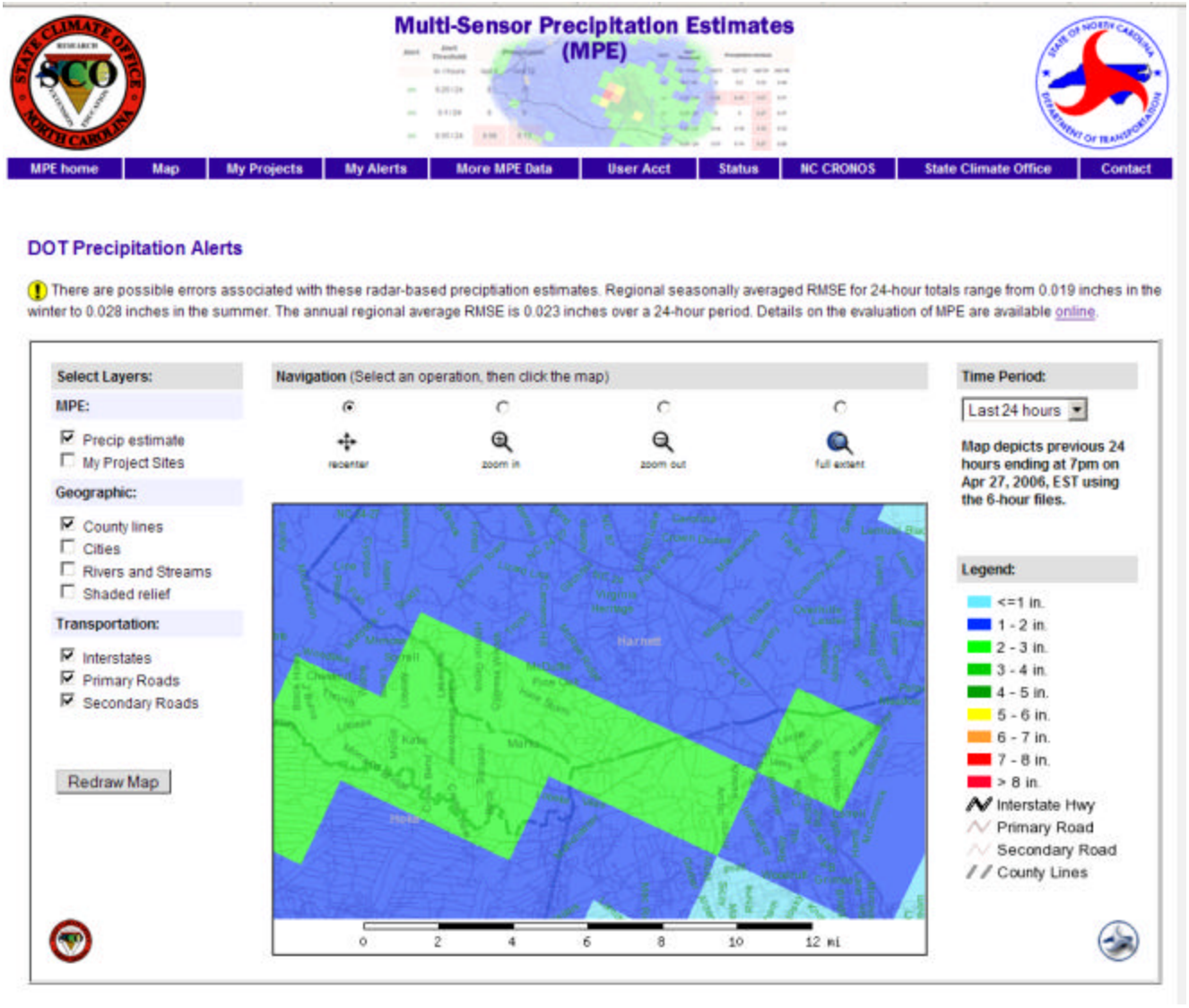
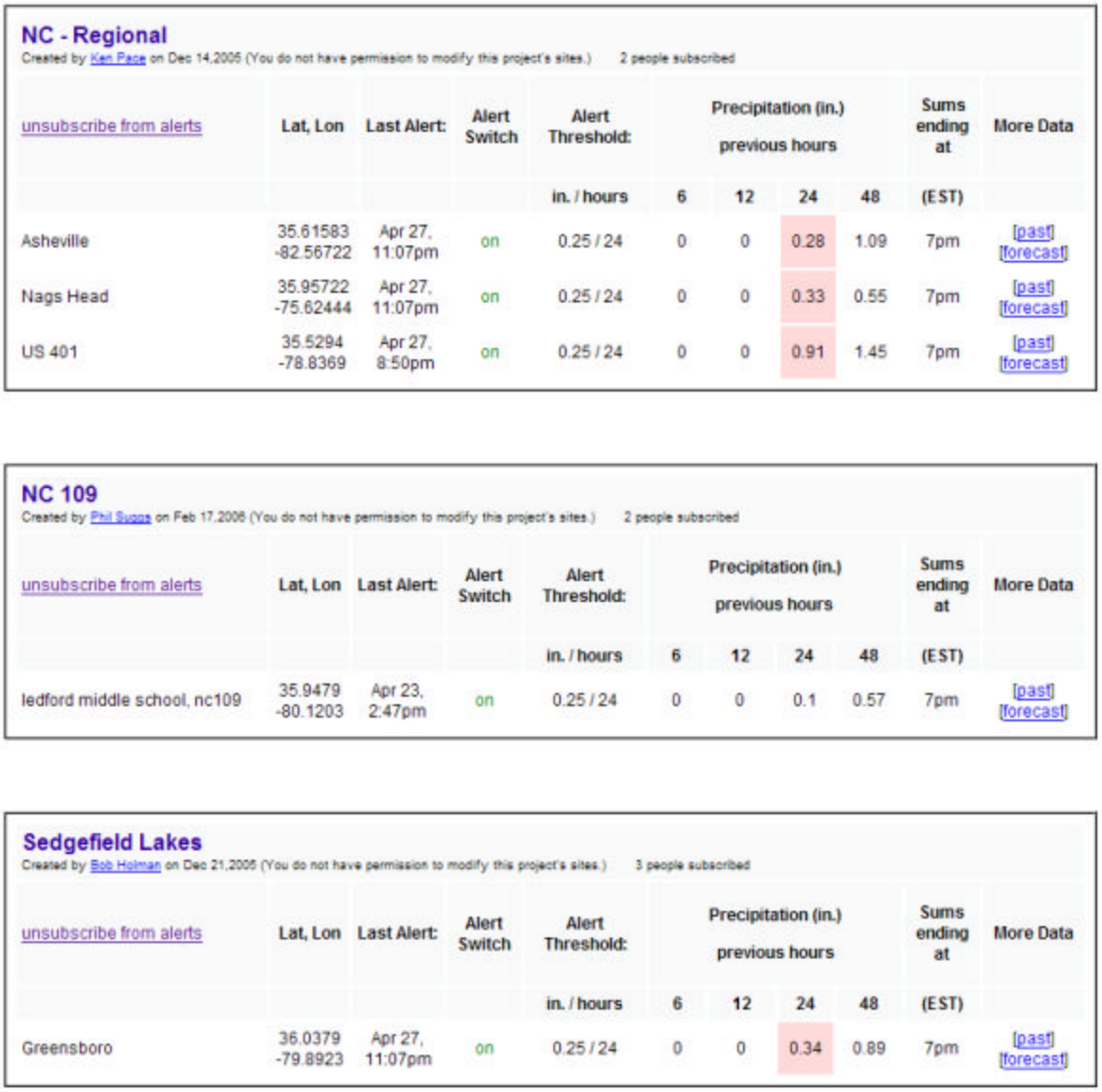


Figure 2. The map interface enables the user to zoom-in to a desired extent. The figure above is zoomed-in on southern Harnett County. DOT primary and secondary roads are drawn for reference. This can be turned on and off by the user on the left side of the map.

2.2 Output in Tabular Format



NC - Regional

Created by Ken Pace on Dec 14,2006 (You do not have permission to modify this project's sites.) 2 people subscribed

unsubscribe from alerts	Lat, Lon	Last Alert:	Alert Switch	Alert Threshold:	Precipitation (in.) previous hours				Sums ending at	More Data
				in. / hours	6	12	24	48	(EST)	
Asheville	35.61583 -82.56722	Apr 27, 11:07pm	on	0.25 / 24	0	0	0.28	1.09	7pm	[past] [forecast]
Nags Head	35.95722 -75.62444	Apr 27, 11:07pm	on	0.25 / 24	0	0	0.33	0.55	7pm	[past] [forecast]
US 401	35.5294 -78.8369	Apr 27, 8:50pm	on	0.25 / 24	0	0	0.91	1.45	7pm	[past] [forecast]

NC 109

Created by Phil Suggs on Feb 17,2006 (You do not have permission to modify this project's sites.) 2 people subscribed

unsubscribe from alerts	Lat, Lon	Last Alert:	Alert Switch	Alert Threshold:	Precipitation (in.) previous hours				Sums ending at	More Data
				in. / hours	6	12	24	48	(EST)	
ledford middle school, nc109	35.9479 -80.1203	Apr 23, 2:47pm	on	0.25 / 24	0	0	0.1	0.57	7pm	[past] [forecast]

Sedgefield Lakes

Created by Bob Holman on Dec 21,2006 (You do not have permission to modify this project's sites.) 3 people subscribed

unsubscribe from alerts	Lat, Lon	Last Alert:	Alert Switch	Alert Threshold:	Precipitation (in.) previous hours				Sums ending at	More Data
				in. / hours	6	12	24	48	(EST)	
Greensboro	36.0379 -79.8923	Apr 27, 11:07pm	on	0.25 / 24	0	0	0.34	0.89	7pm	[past] [forecast]

Figure 3. The "My Projects" webpage shows details of all projects and corresponding locations. The user can subscribe or unsubscribe from a project, which adds or removes that user from the e-mail alerts. If the estimated precipitation amount at a particular location has exceed the user-defined threshold, an e-mail alert is generated and it is highlighted on the "My Projects" webpage, as shown above. Links to the right of each location let the user get a point-specific forecast from the NWS and retrieve past data.

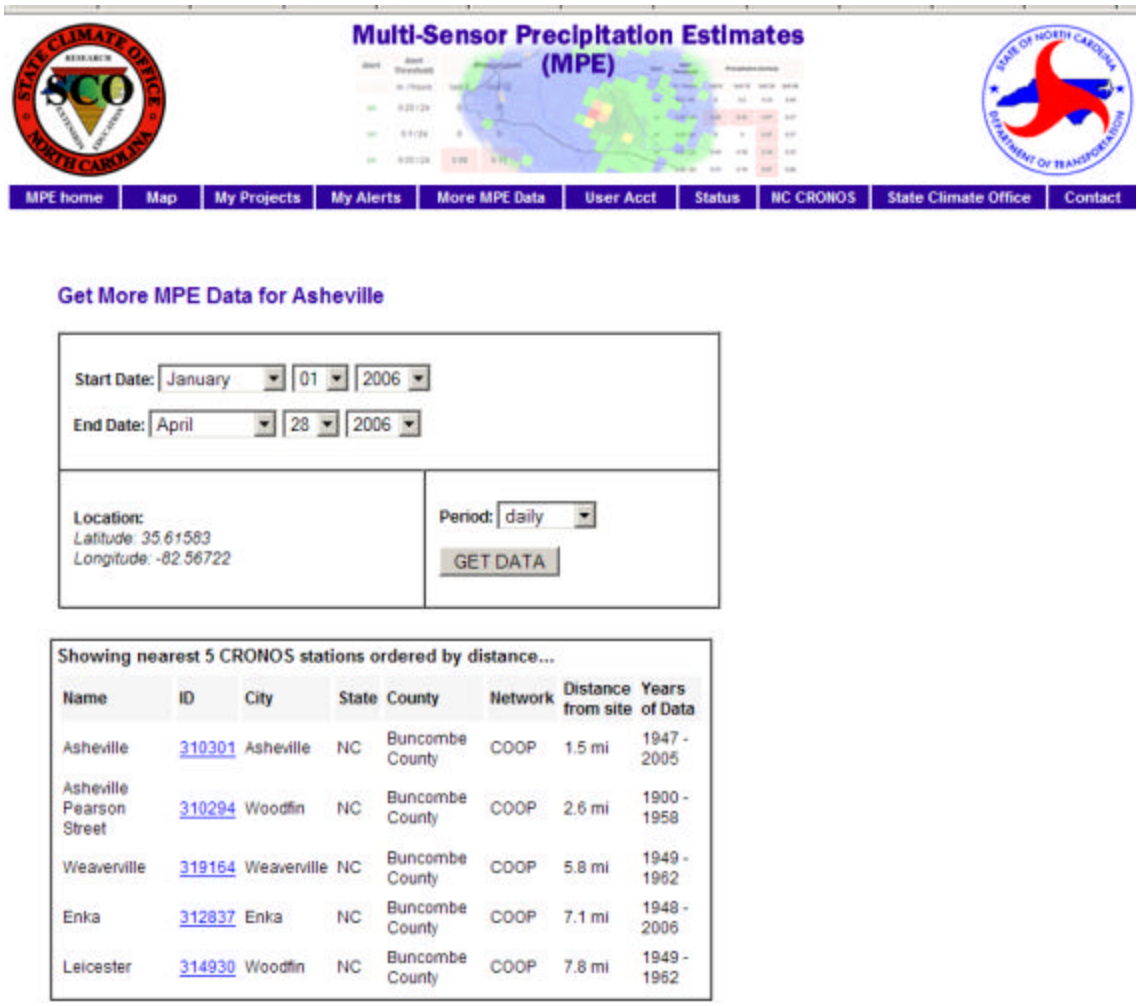


Figure 4. If the user clicks the link for a location to get more data, a page similar to this will be shown. The user can define any date range after 2002, indicate hourly, 6-hourly, or daily data and retrieve it. Also shown are the nearest five ground stations for reference and/or comparison. The user can also enter a different latitude/longitude if desired.

Observation Date & Time (EST)	Precipitation (inches)
2006-01-01 07:00:00	0
2006-01-02 07:00:00	0
2006-01-03 07:00:00	0.807
2006-01-04 07:00:00	0
2006-01-05 07:00:00	0
2006-01-06 07:00:00	0
2006-01-09 07:00:00	0
2006-01-10 07:00:00	0
2006-01-11 07:00:00	0.02
2006-01-12 07:00:00	0
2006-01-13 07:00:00	0
2006-01-14 07:00:00	0.622
2006-01-15 07:00:00	0
2006-01-16 07:00:00	0
2006-01-17 07:00:00	0.142

Figure 5. When retrieving more data, the output is formatted in an easy to read table. At the bottom of the tabular output, the total sum is displayed. By clicking the graphing icon above the precipitation column, a bar graph is generated and displayed over the same time period.

2.3 Graph of Data

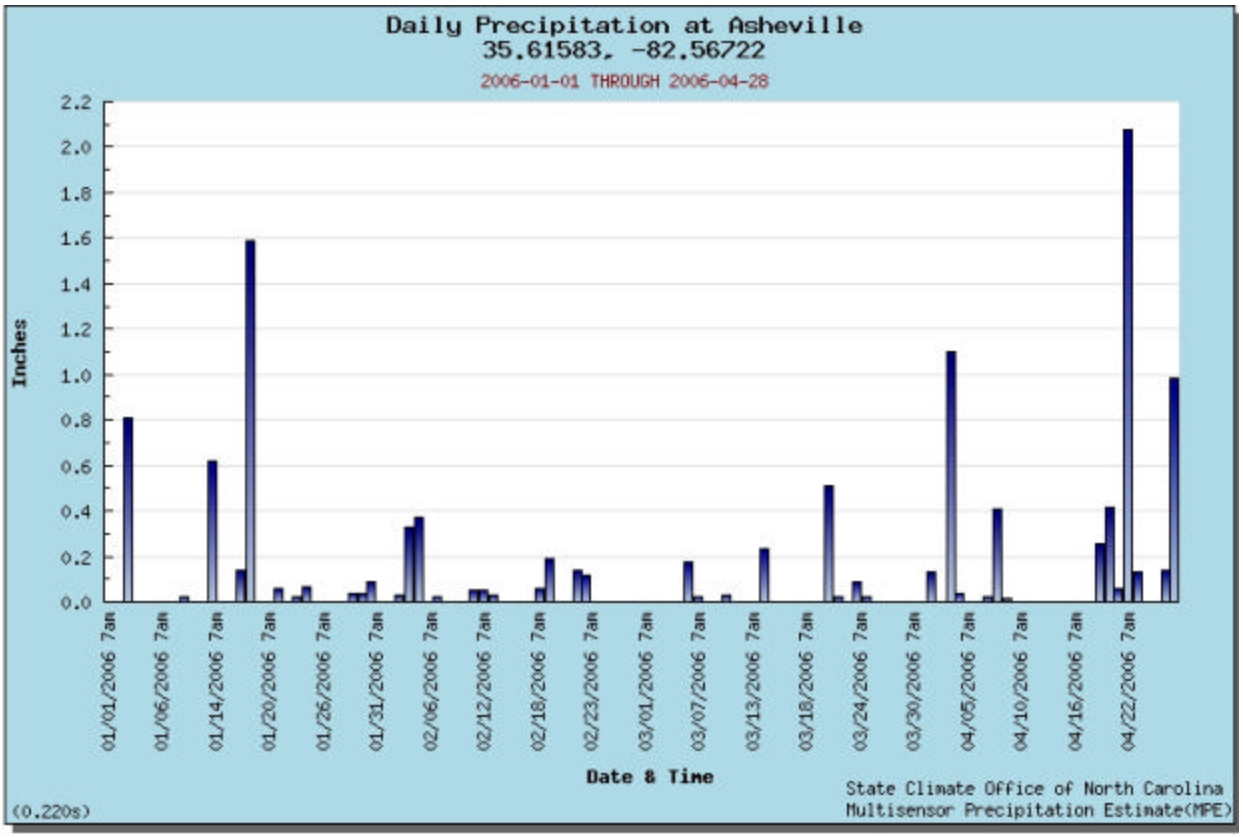


Figure 6. Time series graph of estimated precipitation for a user-defined location and time period.

2.4 E-mail Alerts

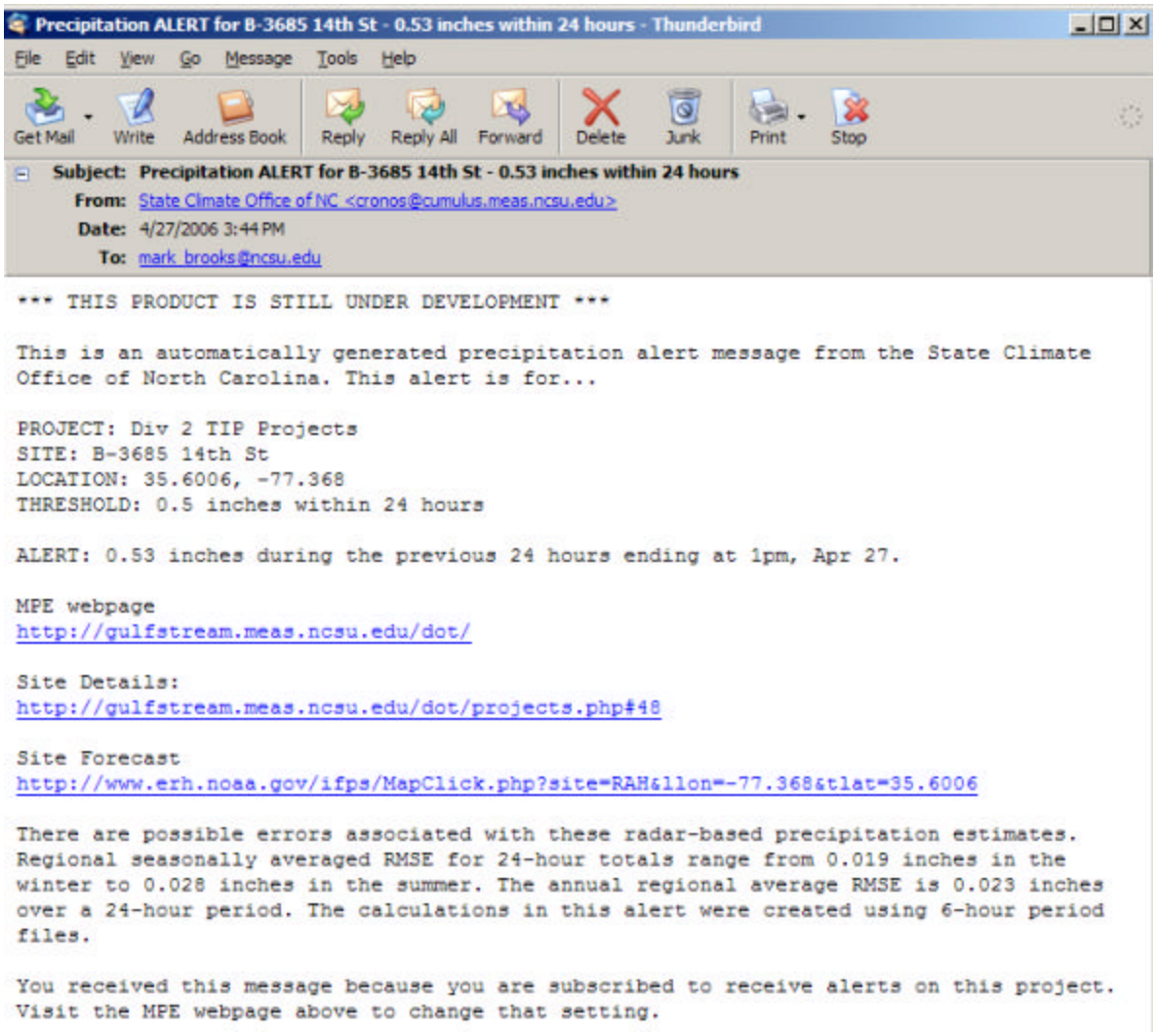


Figure 7. Sample e-mail output. The contents of the e-mail alert contain details about the site and the estimated precipitation amount. The alert is sent to all users subscribed to receive alerts from the project that the site is associated with.

3.0 OVERALL CONCLUSIONS AND RECOMMENDATIONS

The purpose of this project was to develop an Internet resource to monitor local precipitation at DOT work sites. The system developed is an innovative application of new technologies, data sources and open-source software packages, all of which are still maturing. The challenge for SCO staff was to bring all these technologies together into an intuitive and practical interface. The final product meets and exceeds the requirements of NCDOT.

3.1 Looking Ahead

Maintenance of the existing system is critical to ensuring reliable performance and operation. This includes software bug fixes and replacing failed hardware. A mirrored backup should be implemented so that if the primary computer were to fail, the entire system won't fail. A change in the format of digital data downloaded from NCEP is expected in 2006. This will need to be addressed in software written at the SCO to appropriately handle such a change.

New, more robust hardware will be needed as more NCDOT personnel begin using the website. The biggest strain on the system will be drawing maps for multiple users simultaneously. Additionally, as more user-defined locations are created on the website, more computing power will be required to generate alerts.

Many enhancements are possible and recommended. The map interface can be made more interactive. For example, software could be written that will enable the user to click a point on the map to create a new location to monitor. This would eliminate the need for the user to know precisely what the latitude/longitude is. AJAX could also be implemented. This would allow the user to manipulate the map without reloading the entire webpage, which will increase performance. These are some of the future options that NCDOT may consider.