Report as of FY2007 for 2006FL140B: "A comparison of FSU/NWS and OneRain precipitation data and their insertion into the WAM hydrologic model"

Publications

- Conference Proceedings:
  - Fuelberg, H.E., S.M. Martinaitis, J.L. Sullivan, Jr., and C.S. Pathak, 2007: An intercomparison of precipitation values from the OneRain Corp. algorithm and the National Weather Service Procedures. World Environmental and Water Resources Congress, Tampa, May 2007, in press.
  - Fuelberg, H.E., D.D VanCleve, Jr., and T.S. Wu 2007: An intercomparison of mean areal precipitation from gauges and a multisensor procedure, World Environmental and Water Resources Congress, Tampa, May 2007, in press.
  - D.D. VanCleve, and H.E. Fuelberg, 2007: An intercomparison between mean areal precipitation from gauges and a multisensor procedure, 21st Conf. on Hydrology, Amer. Meteor. Soc., San Antonio, January 2007, in press.
  - Martinaitis, S.M., H.E. Fuelberg, J.L. Sullivan, Jr., and C. Pathak, 2007: An intercomparison of precipitation values from the OneRain Corp. algorithm and the National Weather Service procedure. 21st Conf. on Hydrology, Amer. Meteor. Soc., San Antonio, January 2007, in press.

Report Follows

Progress Report

"A Comparison of FSU/NWS and OneRain Precipitation Data and Their Insertion Into the WAM Hydrologic Model"

Submitted by

Henry E. Fuelberg
Florida State University

This project compares precipitation values from two procedures (National Weather Service (NWS) and the OneRain Corp. (OR)) that combine radar- and gauge-derived precipitation estimates into a single high resolution dataset over areas of the South Florida Water Management District. The NWS scheme is used operationally by the NWS to issue flood watches and warnings. The OR scheme is used by various private and government agencies to monitor potential flood situations and as data for making decisions about water quality regulations. This project intercompares the two procedures, noting their strengths and weaknesses, and using the two procedures as input to the WAM hydrologic model. The project research constitutes the M.S. thesis research for Mr. Steve Martinaitis.

The statistical intercomparison of precipitation from the two procedures is well underway. Initial results have been obtained for calendar years 2004 and 2005. A detailed study of rainfall differences during Hurricane Wilma also is well underway. The OR data are on a 2×2 km Cartesian grid at 15 min intervals, while the NWS hourly data are on a 4×4 km grid that is oriented approximately northeast-southwest. The OR data were summed to hourly values and placed onto the coarser NWS grid using procedures within GIS. Results show that this transformation was achieved with a very high degree of accuracy—differences between original and transformed data were < 1%. Our various kinds of intercomparisons are based on these data sets now on a common grid. Standard statistical products have been computed to quantify spatial and area-wide differences over days, months, and years. This is being done for individual basins within the SFWMD as well as for their entire area of jurisdiction.

Insertion of the two data types into the WAM Hydrologic Model is just beginning. The source code has been obtained from its inventors (SWET Corp. of Gainesville, FL), and the graduate student has been trained by SWET personnel. Some modifications currently are being made to the WAM model so it can accept the high resolution radar-derived data. These modifications will insure that differences in streamflow will be due to differences in the input rainfall data, and not to other factors.

We have made excellent progress so far. The results to date have been presented at seminars at the South Florida Water Management District in West Palm Beach and at the Florida Department of Environmental Protection in Tallahassee. The results will be presented as two accepted papers at the 2007 World Environmental and Water Resources Congress and two papers at the 21st Conference on Hydrology (sponsored by the American Meteorological Society). As soon as the research is completed, results will be submitted to a refereed journal for publication. The results may be split into two manuscripts An additional one year of funding will be required for the graduate student to complete all of the tasks of the project.

Additional project details and long-term objectives are discussed in the following sections.

A Comparison of FSU/NWS and OneRain Precipitation Data and Their Insertion Into the WAM Hydrologic Model—Phase II

Key Words--Radar-derived Precipitation, Hydrologic Modeling

1. Statement of the Florida Water Problem

Two widely used procedures by which radar- and gauge-derived rainfall can be optimally combined are those by the OneRain Corporation and the National Weather Service (NWS). The several Florida Water Management Districts use rainfall data from the OneRain algorithm. Conversely, Florida State University (FSU) has employed the National Weather Service scheme to create an historical precipitation database for the Florida Department of Environmental Protection (FDEP). Although the methodologies to produce each dataset as well as the spatial and temporal resolution of each differ, each is being used by their respective agencies to make water management and regulatory decisions. Thus, it is important to know how rainfall values from the two schemes compare to each other. This research statistically compares results from the two schemes, develops procedures so that both versions of data can be inserted into the WAM hydrologic model, and performs WAM model runs over various watersheds within the South Florida Water Management District (SFWMD) using both datasets.

2. Statement of Benefits

The Florida Water Management Districts and the FDEP will base important decisions on their respective rainfall datasets. Thus, there is the possibility that the two groups will reach different conclusions—each of which is supported by their own data. This research will quantify differences between the two rainfall datasets to determine how similar/dissimilar they are. The research also will expand our understanding of how high resolution rainfall data can be best used effectively in hydrologic modeling.

3. Nature, Scope, and Objectives of the Research

a. Florida State University's High Resolution Historical Database

The FSU precipitation database was prepared for the FDEP using software developed by the NWS for real time use at their regional River Forecast Centers (RFCs) and local forecast offices. Called the RFC-wide Multi-sensor Precipitation Estimator (denoted MPE), the procedure blends radar-derived hourly digital precipitation data at 4 km resolution with hourly gage data. Details of MPE are provided by Fulton et al. (1998), Seo et al. (1999), and Marzen et al. (2005).

Radar Input—The continental United States is scanned continuously by approximately 125 Doppler (NEXRAD) radars operated by the NWS. Each radar produces an hourly estimate of rainfall on a 4 x 4 km grid. Since most grid points within the U.S. are viewed by more than one radar, MPE each hour determines the radar providing the best coverage of each individual 4 km grid point. Although radars provide excellent spatial resolution of rainfall, there are various limitations, many of which are described in Baeck and Smith (1998) and similar publications. These limitations include improper beam filling and the overshooting of low cloud tops at farther ranges, hail contamination, radar mis-calibration, and the unknown relation between radar reflectivity and rainfall (Z-R relations) for a particular storm. Because of these limitations, the MPE procedure also incorporates rain gauge data into its algorithm.

Gauge Input—FSU obtained hourly rain gauge data from each of the State's Water Management Districts and from gauges whose data are archived by the National Climatic Data Center. These gauge data were rigorously quality controlled—a very time consuming but very necessary task. The MPE scheme objectively analyzes the hourly gauge data onto the 4 x 4 km grid employed for the radar data.

Blending the Radar and Gage Estimates--Using pairs of rain gauges and raw radar precipitation estimates, the MPE software calculates bias correction factors each hour for every radar to improve the remotely sensed precipitation values. When the hourly radar-derived precipitation values are multiplied by this correction, radar wide biases due to factors such as radar mis-calibration are removed. Then as a second step, the bias corrected radar-derived precipitation data are merged with the hourly rain gage observations using optimal interpolation. There are a number of "adaptable parameters" within the MPE software that allow users to optimize the procedure for the specific area for which calculations are made.

An example of the final MPE product for the Black Creek Basin of the St. Johns River is given in Fig. 1. The figure shows the summation of hourly values for February 2001.

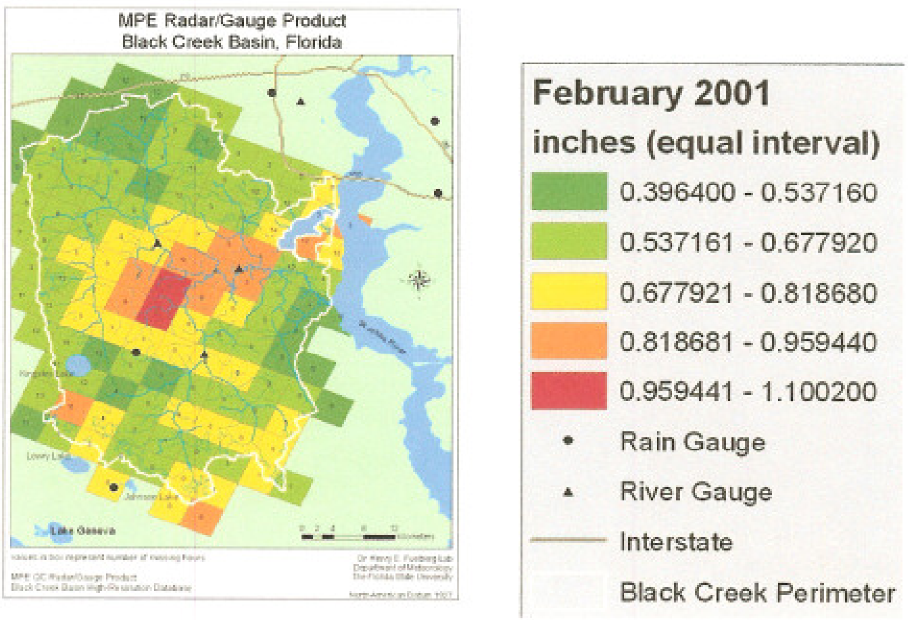

Fig. 1. The Black Creek Basin with superimposed total rainfall (inches) for February 2001. Note that only two rain gauges lie within the Basin.

Recent studies and validations that have utilized radar schemes to estimate precipitation include Smith et al. (1996), Steiner et al. (1999), Klazura et al. (1999), Wang et al. (2000), and Marzen and Fuelberg (2005). These studies have noted the improvements provided by optimally combining radar and gauge information.

b. The OneRain Precipitation Algorithm

The Florida Water Management Districts have contracted with the OneRain Corporation to provide real time and historical precipitation data. The historical database consists of years 2002-2005 (4 years). The OneRain product is on a 2×2 km grid at 15 min. intervals. Although the procedure that OneRain uses is proprietary, the cursory description below is believed to be correct based on information at their web site (http://onerain.com) and in Nelson et al. (2003).

Radar input for the algorithm is the composite radar reflectivity maps produced by the Weather Services International (WSI) Corporation based on data from the national network of WSR-88D radars operated by the NWS and other federal agencies. The Level III radar data from each site (Fulton et al. 1998) are collected by WSI and used to produce a national mosaic of radar-derived precipitation at 15 min. intervals on a 2×2 km grid. When one or more radars overlap a grid point, the greatest rainfall value is used. Rainfall estimates are based on the lowest available antenna angle at each radar. The web site states, "WSI's rainfall estimation procedure uses a dynamic weather condition-based algorithm to convert reflectivity values to rainfall estimates The WSI procedure uses a variety of weather parameters to sense what type of weather condition exists, then chooses the most appropriate conversion from reflectivity to rainfall rate."

Rain gauge-derived precipitation also is input to the OneRain algorithm. FSU assumes that data from most or all of the Florida Water Management Districts are employed. We do not know whether NWS or other gauge data are input. FSU also does not know the nature of the quality control that is used on the gauge data. The gauge data are used to calibrate the radar-derived dataset. The OneRain site states that if there is an insufficient number of gauges with 15-min data, "daily and hourly data were disaggregated to 15 min time steps using the normalized radar data at each gauge location as the distribution function. Calibrations were performed to adjust the radar estimates to match the rain gauge estimates, on average, at the monthly level."

Rainfall values from the OneRain and FSU/NWS procedures have never been compared by any group. Thus, this research will demonstrate the characteristics of these data within Florida.

c. Objectives

Available information about the OneRain and FSU/NWS precipitation algorithms clearly indicates that different methodologies and input data are used. The resolutions of the final products also differ, i.e., 2×2 vs. 4×4 km grid, and 15 min. vs. hourly intervals. This suggests that values from the two algorithms also differ. The objectives of this research are to 1) quantify the amount of that difference and 2) develop procedures to insert both types of rainfall data into the WAM hydrologic model, and make separate runs using each type of data for selected watersheds within the SFWMD.

d. Estimated Timeline—Task 1 (described below) will be completed by the end of the initial one year period (Spring 2007). Tasks 2 and 3 (described below) will be completed by the end of the second year of funding.

4. Methods and Procedures

Task 1—FSU will quantify differences between the FSU/NWS historical dataset and the OneRain dataset using standard statistical procedures (scatter diagrams, mean differences, standard deviation of differences, etc.). This will be done for the four year period of record 2002-2005 when both datasets are available. This step is virtually complete, and a summary of results is provided in the following major section

Task 2—FSU will develop procedures so that both the OneRain and FSU datasets can be input to the Watershed Assessment Model (WAM) hydrologic model such that optimal results are obtained. WAM is a GIS-based model developed by Soil and Water Engineering Technology, Inc. (SWET) of Gainesville, FL. It is described in detail in a number of publications by SWET personnel. WAM simulates the hydrology of a watershed using various imbedded models. Although WAM has been coded to accept the FSU 4×4 km MPE rainfall, initial streamflow results for the Black Creek Basin were mixed (SWET report to FDEP, 2003). These findings are counter to most of the literature which indicates superior results from radar-derived precipitation. This suggests that WAM must be modified to properly utilize the high resolution data. That is one of the goals of the current proposed effort.

Successful use of either OneRain or FSU/NWS data requires more than just changing format input statements from accepting rain gauge data to accepting the gridded gauge plus radar combination. For example, a number of run off and percolation schemes have been developed for use in hydrologic models. GLEAMS is designed for daily precipitation input and works best in well drained soil. The EAAMod scheme can use any interval of rainfall data (hourly, daily, etc.) and was designed for regions with a high water table. A number of other models are described in the literature, and the SWET team currently is preparing alternative schemes for use in WAM. With the assistance of SWET personnel, several schemes will be tested within WAM to determine their impacts on runoff and percolation. Based on the results, FSU and SWET will select the most appropriate equation to use for each dataset, and develop coefficients for use with the various spatial and temporal scales of the rainfall data. Thus, the goal is to optimize WAM for using high resolution rainfall data.

It should be noted that the FDEP currently is supporting the Task 2 efforts for FSU/NWS input. One FSU student has received WAM training by SWET personnel, and SWET has been collaborating with us. The funds requested here will support similar efforts for OneRain data.

Task 3--This task will perform WAM-based hydrologic modeling using data from both the FSU/NWS and OneRain procedures.

a. Several basins will be selected for study. These basins will be of special interest to the Water Management Districts and to FDEP. SWET either already will have configured WAM for these basins or will currently be configuring them. FSU is not expected to perform the detailed model configuration for a basin.

b. FSU will make WAM runs over the selected basins over various periods of time and for various rainfall scenarios. These scenarios will include widespread heavy or light precipitation as well as scattered convective rain, different seasons, different basin sizes, etc. One set of runs will utilize the OneRain dataset. A second set of runs will utilize the FSU/NWS dataset and hopefully will be sponsored by FDEP.

c. The various computed streamflows, together with observed streamflows, will be compared using hydrographs and various statistical tools. As a result, we will understand the role of differences in the OneRain and FSU/NWS datasets in producing differences in streamflow.

5. Accomplishments from Last Year

The statistical intercomparison of precipitation from the two algorithms is almost complete. Results have been obtained for calendar years 2004 and 2005. A detailed study of rainfall differences during Hurricanes Wilma and Katrina also is nearly complete. The OneRain data on a 2×2 km Cartesian grid at 15 min intervals were summed to hourly values and placed onto the coarser hourly, 4×4 km NWS grid using procedures within GIS. This transformation was achieved with a very high degree of accuracy—differences between original and transformed data were $< 1\%$. Our various inter-comparisons are based on these data sets now on a common grid. Standard statistical products have been computed to quantify spatial and area-wide differences over days, months, and years. As an example, Figure 2 shows spatial fields of the OneRain and NWS/FSU annual rainfall totals for 2004. The right panel of Fig. 2 shows that OneRain annual rainfall is greater than the FSU amounts over much of the area. Figure 3 shows scatter diagram comparing the two versions of rainfall for two individual months during 2004. Statistics also are being compiled for individual basins within the SFWMD. Table 1 compares mean areal precipitation for the Tamiami East Watershed.

Insertion of the two data types into the WAM Hydrologic Model is just beginning. The source code has been obtained from its inventors (SWET Corp. of Gainesville, FL), and a graduate student has been trained by SWET personnel. Some modifications currently are being made to the WAM model so it can accept the high resolution radar-derived data. These modifications will insure that differences in streamflow will be due to differences in the input rainfall data, and not to other factors.

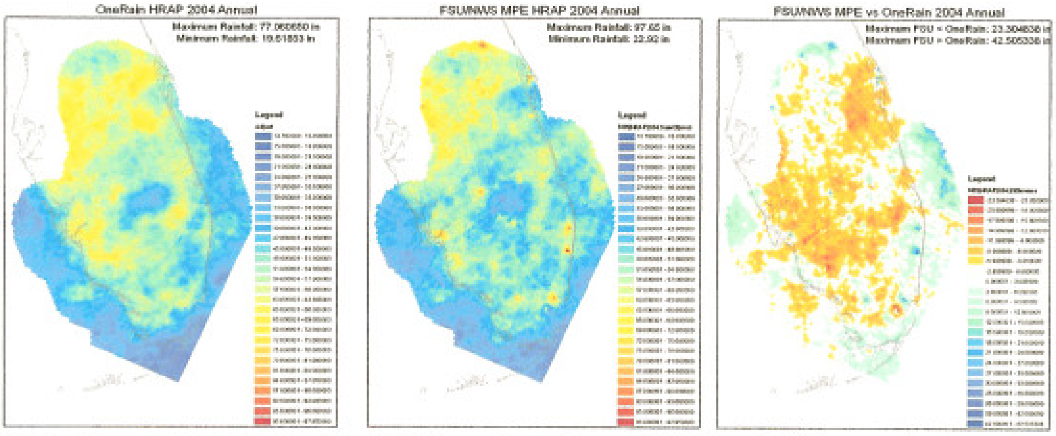

Fig. 2. Annual precipitation for 2004 from OneRain and MPE, and differences between the two products. Warm colors show greater estimates from OneRain. Cool colors show greater estimates from FSU/NWS.

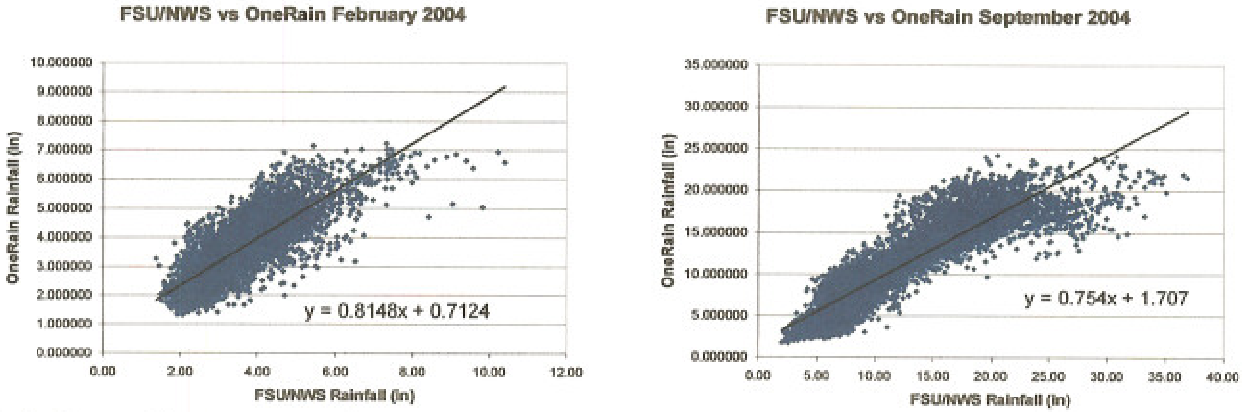

Fig. 3. Scatter diagrams comparing values of FSU/NWS pixel values with those from OneRain for February and September 2004.

Table 1. Comparison of Mean Areal Precipitation (MAP) for the Tamiami East Watershed.

Month/Year	MAP FSU/NWS (in.)	MAP OneRain (in.)	MAP Difference (in.)	Percent Difference
Jan 2004	2.378031	2.151367	0.226664	9.532 %
Feb 2004	3.482546	3.457805	0.024741	0.710 %
Mar 2004	1.278589	0.902159	0.376430	29.441 %
Apr 2004	3.935067	2.967373	0.967694	24.592 %
May 2004	2.582166	1.435037	1.147129	44.425 %
Jun 2004	3.778446	2.632247	1.146199	30.335 %
Jul 2004	7.677876	6.886893	0.790983	10.302 %
Aug 2004	10.503016	12.410105	-1.907089	-18.158 %
Sep 2004	13.585865	9.677520	3.908345	28.768 %
Oct 2004	6.930458	5.161953	1.768505	25.518 %
Nov 2004	1.009164	0.919753	0.089411	8.860 %
Dec 2004	0.855655	0.421506	0.434149	50.739 %
Annual 2004	57.996878	49.023713	8.973165	15.472 %

Publications During Last Year

Fuelberg, H.E., S.M. Martinaitis, J.L. Sullivan, Jr., and C.S. Pathak, 2007: An intercomparison of precipitation values from the OneRain Corp. algorithm and the National Weather Service Procedures. World Environmental and Water Resources Congress, Tampa, May 2007, in press.

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Presentations During Last Year

Seminar at the South Florida Water Management District Headquarters on October 4, 2006.

Seminar at the Florida Department of Environmental Protection on December 5, 2006

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7. Training Potential

One graduate student, Steven Martinaitis, is supported by this project and thereby receives training from it. Mr. Martinaitis collaborates with another graduate student, John Sullivan, who is supported by the FDEP and whose graduate research utilizes the FSU/NWS dataset. Thus, two graduate students will benefit from the project.