A COMPARISON OF PRECIPITATION ESTIMATION TECHNIQUES OVER LAKE OKEECHOBEE, FLORIDA

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Abstract. Lake Okeechobee is a vital component in the hydrologic system of southern Florida. Currently, the lake and its tributaries are being modeled to provide for predictive capabilities of water resources and water availability. In the modeling scheme, the most important component is the input of water from direct precipitation over the lake. Therefore, an accurate precipitation time series is needed for calibration and operational use.

This study compared the National Weather Service (NWS) and South Florida Water Management District (SFWMD) gage networks with the NWS Stage III multisensor radar estimates over the lake in order to see which provided a better time series of precipitation. It was found that the SFWMD network provided the most consistent and believable mean areal precipitation (MAP) estimates over the surface of Lake Okeechobee, with the radar estimates slightly underestimating those values during the three-year (1997-1999) study period. Additionally, the NWS network around the lake was found to include noticeable bias towards high estimates due to specific gage locations, and was considered unusable.

INTRODUCTION

Lake Okeechobee, located in southern Florida, is a key component in the local and regional hydrologic system. The lake and its watershed are vital to the Kissimmee-Okeechobee-Everglades ecosystem, which ranges from the headwaters of the Kissimmee River in the north to Florida Bay in the south. It is a multi-faceted resource, providing drinking water to adjacent cities and towns as well as being a backup water supply for communities along the lower east coast of Florida. In addition, the lake is a major supplier of irrigation water for surrounding agricultural areas, and is a crucial supplemental water supply for the Everglades.

As a result of concerns regarding agricultural, ecological, and water resource issues, water levels in the lake and many of its tributaries and outflows are strictly monitored in order to meet water resource demands and to provide information regarding past and present trends of water resources and availability.

As the importance of the water stored in Lake Okeechobee increases, so does the need to provide accurate and reliable predictions of short- and long-term lake levels for flood protection and water resource outlooks. The Southeast River Forecast Center (SERFC) has been charged with the duty of setting up and maintaining a modeling scheme for the Lake Okeechobee hydrologic system for the purpose of providing river and lake level forecasts. As a result, a preliminary setting including Lake Okeechobee and two of the major tributary inflows, Kissimmee River and Fisheating Creek, are currently part of the National Weather Service River Forecast System (NWSRFS).

In setting up the forecast sites, calibration is one of the foremost issues. Normally, basin attributes are calibrated based on historical precipitation and discharges, and in smaller lakes, the approach adopted by the SERFC has been to assume that precipitation that falls directly over the lake is insignificant compared to the surface inflows. However, due to the large surface area of Lake Okeechobee, this approach is not valid; therefore, special consideration will be given to the issue of precipitation estimation.

Objectives

The goal of this research is to determine the limitations and strengths of precipitation estimation methods used to compute the mean areal precipitation in a lumped model of the lake. This paper focuses on the aspect of finding the most accurate way to estimate the precipitation that falls on Lake Okeechobee in an effort to quantify its value so that all major inflows to the lake can be known. In order to accomplish this, different methods and precipitation data types will be compared in order to ascertain which is better suited to be used over the lake basin. Data types include gage-recorded precipitation as well as radar-derived multisensor precipitation estimates. Due to operational issues, such as the occasional malfunction of precipitation gages or radar, many times the mean areal precipitation will need to be based on different data sources than those used for calibration; therefore, the knowledge of how well these estimates compare will aid in the forecasting of lake levels.

Results obtained from analyses of the data will be compared, and recommendations will be given as to what source of data should be used in the calibration of the Lake Okeechobee basin. Ultimately, this system will be used operationally to simulate water levels in Lake Okeechobee using computed inflows from the major tributaries, precipitation and evaporation over the lake, as well as the most significant regulated outflows from the lake.

DATA AND METHODOLOGY

Within this project, data from three individual sources were utilized for comparison. These included gage-recorded precipitation from the NWS cooperative and first-order network, as well as gage data from the South Florida Water Management District (SFWMD) Lake Okeechobee network. In addition, multisensor precipitation estimates from WSR-88D StageIII data were incorporated in the analyses.

With respect to the surface observations, only gages that could provide hourly precipitation observations were considered. After removing stations that were too far from the lake or that contained an incomplete time series, five stations from the NWS network and 20 stations from the SFWMD network were included in the analyses.

Within the study area of Lake Okeechobee, radar estimates of precipitation have been archived from December 1996 to the present, while NWS gage data is only available until December 1999. Therefore, gage and radar data from January 1997 to December 1999 were used.

COMPUTATION OF MEAN AREAL PRECIPITATION

The study area of this project involves a 1732 km^2 (669 mi^2) basin, therefore the analyses will not be done to the detail of a Hydrologic Rainfall Analysis Project (HRAP) grid cell (4 Km x 4 Km), such as used by Fuelberg et al. (2002) and Young et al. (2000). Instead, a similar procedure to that used by Stellman et al. (2000) will be followed, which utilized mean areal precipitation estimates over a specific region.

Mean Areal Precipitation (MAP) is a method in which values of precipitation over a region are used to calculate, using some averaging technique (in this case, the Theissen polygon method), a single mean precipitation depth that is meant to represent a given area over a specific time. This type of procedure is necessary to provide precipitation estimates for a lumped modeling approach, such as used in the NWSRFS. In this way, each basin included in the model is assigned a single value of precipitation for each operational time step. In the case of this project, the boundary of Lake Okeechobee, as defined by the extent of the Herbert Hoover Dike system, is considered a single basin; therefore, all data considered for this study must be organized into a MAP time series in order to be equally compared.

Before the NWS and SFWMD rain gage data were used to calculate a MAP over Lake Okeechobee, they were first analyzed for completeness and consistency. A double mass analysis for each group of data was exercised to determine discontinuities and outliers. Proper adjustments were performed so that the data used in the computations were homogeneous.

Mean Areal Precipitation Using Gages: MAP

Two sets of MAP time series were created for this project: one using NWS precipitation gages and one using SFWMD precipitation gages. Subsequently, two MAP's were created for each station network, a 1-hour and a 6-hour time series. During operations, the NWSRFS model is run on a 6-hour time step due to constraints in the preprocessing software for the gage-only rainfall data.

In the future, the processing algorithms might be modified to handle a smaller time step; therefore, hourly comparison of rainfall under an operations framework could be performed. Series utilizing both time steps were created so that the general precipitation patterns could be determined using the 6-hour time step MAP and more detailed single event studies could be carried out using the 1-hour MAP.

Mean Areal Precipitation Using Radar: MAPX

The MAPX preprocessor is a function used by NWSRFS to compute radar-based mean areal precipitation (MAPX). The data used as input to MAPX are gridded estimates of precipitation, based on multisensor StageIII output. The mosaic field, as output from the Stage III process, produces xmrg files that are stored in binary format. The xmrg files contain the hourly precipitation amounts on a HRAP grid for the complete RFC area.

Although Stage III gridded precipitation values are kept for the entire RFC, MAPX is computed for a given basin by calculating the number of grid points in the area, as well as the sum of the precipitation for all grid points. The precipitation sum is then divided by the number of grid points and the result is the MAPX for that area. If missing data are encountered, a missing MAPX value is written in the Processed Database. In this report, missing data values were set to zero precipitation.

RESULTS AND ANALYSIS

Looking at the patterns of cumulative precipitation between the SFWMD MAP, the NWS MAP, and the MAPX over the entire study period, the relative difference between the magnitudes of each were found (Figure 1). Since January 1, 1997, when the study period began, the NWS MAP was consistently larger than either the SFWMD MAP or MAPX, while the SFWMD MAP was larger than MAPX. This translates into the argument that the multi-sensor radar precipitation estimate does not observe as much precipitation as the surface observation stations. The reasons for this may not be limited to merely sensor accuracy or sensitivity, but may be attributable to the location of specific observation stations in regards to the overall precipitation distribution.

For the surface observation stations, such as the NWS and SFWMD networks, the specific location of stations is important when estimating mean areal precipitation. This is especially true for the NWS stations due to the poor spatial distribution. With three of the five NWS sites located adjacent to known precipitation maximums and the remaining two located some distance away from any minimums, it is obvious that there is a high probability that the NWS cooperative network is biased towards a higher MAP than is actually occurring. For this reason, it is safe to assume that the NWS MAP is not accurate in regards to the actual volume of precipitation falling over the surface of Lake Okeechobee. The same problem could just as well be true for the SFWMD data, however the greater number of stations and overall improved spatial distribution would minimize such an effect.

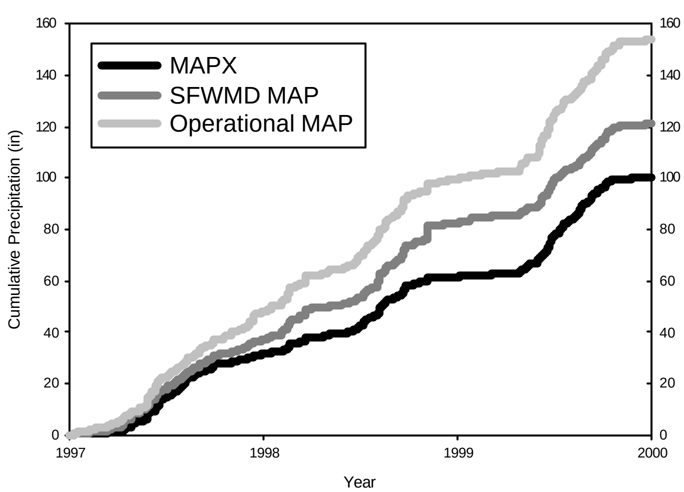

Figure 1. Cumulative SFWMD MAP, NWS MAP, and MAPX over total study period.

Analyses of the complete time series of the cumulative MAP’s and MAPX shows two points within the study period during which the divergence between the cumulative SFWMD MAP and MAPX decreased (Figure 1). This can logically be a result of the winter dry season, since the precipitation estimates will obviously compare better when there is little or no precipitation occurring. In fact, it is only during the summer wet months that the MAP’s can truly be scrutinized since this is when most of the precipitation is occurring. For this reason, two more analyses were done that focused on the respective summer months, starting in May 1998 and May 1999. This will give a better idea as to the behavior of the time series for each year.

By looking at the patterns of the cumulative precipitation from the SFWMD MAP, the NWS MAP, and the MAPX from May 1998 until December 1999 (Figure 2), it can be seen that the SFWMD MAP diverges to larger values relative to the MAPX until November 1998. At that point, the two estimation techniques appear to provide equal volumes of precipitation as the winter dry season sets in. Beginning in May 1999 (Figure 3), the MAPX begins to estimate a larger cumulative volume of precipitation than the SFWMD MAP as the summer wet season begins. This is a surprising result considering that all previous comparisons between the SFWMD MAP and MAPX show the opposite to be true. This is definitely a significant finding, because it can be assumed that all future MAP values computed using the SFWMD stations may be nearly equal to MAPX computed values, and the two can be interchanged with minimal error.

Since the previous analyses were done using cumulative values over a relatively long time period, it is difficult to accurately ascertain how the two estimation techniques compare over a short time period, such as hours or days. For this reason, individual precipitation events are focused on in an effort to

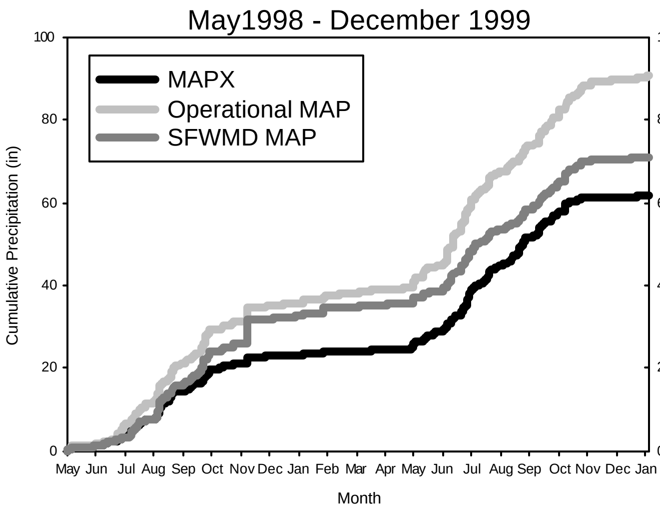

Figure 2. Cumulative SFWMD MAP, NWS MAP, and MAPX from Jul. 1998 – Dec. 1999.

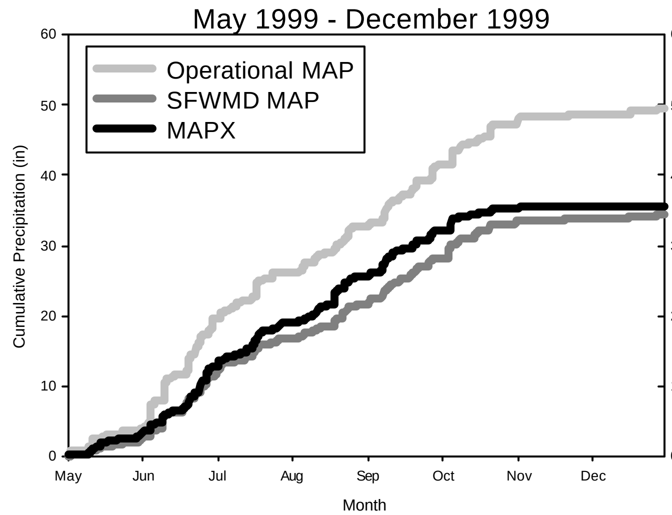

Figure 3. Cumulative SFWMD MAP, NWS MAP, and MAPX from May 1999 – Dec. 1999.

visualize the possible differences between the SFWMD MAP and the MAPX at short time scales.

During the period of May 6-16, 1997 (Figure 4), there was a peak precipitation estimate on the 11th given by the SFWMD MAP of 0.32 in., with no corresponding MAPX value. However, immediately following were several days with observed precipitation, with the SFWMD MAP estimating a total volume of rain on the 11th of 0.87 in., along with 0.17 in. on the 12th. The MAPX shows an opposite pattern by estimating a larger volume of precipitation on the 12th than on the 11th, with values of 0.30 in. hr^{-1} and 0.22 in. hr^{-1}, respectively. This corresponds to a two day total precipitation volume of 1.04 in. for the SFWMD MAP, and only half of that, 0.53 in., for the MAPX. The early peak by the SFWMD MAP is possibly a result of the stations outside the lake measuring precipitation where the MAPX is not considered. It is not until precipitation falls directly on the water surface that both the SFWMD MAP and MAPX show corresponding values. The greater values of MAPX on the 12th are most likely attributable to shortcomings in the SFWMD spatial distribution, where the majority of the precipitation falls between stations.

During the period of June 2-12, 1999 (Figure 5), specifically on June 7, there was a sharp spike in precipitation recorded by the SFWMD MAP that

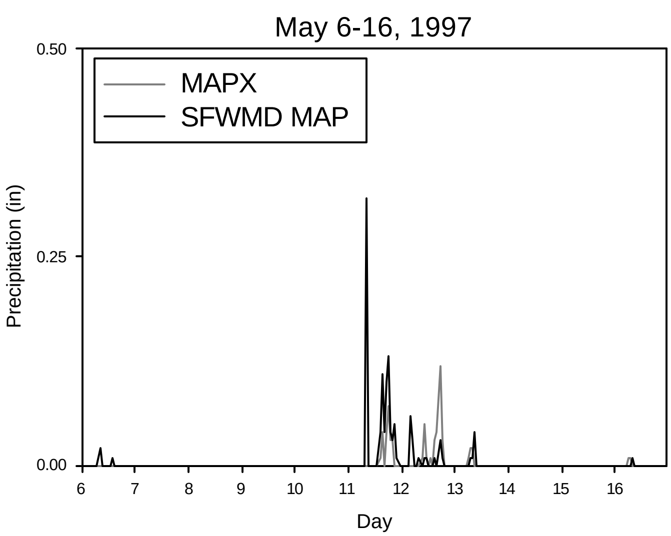

Figure 4. Hourly MAPX and SFWMD values for May 6-16, 1997.

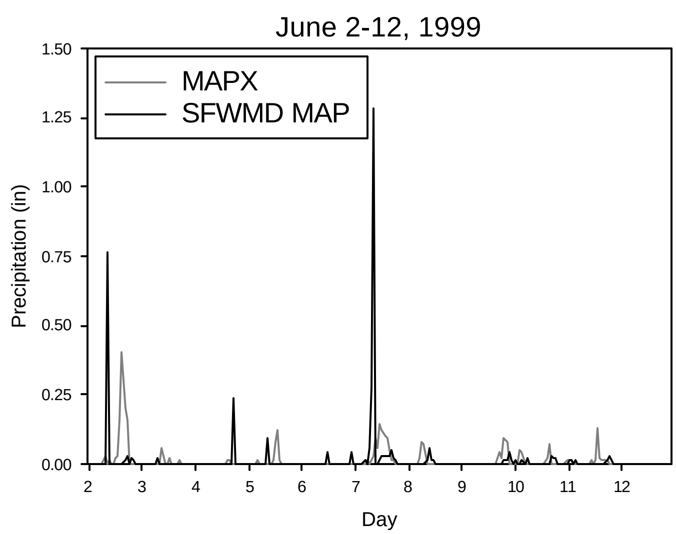

Figure 5. Hourly MAPX and SFWMD values for June 2-12, 1999.

corresponds to a depth of 1.28 in. There is also a secondary peak of 0.76 in. by the SFWMD MAP on the 2nd, which is followed by a lesser but still significant hourly precipitation estimation of 0.40 in. by the MAPX. For most of the other precipitation observations, the MAPX tends to estimate a slightly larger volume than the SFWMD MAP, with the latter giving estimates roughly 46% less than the former for events under 0.50 in. This is in all probability caused by the radars consistently measuring precipitation from the storm(s) as they move across the lake, while the surface stations only measure precipitation when the storm crosses one of their locations.

CONCLUSIONS

Through analyses of three independent mean areal precipitation techniques derived from NWS cooperative precipitation sites, SFWMD precipitation sites, and multi-sensor radar estimates, the relative differences between each were found. It was deduced that problems with station location and spatial distribution led to large biases in the NWS MAP's that were created using the NWS cooperative sites; therefore, the use of this product for purposes of precipitation calibration over Lake Okeechobee was not a valid option.

Regarding MAPX precipitation estimates, the available time series is at the minimum length for calibration purposes (available since 1996), which makes it a poor candidate. More importantly, there are known changes in the pattern of the time series resulting from changes in the processing algorithms used to provide precipitation estimates; therefore, it is not feasible to use this data for calibration purposes. In the future, in order to see if the precipitation estimates show better agreement with other observations, this method should be re-evaluated, particularly after the radar algorithms remain unchanged over a several year period.

In conclusion, the SFWMD stations should be used to provide an estimate of mean areal precipitation over Lake Okeechobee. This would provide a far better spatial distribution of recording stations than is currently available with the NWS cooperative network around Lake Okeechobee. In addition, the distribution could be improved by using the SFWMD stations along with the NWS cooperative precipitation sites. This would provide a network of at least 25 hourly precipitation observation stations in and around Lake Okeechobee.

REFERENCES

Abtew, W., 2001. Evaporation estimation for Lake Okeechobee in South Florida. *Journal of Irrigation and Drainage Engineering* 127: 140-147.

Briendenbach, J. D.J. Seo, and R. Fulton, 1998. Stage II and III post processing of NEXRAD precipitation estimates in the modernized Weather Service. *AMS 78th Annual Meeting*, Phoenix, AZ.

Fuelberg, H.E., G.S. Quina, B. Mroczka, R.J. Lanier, J.S. Bradberry, and J.P. Breidenbach, 2002. A high resolution precipitation data base for Florida. *2nd Federal Interagency Hydrologic Modeling Conference*, Las Vegas, Nevada.

Stellman, K.M., H.E. Fuelberg, R. Garza, and M. Mullusky, 2000. An Examination of Radar and Rain Gauge-Derived Mean Areal Precipitation over Georgia Watersheds. *Weather and Forecasting* 16: 133-144.

Young, C.B., A.A. Bradley, W.F. Krajewski, A. Kruger, and M.L. Morrissey, 2000. Evaluating NEXRAD multisensor precipitation estimates for operational hydrologic forecasting. *Journal of Hydrometeorology* 1: 241-254.