Validation of IMERG rainfall to monitor onset and demise of the rainy season over Peninsular Florida.

Undergraduate Honors Thesis

Parker Beasley,
Meteorology Program
Department of Earth, Ocean, and Atmospheric Science,
Florida State University

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Honors Thesis Committee members:

Dr. Vasubandhu Misra
Dept. of Earth, Ocean, and Atmospheric Science

Dr. Mark Bourassa
Dept. of Earth, Ocean, and Atmospheric Science

Dr. Ingo Wiedenhoever
Dept. of Physics

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1.ABSTRACT

This study was motivated to assess the fidelity of gridded, remotely sensed rainfall analysis for real time monitoring of the wet season over the five water management districts (WMDs) of Florida. All five WMDs have a significant fraction of the annual rainfall occurring in the wet season. Therefore, monitoring and anticipating its variations from year to year would be critical to manage water resources in the WMDs.

In this study we analyzed the fidelity of the Integrated Multi-Satellite Retrievals for Global Precipitation Mission version 6 (IMERG) late run at 12 hour latency and final run at 3.5 month latency with respect to the rain gauge based analysis from the National Oceanic and Atmospheric Administration (NOAA) Climate Prediction Center (CPC). The 3.5 month latency product ingests a larger volume of data for analysis and uses a more rigorous analysis technique, which would lead to the anticipation of a better rainfall analysis than the former 12 hour latency product.

Our study finds that indeed the 3.5 month latency product of IMERG reduces the RMSE of the seasonal rainfall of the wet season systematically over all five WMDs relative to the 12 hour latency product. However, in terms of the diagnosis of the onset and the demise dates, and the seasonal length of the wet season, the results are somewhat mixed. In some WMDs the RMSE of the onset date, demise date, and the seasonal length of the 3.5 month latency dataset shows a deterioration relative to the 12 month latency (e.g., Southwest Florida, St. Johns River, and Suwannee River). Over Northwest Florida WMD, the RMSE of the 3.5 month latency shows a marginal improvement over the 12 hour latency in these parameters of the wet season. Similarly, the correlations of these three parameters of the wet season with the CPC rainfall dataset are higher in the 12 hour latency compared to 3.5 month latency datasets over Southwest Florida and St. Johns River WMD. But in all instances, the correlations between the 12 hour latency dataset and the CPC dataset for all parameters of the wet season over all five water management districts are distinctly significant at 95% confidence interval according to t-test. Therefore, despite the relatively larger RMSE than the 3.5 month latency dataset in some of these parameters, the 12 hour latency product of IMERG may be reasonable to use for monitoring the evolution of the wet season over all five water management districts of Florida.

2.INTRODUCTION

Peninsular Florida (PF) is a unique geographical region of continental US with its peninsular structure and its residence in the tropical latitudes. The shape and the width of PF offers convergence of sea breeze thunderstorms that develop initially along its Atlantic and Gulf coasts (Xian and Pielke 1991). Misra et al. (2018a) identified a distinct rainy season over PF that overlaps to some extent with the boreal summer season. Misra et al. (2018a) showed that the evolution of the rainy season over PF coincides with the warming of the Gulf of Mexico and the weakening of the trade winds in the tropical Atlantic. Therefore, it is suggested that the rainy season over PF is a coupled ocean-atmosphere phenomenon, which evolves slowly and deliberately both in the oceanic and atmospheric components of the climate system.

A unique aspect of the definition of the rainy season as introduced in Misra et al. (2018a) is that the length of the season varies from year-to-year. Unlike traditionally fixing the length of the season to calendar dates, the meteorological definition of the rainy season in Misra et al. (2018a) allows for the onset date and the demise date of the season to vary. Therefore, in addition to variable rain rates, the length of the season variations also contributes to the seasonal anomalies of the rainy season over PF. Several studies have related the variability of the variations of the rainy season over PF across temporal scales to other climatic variations like El Niño and the Southern Oscillation (ENSO), Atlantic warm pool variations, and variations in the Loop Current (e.g., Misra and DiNapoli 2012; Misra and Mishra 2016; Misra et al. 2017; Misra and Bhardwaj 2020).

The onset of the rainy season is rather dramatic (Misra et al. 2018a). Over a period of one day the average daily rain rates across PF jump from around less than 3mm/day to over 7mm/day, which Misra et al. (2018a) mark as the onset date of the rainy season over PF. Likewise, the demise of the rainy season over PF also shows a significant drop in daily rain rate from over 10mm/day to less than 5mm/day.

There is however significant spatial heterogeneity of the rainy season over PF (Misra and Bhardwaj 2020). For example, climatologically the length of the rainy season is shorter in central Florida by one week compared to that in south Florida. Similarly, the length of the season between Tampa and Jacksonville (north Florida) is shorter by almost three weeks compared to that over south Florida (Misra and Bhardwaj 2020). Similarly, Misra et al. (2018b) find that the urban and rural areas display shorter and longer rainy seasons over PF, respectively. However, the seasonal rainfall accumulation over the rainy season does not differ between urban and rural areas over PF, leading Misra et al. (2018b) to conclude that the average daily rain rate in the rainy season over the urban areas is higher than over the rural areas.

The robust seasonal cycle of the rainy season of PF and its year-to-year variations leads us to investigate the ability to monitor the evolution of the rainy season with some of the available rainfall analysis products. One of the obvious motivations is to assess and quantify the variations of the rainy season. However, an additional motivation is that several studies have shown that the onset date variations of the rainy season over PF has a bearing on the forthcoming evolution of the season (Misra et al. 2018a, c). For example, an early or delayed onset of the monsoon is likely to lead to a wetter or a drier rainy season, respectively. Therefore, monitoring the onset of the rainy season over PF could also serve in providing an outlook for the season.

The objective of this work is to assess the fidelity of two remotely sensed rainfall analysis in monitoring the evolution of the rainy season over PF. These remotely sensed rainfall analysis is compared with rain gauge-based rainfall analysis. In order for this to be further useful, we aggregate the region based on the five water management districts (WMD) of Florida viz., South

Florida (SFL), Southwest Florida (SWFL), St. Johns River (ST JRVR), Suwannee River (SRVR), and Northwest Florida (NWFL; Fig. 1). These five Water Management Districts (WMDs) have the core mission of monitoring and assessing water supply, water quality, operating and managing flood protection and floodplain management, and evaluating and protecting natural systems by regulating freshwater flows. Therefore, the decisions made in these WMDs are most affected by the variations of the wet season. In the following section we describe the datasets, followed by a discussion of the methodology to diagnose onset and demise of the rainy season over PF. The results are presented in Section 4 followed by concluding remarks in Section 5.

3.DATA DESCRIPTION

As noted earlier, the objective of this work is to assess the fidelity of two remotely sensed rainfall analysis against another rainfall analysis based primarily on in situ measurements of rainfall from rain gauges. The three rainfall analysis are: 1) The Climate Prediction Center (CPC) unified gauge-based analysis of global daily precipitation (Xie et al. 2007, Chen et al. 2008a, b). The remaining two datasets are from the Integrated Multi-Satellite Retrievals for Global Precipitation Mission version 6 (IMERG; Huffman et al. 2019) available as 2) Late run or with 12-hour latency, and 3) Final run or with 3.5-hour latency.

i) The CPC rainfall dataset

A rain gauge-based analysis of daily precipitation using gauge reports from over 30,000 stations over the global land areas collected by the National Oceanic and Atmospheric Administration (NOAA) Climate Prediction Center (CPC) and has been prepared from 1979 to the present (Xie et al. 2007; Chen et al. 2008a, b). The data sources include daily summary files from the global teleconnection system, CPC unified daily gauge data sets over the contiguous United States, Mexico, and South America, and other international agencies. A quality control of the datasets is performed through comparisons with historical records and independent measurements at nearby stations, concurrent radar/satellite observations and short-term numerical forecasts. The daily analysis of rainfall is created on 0.125° lat/lon grid over the global domain using the optimal interpolation algorithm following Gandin (1965) and released on a 0.5° lat/lon grid so that the final product represents the area-averaged values of daily precipitation over the grid boxes. Chen et al. (2008a) indicate that the quality of the rain gauge based CPC rainfall analyses degrades as the density of station observations become sparser. We use this CPC rainfall dataset as a benchmark against which the remaining two IMERG rainfall products are validated.

ii) The IMERG dataset

The IMERG rainfall dataset comes from the Global Precipitation Measurement (GPM) mission launched in 2014 and developed jointly by NASA and the Japanese Aerospace Exploration Agency (JAXA). The GPM mission followed the successful Tropical Rainfall Measuring Mission (TRMM), which was launched in 1997. In comparison to TRMM, GPM has larger spatial coverage and higher temporal resolution, and is capable of detecting precipitation less than 0.5mm/hour. The GPM mission was built from an unprecedented international cooperation in sharing space assets and scientific collaboration to advance precipitation measurement from space for research and applications. The GPM mission concept revolves around deploying advanced combined active and passive sensor packages from a constellation of satellites provided by a consortium of international partners (Fig. 2). The GPM core observatory carries, a dual-frequency precipitation radar (Ku-band and Ka-band) and a conical-scanning multichannel GPM Microwave Imager (GMI, 10–183 GHz).

The IMERG data is available at 0.1° grid spacing at hourly interval from the year 2000 to 2019. The IMERG dataset includes early, late, and final run products that have ~ 4 hour, 12 hour and 3.5 month latency. The GPM low-orbit microwave satellites downlink their data once or twice an orbit (which is ~90 minutes long) to the operating agency. A Precipitation Processing System (PPS) then accesses the numerical forecasts from the Goddard Earth Observing System version 5 (GEOS-5) model (Molod et al. 2015), infra-red, and microwave radiance data from the satellites by about 3 hours after observation time and converts to precipitation estimates using a forward propagation morphing technique, producing a rainfall analysis by about 4 hours after the observation time. The IMERG late run, which has a latency of 12 hours, differs from the early run in using both forward and backward propagation morphing processing. This implies that PPS has to wait for the following microwave overpass to occur before it can start processing and converting the microwave data to precipitation estimates (through backward propagation). The time to allow for the next microwave overpass to occur is approximately 11 hours. This means that the whole process to produce the precipitation estimate is anywhere between 11-14 hours, but the average time is about 12 hours for the IMERG late run dataset. The IMERG final run rainfall product with 3.5 month latency uses additionally Modern-Era Retrospective Analysis for Research and Applications, version 2 (MERRA2; Gelaro et al. 2017), monthly rain gauge analysis dataset, and the revised precipitation retrievals that uses ERA-5 (Hersbach et al. 2019) and ERA-Interim (Dee et al. 2011) reanalysis.

There are a number of studies that have compared TRMM rainfall products with IMERG over various regions of the globe (Tang et al. 2016; Liu et al. 2016; Xu et al. 2019). A majority of these studies claim that the IMERG 3.5 month latency dataset is superior to the TRMM datasets (e.g., Tang et al. 2016, Xu et al. 2109). On the other hand, there are far fewer studies comparing the early, late, and final runs of IMERG (Tang et al. 2020). Although, Tang et al. (2020) conclude from their study on rainfall characteristics over the Sichuan Basin of China that final run product of IMERG is not necessarily superior to its early and the late run products in the detection of rainfall in all seasons, with the late run in fact showing the best fidelity in summer and autumn seasons. And given the objective of his work in evaluating the rainfall analysis for potential real time application of monitoring the onset and the demise of the rainy season over PF, it is imperative to assess the fidelity of the IMERG products over PF. The early run of IMERG was deliberately ignored in our analysis because the application to monitor the seasonal evolution of the wet season over PF allows for the tolerance for latency to be well beyond 12 hours.

4.METHODOLOGY

The objective definition of the onset and the demise of the wet season over PF following Misra et al. (2018a) is applied in this study. Essentially, the onset and the demise date of the wet season is defined as the first day of the year when the daily rain rate exceeds and the last day of the year when the daily rain rate falls below the climatological annual mean rainfall rate (Misra et al. 2018a). The onset/demise dates over each of the five WMDs of Florida are therefore diagnosed as inflection points of the cumulative daily anomaly of rainfall given by:

$$R'_n(k) = \sum_{m=1}^{k} \left[R_n(m) - \bar{\bar{R}}\right] ------------------------(1)$$

where, $R_n(m)$ is the area average daily rainfall for day m of year n averaged over each of the five water management districts, $\bar{\bar{R}}$ is the corresponding annual mean climatology of the rainfall. The inflection points are the minima for onset and maxima for demise dates in the cumulative anomaly curve. Figure 3 illustrates the onset and the demise date for each of the five WMDs using the IMERG 12-hour latency dataset for the year 2001.

Once the onset date, and the demise date are diagnosed then the seasonal length is computed as the difference between the two dates and daily rainfall is accumulated between these dates to account for the seasonal accumulation of rainfall for each of the 5 WMDs over the nineteen-year period. The procedure is repeated separately to diagnose the onset/demise dates, seasonal length, and seasonal rainfall anomalies from the CPC, IMERG 12 hour and 3.5 month latency datasets for each of the five WMDs.

5.RESULTS

i) South Florida Water Management District

In Figs. 4a, b, c, and d we present the time series of the onset date, demise date, seasonal length, and seasonal accumulation of rainfall for the South Florida WMD from all three rainfall datasets. The RMSE and correlation values from these graphs for the IMERG 12 hour and 3.5 month latency, computed with respect to the CPC rainfall dataset are indicated in Table 1. Table 1 indicates that except in the case of the diagnosis of the onset date, the 3.5 month latency of IMERG data improves upon the 12 hour latency version with respect to both RMSE and correlation values. However, the correlation values are far more comparable between the two datasets and in both instances are statistically significant at 95% confidence interval (Table 1), suggesting that the 12 hour latency dataset of IMERG may be appropriate to diagnose the variations of the rainy season over South Florida, albeit with some systematic bias correction. But it is interesting to note that the diagnosis of the onset date of the rainy season is far more reliable in the 12 hour latency version of IMERG (Table 1). The onset date variations of the rainy season happen to be an important variable that is observed to be associated with the seasonal rainfall anomaly and therefore could be used to prepare a seasonal outlook of the wet season over PF at the start of the season (Misra et al. 2018a; Misra and Bhardwaj 2020).

ii) Southwest Florida Water Management District

Figs. 5a-d show the time series of the variations of the wet season over the Southwest Florida WMD with the corresponding RMSE and correlations indicated in Table 2. Amongst all five WMDs, the 12 hour latency version of IMERG shows the highest fidelity in terms of the high correlation and low RMSE over Southwest Florida for onset and demise dates, and seasonal length of the wet season (Table 2). The values in Table 2 clearly show that the 12 hour latency is far more superior over Southwest Florida WMD in comparison to the 3.5 month latency for all parameters of the wet season except the seasonal rainfall. This again suggests that the 12 hour latency version of IMERG is reasonable to use for monitoring the evolution of the wet season over Southwest Florida WMD.

iii) St. Johns River Water Management District

Similarly, Figs. 6a-d show the variations of the parameters of the wet season over the St. Johns River WMD with the corresponding correlations and RMSE in Table 3. Like over Southwest Florida WMD, the 12 hour latency version of IMERG dataset shows significant improvement over the 3.5 month latency version of IMERG both with respect to RMSE and correlation values for the parameters of the onset and the demise dates and seasonal length of the wet season. The correlation values are substantially higher (and statistically significant at 95% confidence interval) and the RMSE values are substantially lower in Table 3 to suggest that the 12 hour latency version of IMERG may be appropriate to monitor the onset and demise of the rainy season over St. John River WMD. However, it may be noted that the RMSE of the seasonal rainfall is considerably less in 3.5 month latency dataset compared to the 12 hour latency (Table 3), which suggests that the latter dataset has a bias in diagnosing the rain rates over the wet season.

iv) Suwanee River Water Management District

The time series of the onset date, demise date, seasonal length, and seasonal rainfall of the wet season over the Suwanee River WMD from all three datasets are shown in Figs. 7a-d. The corresponding RMSE and correlation values are shown in Table 4. In this case, although the 12 hour latency version of IMERG shows considerable improvement over the 3.5 month latency of IMERG in terms of RMSE, the correlation values are far more comparable between the two datasets. Furthermore, the 12 hour latency dataset shows a larger RMSE for seasonal rainfall than the 3.5 month latency dataset (Table 4). Again, we find that the correlation values are statistically significant in both datasets at 95% confidence interval for all 4 parameters of the wet season (Table 4) to suggest that the 12 hour latency product of IMERG could be used to monitor the rainy season over the Suwannee River WMD, albeit with some systematic bias correction.

v) Northwest Florida Water Management District

The variations of the onset date, demise date, seasonal length, and seasonal rainfall of the wet season over the Northwest Florida WMD from the three rainfall datasets are indicated in Figs. 8a-d. Their corresponding RMSE and correlation values are shown in Table 5. We find in this case that the correlations are slightly higher in 3.5 month latency version of IMERG relative to the 12 hour latency of IMERG for all parameters except the demise date (Table 5). However, in both cases the correlation values are statistically significant at 95% confidence interval according to t-test. Similarly, we find that the RMSE is reduced in 3.5 month latency version of IMERG relative to 12 hour latency for all four parameters (Table 5). But given the relative statistical significance of the correlations of the 12 hour latency in Table 5, it is suggested that the dataset could be used to monitor the variations of the wet season over Northwest Florida.

6.CONCLUSIONS

This study was motivated to assess the fidelity of gridded, remotely sensed rainfall analysis for real time monitoring of the wet season over the five WMDs of Florida. All five WMDs have a significant fraction of the annual rainfall occurring in the wet season. Therefore, monitoring and anticipating its variations from year to year would be critical to manage water resources in the WMDs. The recent launch of the GPM mission and its remotely sensed rainfall products offer new opportunities to leverage for this monitoring effort.

In this study we have evaluated two remotely sensed rainfall products from GPM relative to a rain gauge based analysis. The remotely sensed rainfall products are based on microwave sensors and precipitation radar in the GPM constellation of satellites that are merged with numerical forecasts and atmospheric reanalysis to produce gridded rainfall analysis available at 0.1° grid resolution at hourly interval at a latency of 12 hours and 3.5 months. The latter product ingests a larger volume of data for analysis and a more rigorous analysis technique, which would lead to the anticipation of a better rainfall analysis than the former 12 hour latency product.

Our study finds that indeed the 3.5 month latency product of IMERG reduces the RMSE of the seasonal rainfall of the wet season systematically over all five WMDs relative to the 12 hour latency product. However, in terms of the diagnosis of the onset and demise dates, and the seasonal length, the results are somewhat mixed. In some WMDs the RMSE of the onset date, demise date, and the seasonal length of the 3.5 month latency dataset shows a deterioration relative to the 12 month latency (e.g., Southwest Florida, St. Johns River, and Suwannee River). Over Northwest Florida WMD, the RMSE of the 3.5 month latency product for these three parameters of the wet season (onset and demise dates, and seasonal length) shows a marginal improvement over the 12 hour latency. Similarly, the correlations of these three parameters of the wet season are higher in

12 hour latency compared to 3.5 month latency over Southwest Florida and St. Johns River WMD. But the correlations between the 12 hour latency dataset and the CPC dataset for all parameters of the wet season over all five WMDs are distinctly significant at 95% confidence interval according to t-test. Therefore, despite the relatively larger RMSE than the 3.5 month latency dataset in some of these parameters, the 12 hour latency product of IMERG may be reasonable to use for monitoring the evolution of the wet season over all five WMDs of Florida.

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Table 1: The correlation coefficient and root mean squared error between the onset date, demise date, season length, and total seasonal rainfall anomalies for South Florida from the comparison of the 12-hour latency IMERG and CPC data and the 3.5-month latency IMERG and CPC data. The bold values of the correlation coefficient indicate that they are significant at 95% confidence interval according to t-test.

South Florida		
12hour vs CPC	CorrCoef	RMSE
Onset	**0.58**	10.77
Demise	**0.43**	16.85
Seasonal Length	**0.48**	23.42
Seasonal Rainfall	**0.59**	426.13
3.5month vs CPC	CorrCoef	RMSE
Onset	0.27	28.78
Demise	**0.82**	11.27
Seasonal Length	**0.49**	28.67
Seasonal Rainfall	**0.69**	178.4

Table 2: The correlation coefficient and root mean squared error between the onset date, demise date, season length, and total seasonal rainfall anomalies for Southwest Florida from the comparison of the 12-hour latency IMERG and CPC data and the 3.5-month latency IMERG and CPC data. The bold values of the correlation coefficient indicate that they are significant at 95% confidence interval according to t-test.

Southwest Florida		
12hour vs CPC	CorrCoef	RMSE
Onset	**0.95**	3.48
Demise	**0.88**	7.23
Seasonal Length	**0.93**	7.99
Seasonal Rainfall	**0.79**	343.46
3.5month vs CPC	CorrCoef	RMSE
Onset	**0.59**	24.62
Demise	0.31	18.51
Seasonal Length	**0.52**	28.19
Seasonal Rainfall	**0.7**	189.14

Table 3: The correlation coefficient and root mean squared error between the onset date, demise date, season length, and total seasonal rainfall anomalies for St. Johns River from the comparison of the 12-hour latency IMERG and CPC data and the 3.5-month latency IMERG and CPC data. The bold values of the correlation coefficient indicate that they are significant at 95% confidence interval according to t-test.

St. Johns River		
12hour vs CPC	CorrCoef	RMSE
Onset	**0.78**	7.8102
Demise	**0.59**	18.02
Seasonal Length	**0.59**	21.72
Seasonal Rainfall	**0.85**	212.33
3.5month vs CPC	CorrCoef	RMSE
Onset	0.38	64.474
Demise	**0.53**	41.99
Seasonal Length	0.11	78.65
Seasonal Rainfall	**0.46**	419.45

Table 4: The correlation coefficient and root mean squared error between the onset date, demise date, season length, and total seasonal rainfall anomalies for Suwannee River from the comparison of the 12-hour latency IMERG and CPC data and the 3.5-month latency IMERG and CPC data. The bold values of the correlation coefficient indicate that they are significant at 95% confidence interval according to t-test.

Suwannee River		
12hour vs CPC	CorrCoef	RMSE
Onset	**0.72**	9.39
Demise	**0.71**	14.08
Seasonal Length	**0.79**	15.12
Seasonal Rainfall	**0.69**	223.23
3.5month vs CPC	CorrCoef	RMSE
Onset	**0.65**	31.55
Demise	**0.78**	26.19
Seasonal Length	**0.46**	33.09
Seasonal Rainfall	**0.83**	158.98

Table 5: The correlation coefficient and root mean squared error between the onset date, demise date, season length, and total seasonal rainfall anomalies for Northwest Florida from the comparison of the 12-hour latency IMERG and CPC data and the 3.5-month latency IMERG and CPC data. The bold values of the correlation coefficient indicate that they are significant at 95% confidence interval according to t-test.

Northwest Florida		
12hour vs CPC	CorrCoef	RMSE
Onset	**0.41**	49.11
Demise	**0.71**	16.38
Seasonal Length	0.33	49.83
Seasonal Rainfall	**0.72**	388.99
3.5month vs CPC	CorrCoef	RMSE
Onset	**0.7**	46.73
Demise	**0.61**	16.83
Seasonal Length	**0.57**	42.7
Seasonal Rainfall	**0.82**	211.91

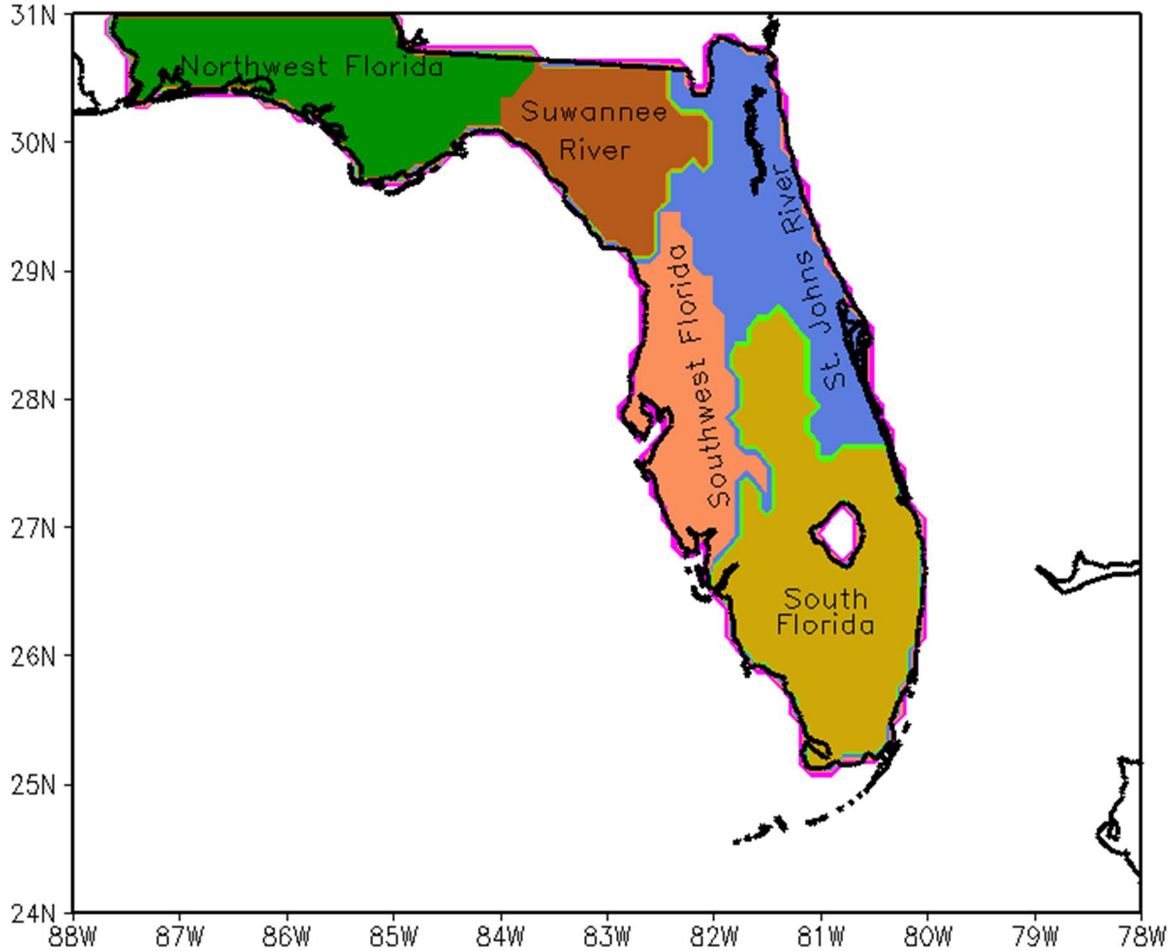

Figure 1: Mask of the water management districts for which the onset and demise of the wet season is diagnosed.

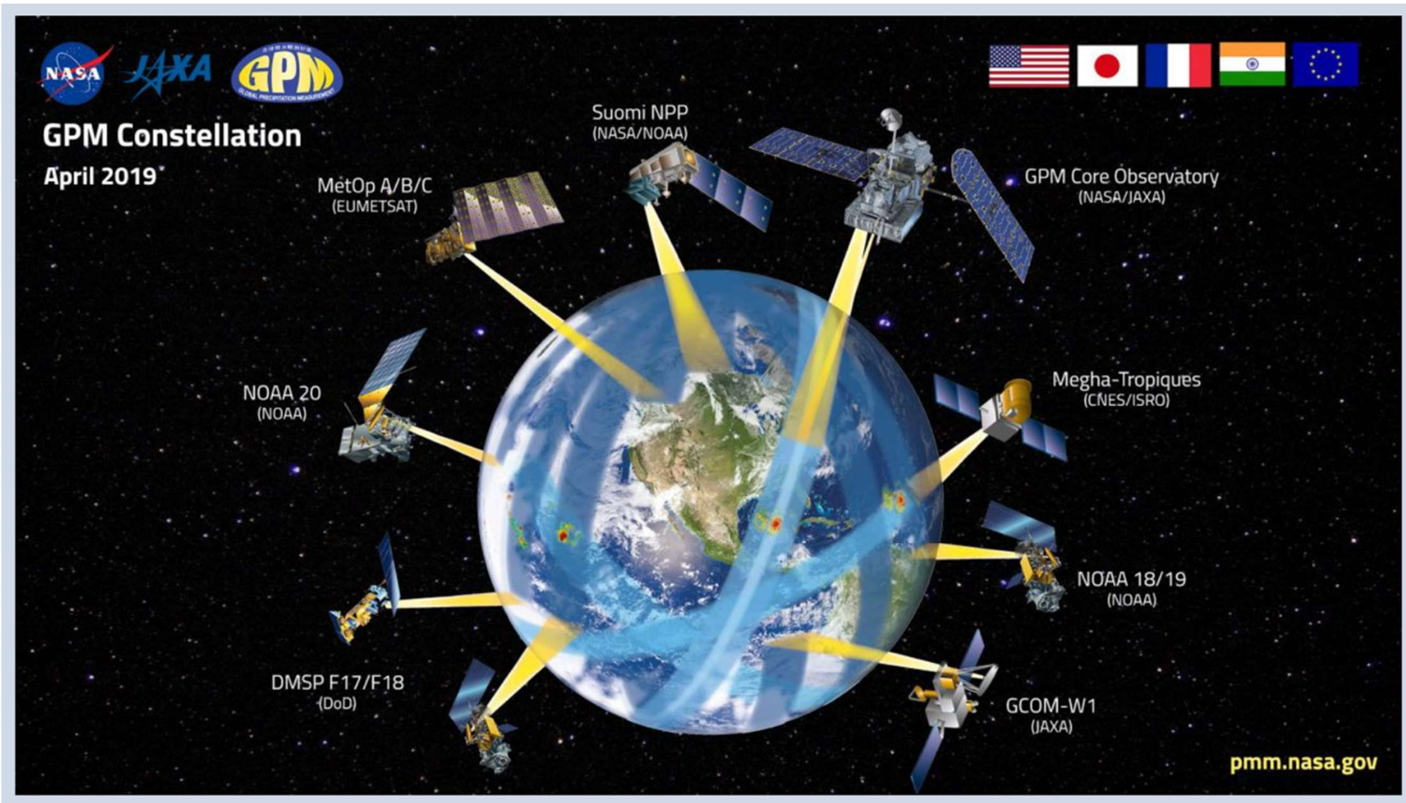

Figure 2: Illustration of the GPM constellation of satellites as of early 2019. Reproduced from: https://gpm.nasa.gov/missions/GPM/constellation.

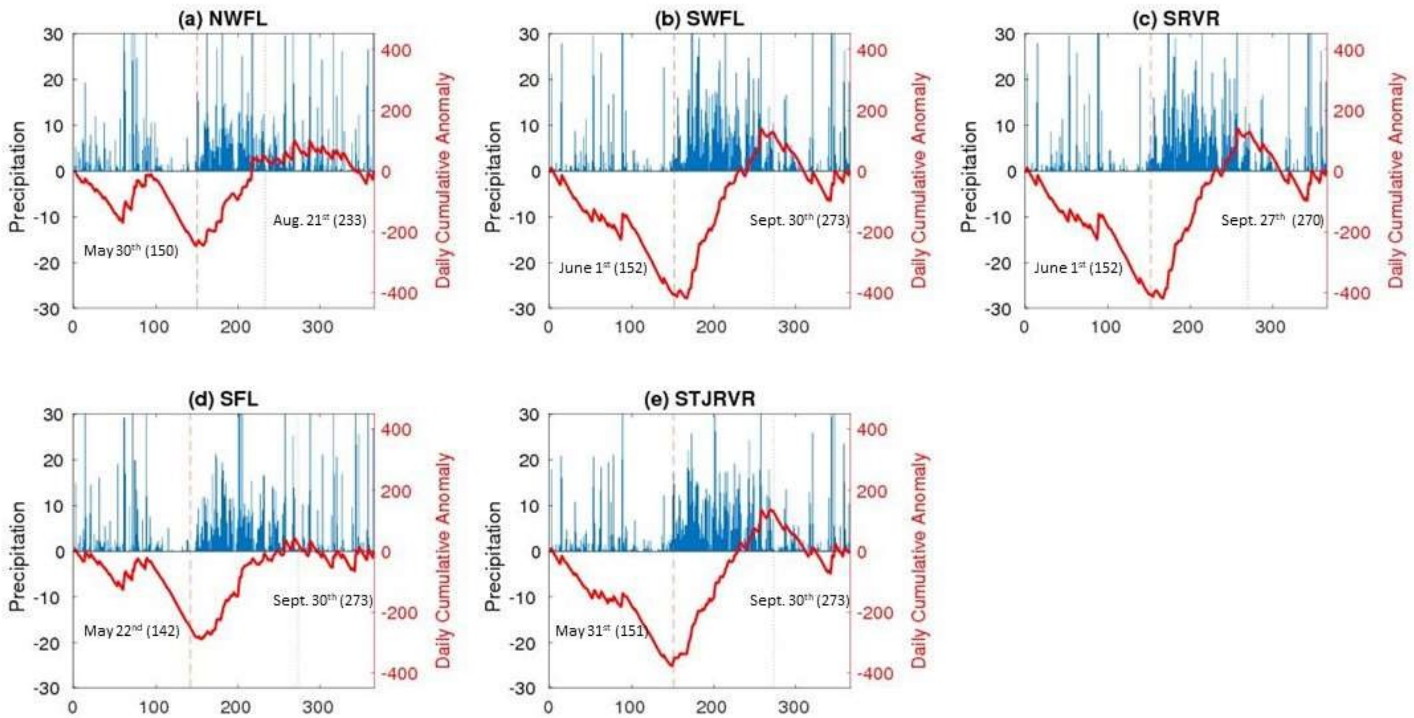

Figure 3: Daily climatological rain rate (in blue; mm/day) over (a) Northwest Florida, (b) Southwest Florida, (c) Suwannee River, (d) South Florida, and (e) St. Johns river with their corresponding daily cumulative anomaly of rainfall (mm) in (red) with their diagnosed onset and demise dates of the wet season in Julian day. This is for the 12hour latency IMERG rainfall dataset for the year 2001.

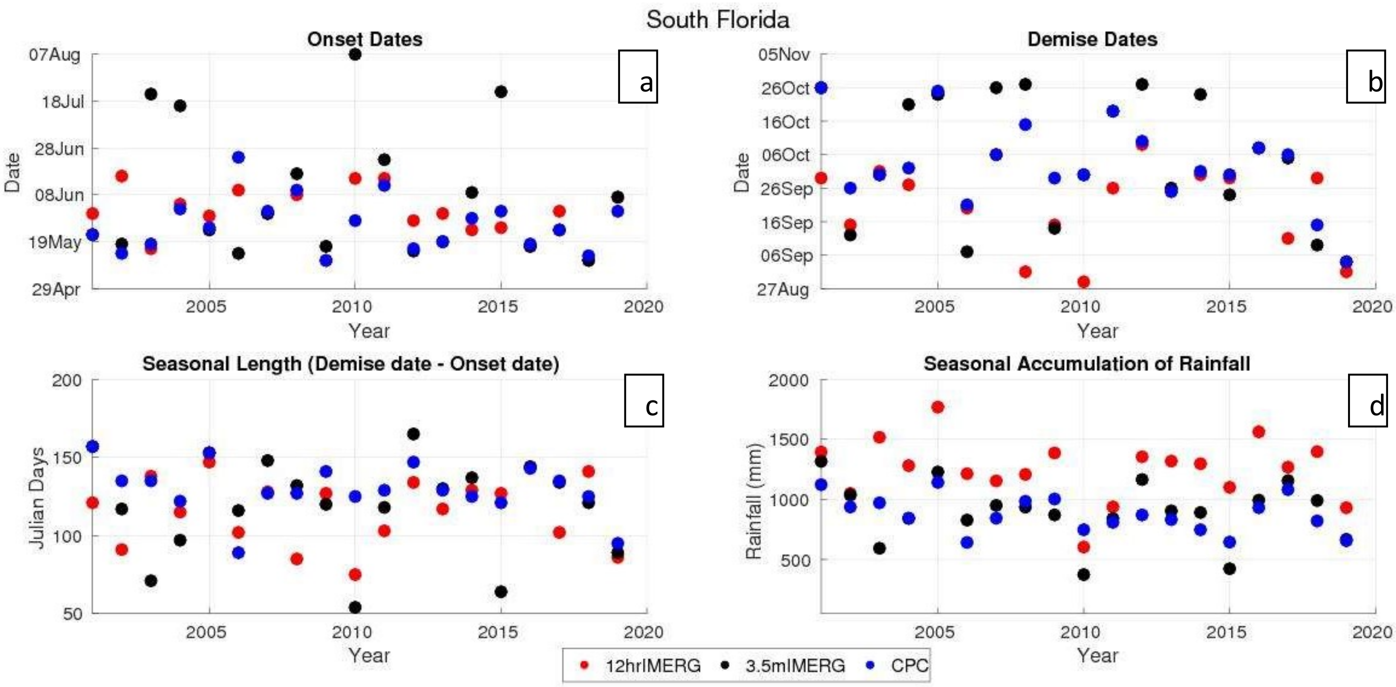

Figure 4: Time series of a) onset date, b) demise date, c) seasonal length, and d) seasonal accumulation of rainfall of the wet season for South Florida. Blue dots are for CPC, black dots are for 3.5-month IMERG and reds dots are for the 12-hour latency IMERG rainfall dataset, respectively.

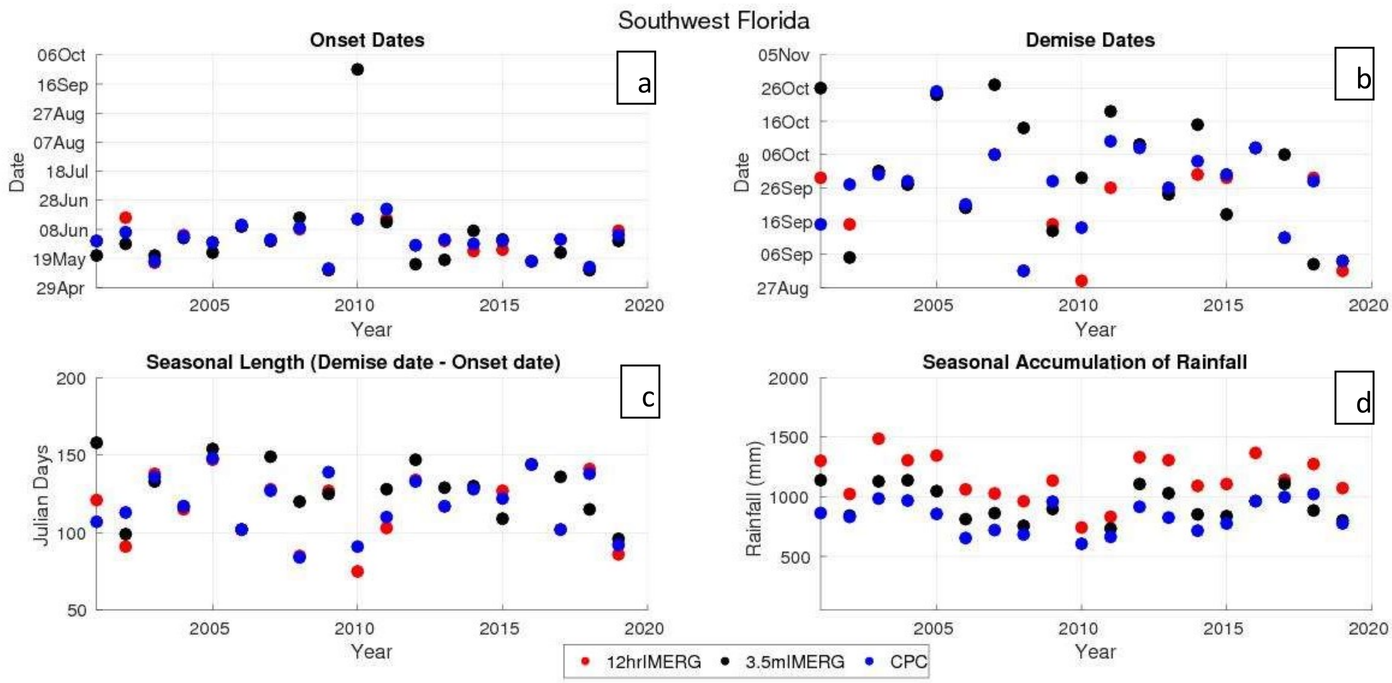

Figure 5: Time series of a) onset date, b) demise date, c) seasonal length, and d) seasonal accumulation of rainfall of the wet season for Southwest Florida. Blue dots are for CPC, black dots are for 3.5-month IMERG and reds dots are for the 12-hour latency IMERG rainfall dataset, respectively.

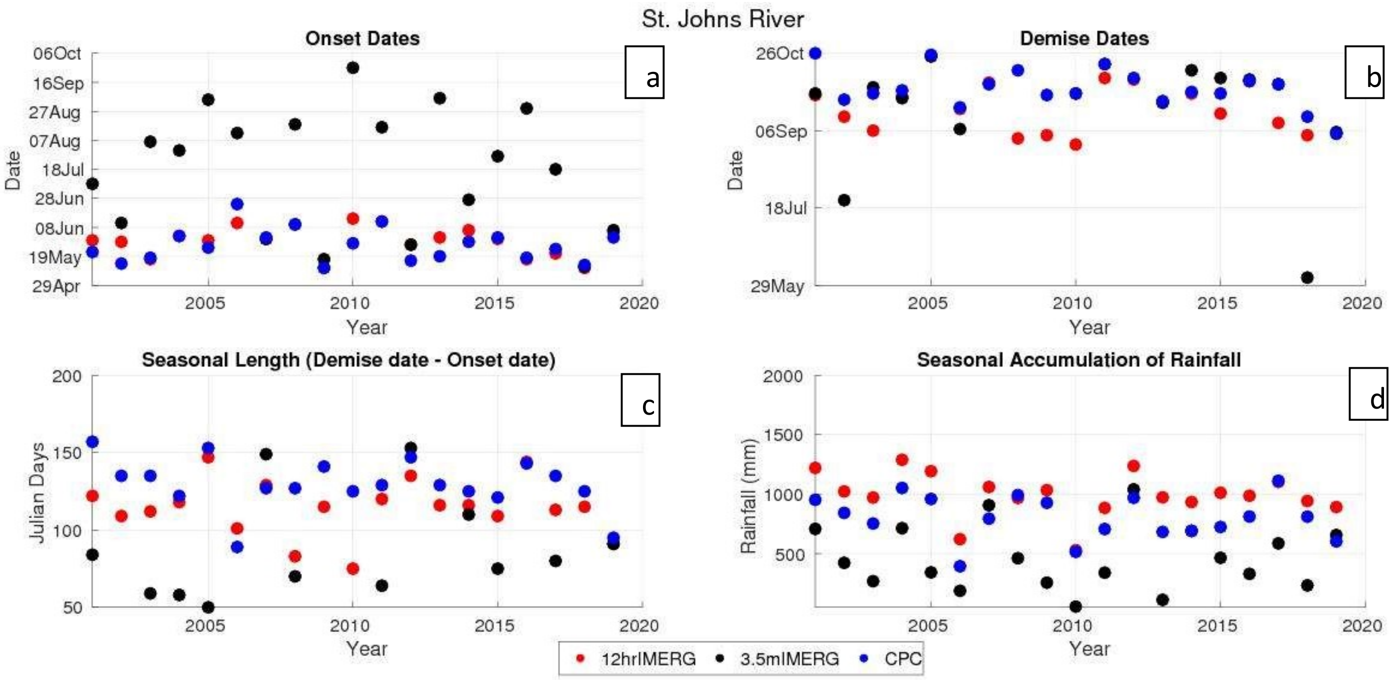

Figure 6: Time series of a) onset date, b) demise date, c) seasonal length, and d) seasonal accumulation of rainfall of the wet season for St. Johns River. Blue dots are for CPC, black dots are for 3.5-month IMERG and reds dots are for the 12-hour latency IMERG rainfall dataset, respectively.

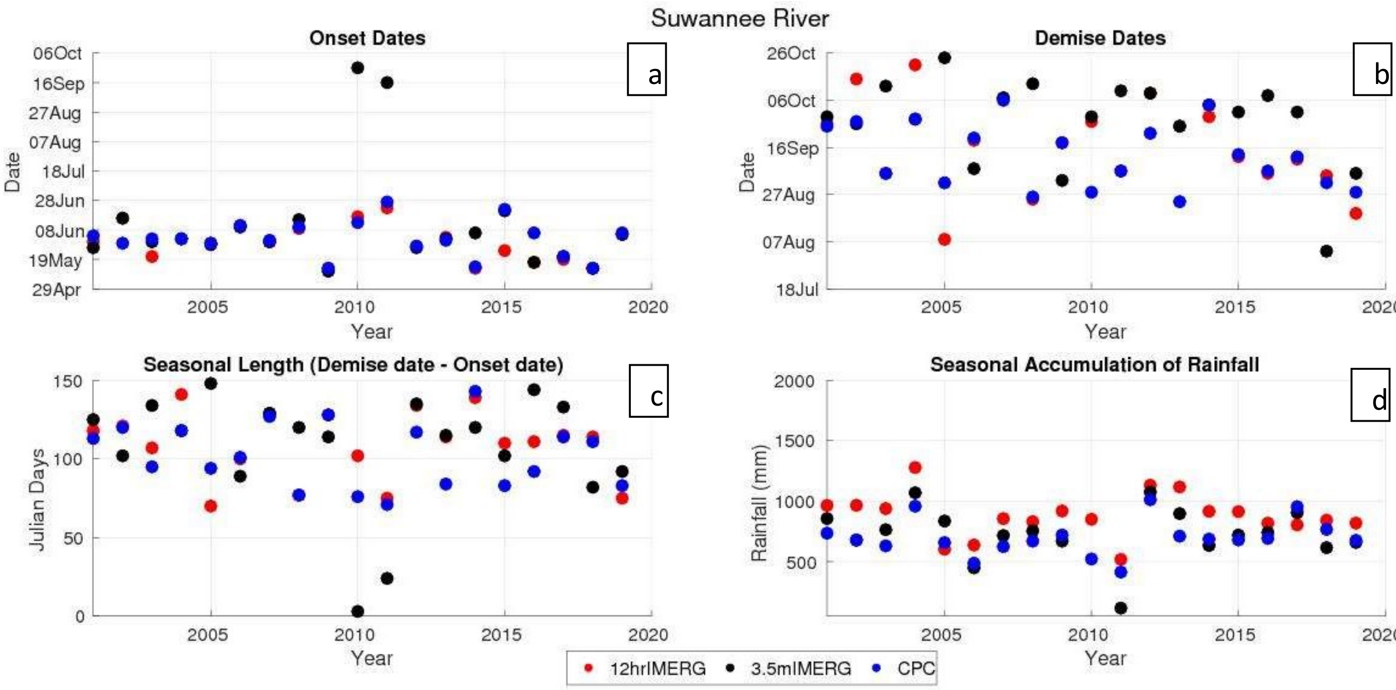

Figure 7: Time series of a) onset date, b) demise date, c) seasonal length, and d) seasonal accumulation of rainfall of the wet season for Suwannee River. Blue dots are for CPC, black dots are for 3.5-month IMERG and reds dots are for the 12-hour latency IMERG rainfall dataset, respectively.

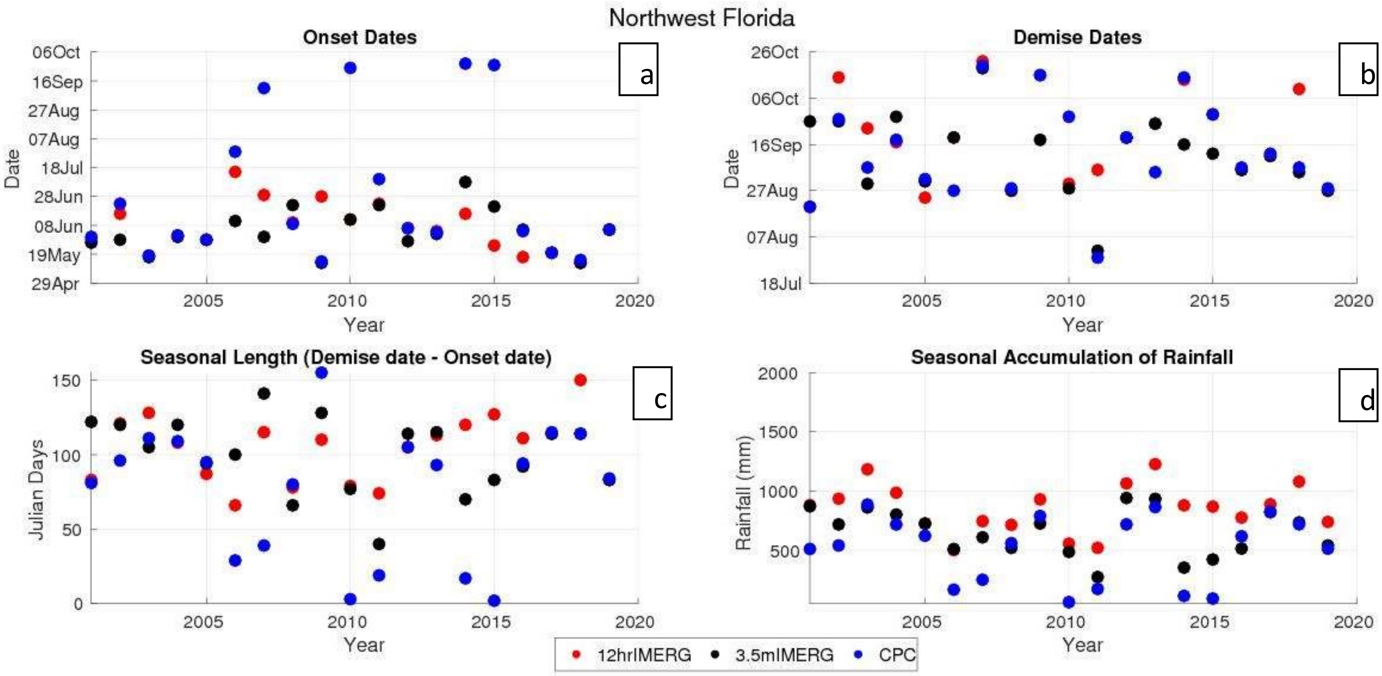

Figure 8: Time series of a) onset date, b) demise date, c) seasonal length, and d) seasonal accumulation of rainfall of the wet season for Northwest Florida. Blue dots are for CPC, black dots are for 3.5-month IMERG and reds dots are for the 12-hour latency IMERG rainfall dataset, respectively.