



Water Resources Research

Supporting Information for

The Role of Intensifying Precipitation on Coastal River Flooding and Compound River-Storm Surge Events, Northeast Gulf of Mexico

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Introduction

The supporting figures and tables are described and discussed in the main text. Additional government reports were accessed for road lengths (U.S. Bureau of Public Roads 1952, 1962, U.S. Federal Highway Administration 1972, 1982, 1992, 2003, 2014, 2021) and population (U.S. Census Bureau 2021).

Supporting Figures

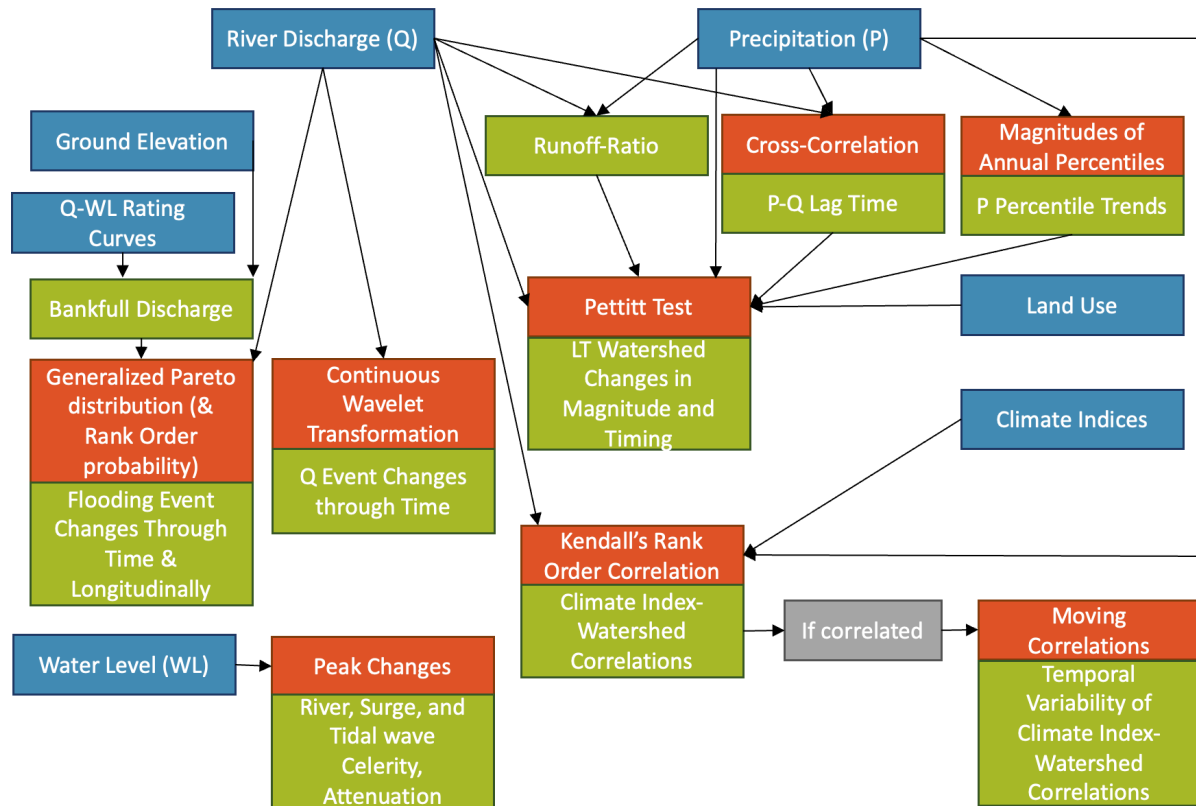


Figure S1. Flowchart of the methodology. Blue, red, and green boxes show observations/source materials, methods, and results, respectively.

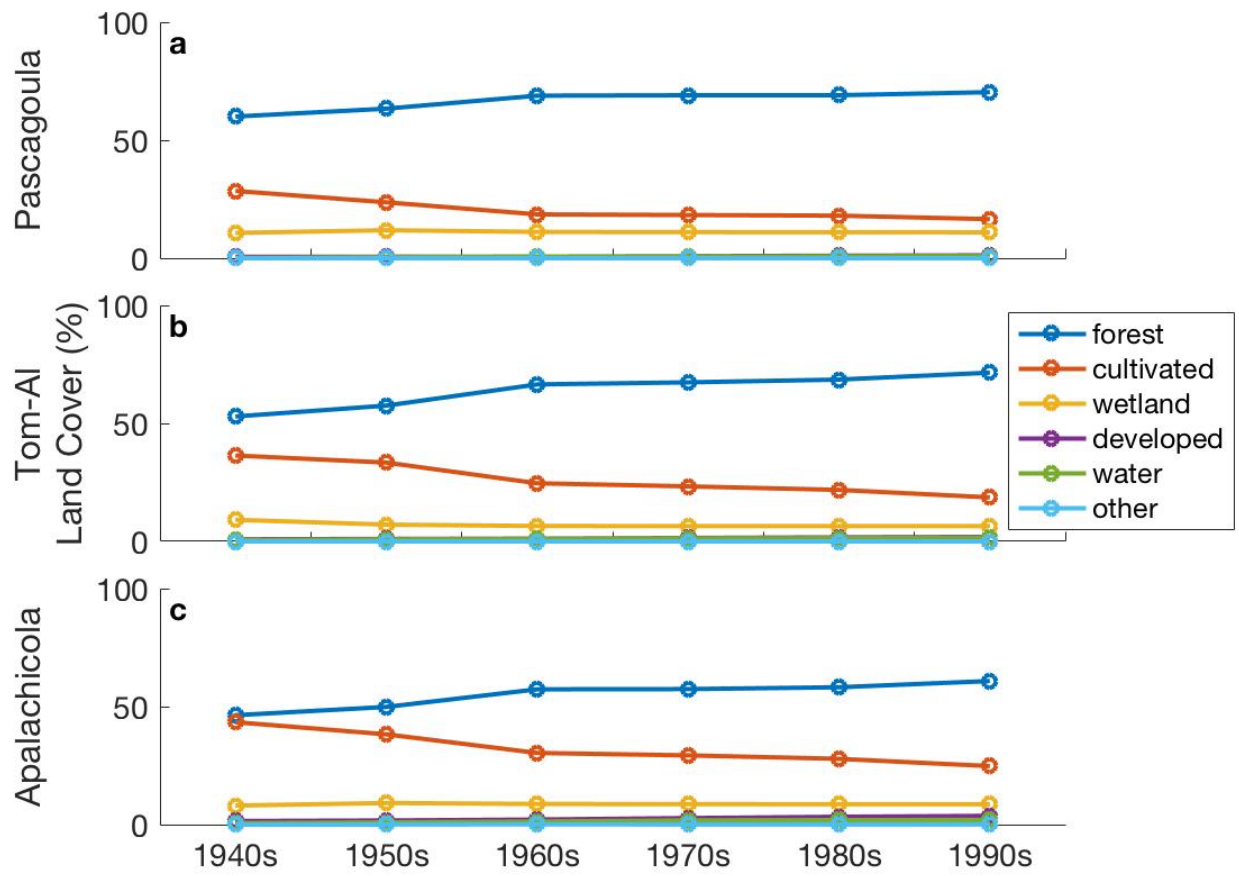


Figure S2. Land cover time series. Land cover is shown by watershed for the (a) Pascagoula, (b) Tombigbee-Alabama, and (c) Apalachicola.

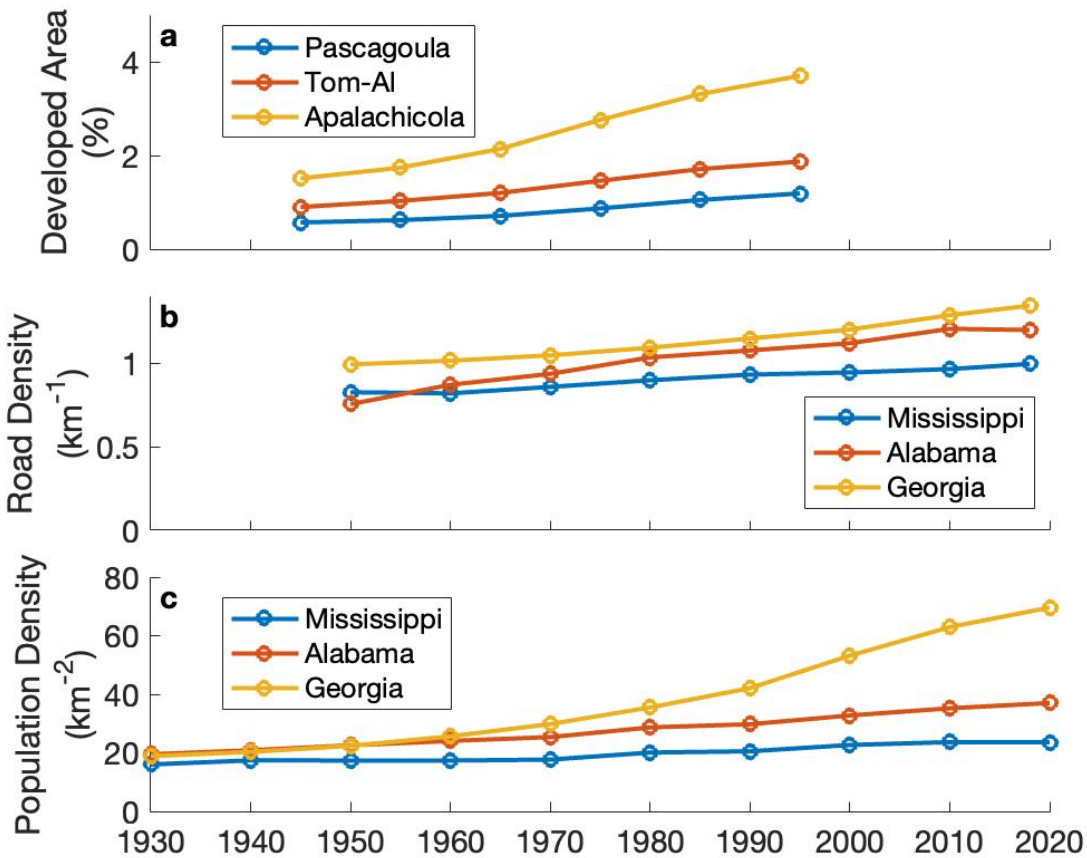


Figure S3. Human development through time. Time series of (a) developed area by watershed and the densities of (b) roads and (c) human population by state. (b) Roads commonly have ditches, which allows them to serve as an estimate to identify changes in drainage density. The Pascagoula, Tombigbee-Alabama, and Apalachicola watersheds are predominantly within the state of Mississippi, Alabama, and Georgia, respectively. (c) Trends in road and population densities support the modeled trends in developed area. The Georgia population trend being steeper than the Apalachicola developed area is likely a result of the metropolitan region of Atlanta, of which only part is within the Apalachicola Watershed. Note: (a) Because developed area is small in context of other land covers (Fig. S2), for clarity, it is also shown here.

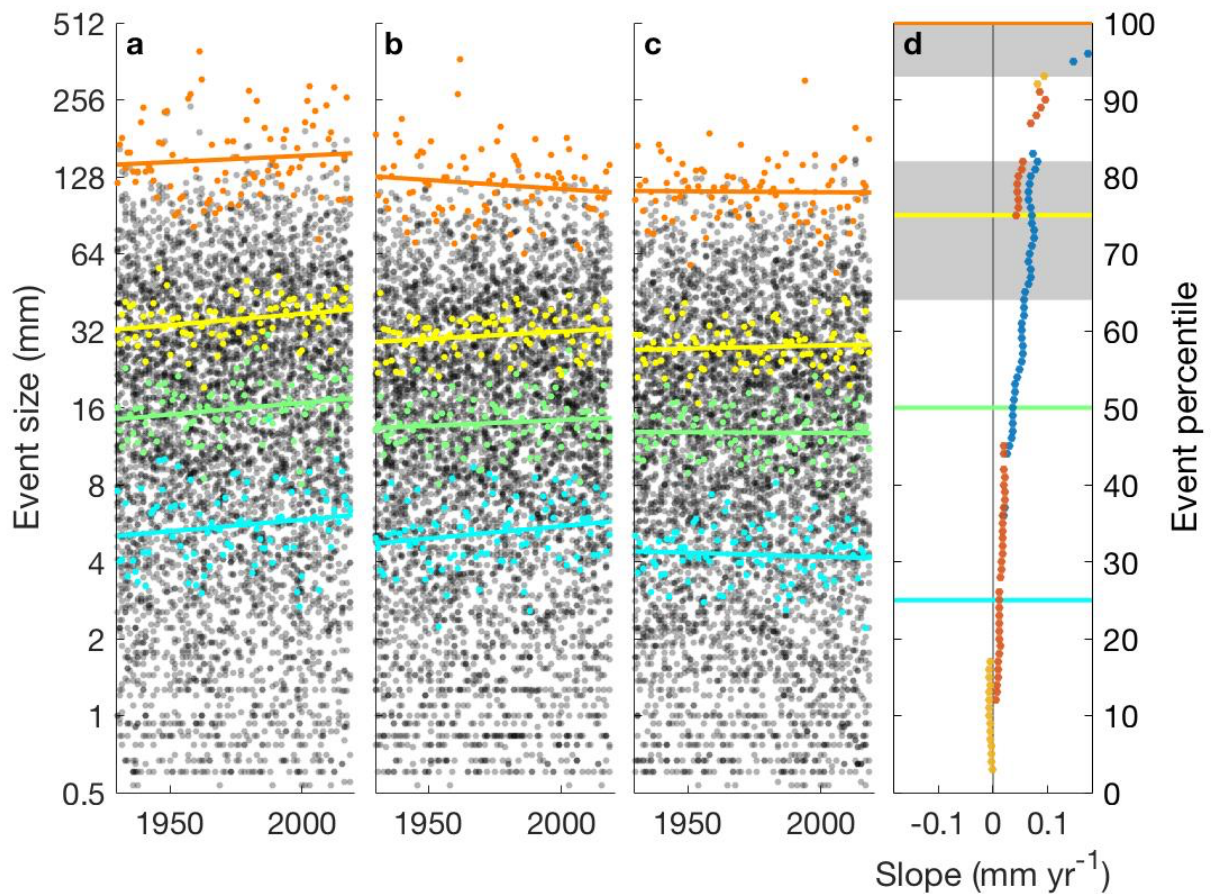


Figure S4. Precipitation event trends. Time series of precipitation event sizes (gray dots) highlighting linear trends of the 25th, 50th, 75th, and 100th percentiles (light blue, green, yellow, and orange lines, respectively) for (a) Pascagoula, (b) Tom-AI, and (c) Apalachicola Watersheds. (d) A summary of significant percentile trends ($p < 0.1$) over time highlights long-term changes in system events where positive slopes indicate increasing magnitudes for Pascagoula (blue), Tom-AI (red), and Apalachicola (dark yellow) Watersheds. Highlighted event percentiles from a, b, and c are shown in contrast to the mean distribution of volume (1st/3rd and 2nd/4th quartiles in white and gray banding, respectively), showing half of all precipitation is represented by the 82nd percentile and came in the largest 18% of events.

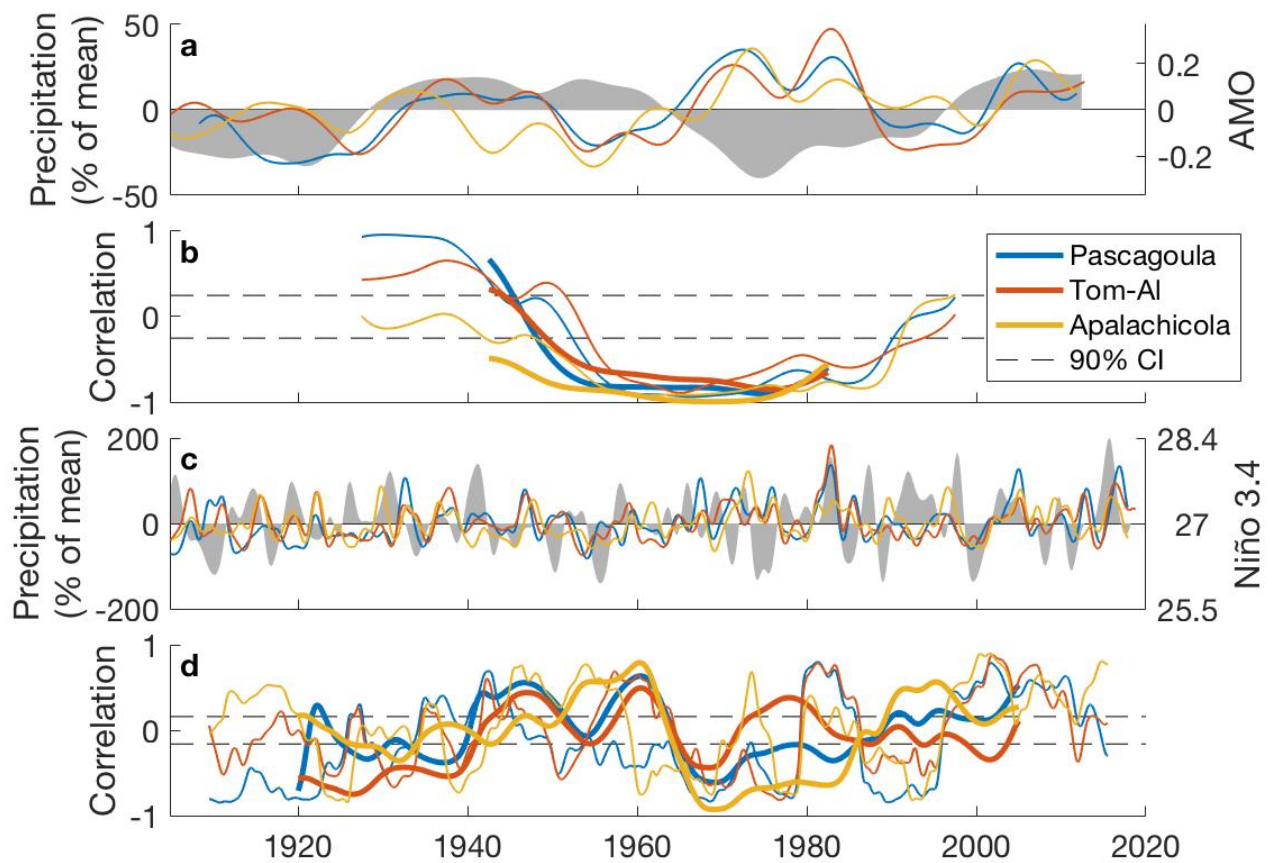


Figure S5. Climate oscillation-precipitation correlation. Time series of (a) very low frequency (15-year filter window) normalized precipitation and the AMO (grey shading), (b) moving correlation between the AMO and precipitation, (c) low frequency (3-year filter window) normalized precipitation and Niño 3.4 (grey shading), and (d) moving correlation between Niño 3.4 and precipitation. In b and d, the thin lines have confidence intervals and correspond to the thin lines and filtering of a and c, respectively, while the bold lines capture lower frequencies with 25 and 10-year filter windows, respectively.

Supporting Tables

Table S1. Data list and sources. Table shows all data used in the study and URLs for direct data access.

Data Type	Source	Name	ID	Resolution	URL	
Precipitation	NOAA	Global Historical Climatology Network			ncdc.noaa.gov/ghcnv2-data-access	
		Aberdeen, MS US	USC00220021	Daily	ncdc.noaa.gov/cdo-web/datasets/GHCND/stations/GHCND:USC00220021/detail	
		Albany 3 SE, GA US	USC00090140	Daily	ncdc.noaa.gov/cdo-web/datasets/GHCND/stations/GHCND:USC00090140/detail	
		Hattiesburg, MS US	USC00223887	Daily	ncdc.noaa.gov/cdo-web/datasets/GHCND/stations/GHCND:USC00223887/detail	
		Leakesville, MS US	USC00224966	Daily	ncdc.noaa.gov/cdo-web/datasets/GHCND/stations/GHCND:USC00224966/detail	
		Montezuma 2 NW, GA US	USC00095979	Daily	ncdc.noaa.gov/cdo-web/datasets/GHCND/stations/GHCND:USC00095979/detail	
		Selma, AL US	USC00017366	Daily	ncdc.noaa.gov/cdo-web/datasets/GHCND/stations/GHCND:USC00017366/detail	
		Shubuta, MS US	USC00228053	Daily	ncdc.noaa.gov/cdo-web/datasets/GHCND/stations/GHCND:USC00228053/detail	
		Talladega, AL US	USC00018024	Daily	ncdc.noaa.gov/cdo-web/datasets/GHCND/stations/GHCND:USC00018024/detail	
		Woodbury, GA US	USC00099506	Daily	ncdc.noaa.gov/cdo-web/datasets/GHCND/stations/GHCND:USC00099506/detail	
Discharge	NOAA	Global Precipitation Climatology Center LTM Total Full V2018	--	0.5 degree*	ftp.cdc.noaa.gov/Datasets/gpcc/full_v2018/precip.mon.ltm.v2018.nc	
	USGS	National Water Information System			waterdata.usgs.gov	
Water level	USGS	Alabama River at Claiborne, AL	02429500	Daily	waterdata.usgs.gov/nwis/inventory/?site_no=02429500&agency_cd=USGS	
		Alabama River at Claiborne...	02428400	Daily	waterdata.usgs.gov/nwis/inventory/?site_no=02428400&agency_cd=USGS	
		Apalachicola River at Chatt...	02358000	Daily	waterdata.usgs.gov/nwis/inventory/?site_no=02358000&agency_cd=USGS	
		Pascagoula River at Merrill, MS	02479000	Daily	waterdata.usgs.gov/nwis/inventory/?site_no=02479000&agency_cd=USGS	
		Tombigbee R at Coffeeville...	02469761	Daily	waterdata.usgs.gov/nwis/inventory/?site_no=02469761&agency_cd=USGS	
Climate Indices	NOAA	Tides & Currents			tidesandcurrents.noaa.gov	
		Dauphin Island, AL	8735180	Hourly	tidesandcurrents.noaa.gov/stationhome.html?id=8735180#info	
		USGS	National Water Information System			waterdata.usgs.gov
		Mobile River at river mile 31.0...	02470629	30 min	waterdata.usgs.gov/nwis/inventory/?site_no=02470629&agency_cd=USGS	
Rating Curves	USGS	Tombigbee R bl Coffeeville...	02469762	Hourly	waterdata.usgs.gov/nwis/inventory/?agency_code=USGS&site_no=02469762	
		Tombigbee River at steamplant...	02470050	Hourly	waterdata.usgs.gov/nwis/inventory/?site_no=02470050&agency_cd=USGS	
		NOAA	Global Climate Observing System			esrl.noaa.gov/psd/gcos_wgsp/Timeseries
		Atlantic multidecadal oscillation	AMO	Monthly	esrl.noaa.gov/psd/data/correlation/amon.us.long.data	
		AMO "not detrended"	AMO (trend)	Monthly	esrl.noaa.gov/psd/data/correlation/amon.us.long.mean.data	
		Dipole Mode Index	DMI	Monthly	esrl.noaa.gov/psd/gcos_wgsp/Timeseries/Data/dmi.long.data	
		Niño 1+2 SST Index	Niño 1+2	Monthly	esrl.noaa.gov/psd/gcos_wgsp/Timeseries/Data/nino12.long.data	
		Niño 3 SST Index	Niño 3	Monthly	esrl.noaa.gov/psd/gcos_wgsp/Timeseries/Data/nino3.long.data	
		Niño 3.4 SST Index	Niño 3.4	Monthly	esrl.noaa.gov/psd/gcos_wgsp/Timeseries/Data/nino34.long.data	
		Niño 4 SST Index	Niño 4	Monthly	esrl.noaa.gov/psd/gcos_wgsp/Timeseries/Data/nino4.long.data	
		North Atlantic Oscillation	NAO	Monthly	esrl.noaa.gov/psd/gcos_wgsp/Timeseries/Data/nao.long.data	
		North Pacific Index	NPI	Monthly	esrl.noaa.gov/psd/gcos_wgsp/Timeseries/Data/np.long.data	
		Pacific Decadal Oscillation	PDO	Monthly	esrl.noaa.gov/psd/gcos_wgsp/Timeseries/Data/pdo.long.data	
		Pacific North American Index	PNA	Monthly	esrl.noaa.gov/psd/data/20thC_Rean/timeseries/monthly/PNA/pna.20crv2c.long.data	
		Southern Annular Mode	SAM	Monthly	esrl.noaa.gov/psd/data/20thC_Rean/timeseries/monthly/SAM/sam.20crv2c.long.data	
Southern Oscillation Index	SOI	Monthly	esrl.noaa.gov/psd/gcos_wgsp/Timeseries/Data/soi.long.data			
Trans Polar Index	TPI	Monthly	esrl.noaa.gov/psd/gcos_wgsp/Timeseries/Data/tpi.long.data			
Watershed	USGS	Watershed Boundary Dataset			sciencebase.gov/catalog/item/5a1632b3e4b09f93dd171e2	
Land Cover	USGS	Maryland Water Science Center Wieczorek et al. 2018	--	10 years	sciencebase.gov/catalog/item/58cbeef2e4b0849ce97dcd61	
Rating Curves	USGS	Rating Curve Builder	various+		waterwatch.usgs.gov/?id=mkrc	
		Peer-Reviewed Literature				
		Dykstra & Dzwonkowski 2020	--		data.gulfresearchinitiative.org/data/R4.x260.000:0125	

*Resolution is spatial

+Station IDs used for discharge rating curves: 02479310 (Graham Ferry), 02479000 (Merrill), 02359170 (Sumatra), 02358700 (Blountstown)

Table S2. Discharge and precipitation (a) p-values and (b) correlations with climate indices.

Results were calculated from monthly averages using Kendall's tau. For full names of indices, see Table S1.

a

Climate Oscillation	Discharge			Precipitation		
	Pascagoula	Tom-AL	Apalachicola	Pascagoula	Tom-AL	Apalachicola
AMO	0.00	0.00	0.00	0.04	0.10	0.07
AMO (trend)	0.00	0.00	0.00	0.20	0.15	0.34
DMI	0.86	0.12	0.94	0.42	0.39	0.35
Niño 1+2	0.00	0.00	0.00	0.39	0.05	0.60
Niño 3	0.00	0.00	0.00	0.82	0.07	0.09
Niño 3.4	0.00	0.00	0.00	0.71	0.18	0.06
Niño 4	0.24	0.06	1.00	0.65	1.00	0.24
NAO	0.00	0.00	0.01	0.75	0.68	0.50
NPI	0.00	0.00	0.02	0.00	0.04	0.00
PDO	0.00	0.23	0.06	0.63	0.91	0.62
PNA	0.63	0.53	0.67	0.94	0.82	0.78
SAM	0.04	0.10	0.00	0.24	0.96	0.62
SOI	0.06	0.18	0.02	0.20	0.37	0.34
TPI	0.01	0.02	0.00	0.71	0.84	0.35

b

Climate Oscillation	Discharge			Precipitation		
	Pascagoula	Tom-AL	Apalachicola	Pascagoula	Tom-AL	Apalachicola
AMO	-0.06	-0.09	-0.10	-0.04	-0.04	-0.04
AMO (trend)	-0.39	-0.44	-0.35	0.03	-0.03	0.02
DMI	0.00	0.03	0.00	0.02	0.02	0.02
Niño 1+2	0.41	0.44	0.38	-0.02	0.04	0.01
Niño 3	0.32	0.34	0.33	-0.01	0.04	0.04
Niño 3.4	0.15	0.16	0.19	0.01	0.03	0.04
Niño 4	-0.02	-0.04	0.00	0.01	0.00	0.03
NAO	0.07	0.08	0.06	-0.01	-0.01	0.01
NPI	-0.08	-0.11	-0.05	0.08	0.04	0.09
PDO	0.07	0.02	0.04	-0.01	0.00	0.01
PNA	-0.01	-0.01	0.01	0.00	-0.01	-0.01
SAM	-0.04	-0.03	-0.08	0.03	0.00	-0.01
SOI	-0.04	-0.03	-0.05	-0.03	-0.02	-0.02
TPI	0.05	0.05	0.09	-0.01	0.00	0.02

Table S3. (a) P-values and (b) correlation between climate indices. Results were calculated from monthly averages using Kendall's tau. For full names of indices, see Table S1.

a

Osillation	AMO	AMO (tre	DMI	Niño 1+2	Niño 3	Niño 3.4	Niño 4	NAO	NPI	PDO	PNA	SAM	SOI	TPI
AMO	0.00	0.00	0.14	0.01	0.55	0.23	0.00	0.00	0.05	0.23	0.30	0.35	0.93	0.31
AMO (trend)	0.00	0.00	0.91	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.57	0.00	0.43	0.31
DMI	0.14	0.91	0.00	0.00	0.00	0.00	0.00	0.15	0.33	0.01	0.45	0.00	0.00	0.00
Niño 1+2	0.01	0.00	0.00	0.00	0.00	0.00	0.14	0.02	0.00	0.00	0.12	0.01	0.00	0.00
Niño 3	0.55	0.00	0.00	0.00	0.00	0.00	0.00	0.69	0.87	0.00	0.00	0.00	0.00	0.00
Niño 3.4	0.23	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00
Niño 4	0.00	0.00	0.00	0.14	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.04	0.00	0.00
NAO	0.00	0.00	0.15	0.02	0.69	0.05	0.02	0.00	0.65	0.54	0.00	0.54	0.34	0.12
NPI	0.05	0.00	0.33	0.00	0.87	0.00	0.00	0.65	0.00	0.00	0.00	0.09	0.00	0.00
PDO	0.23	0.11	0.01	0.00	0.00	0.00	0.00	0.54	0.00	0.00	0.00	0.88	0.00	0.00
PNA	0.30	0.57	0.45	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.86	0.00	0.00
SAM	0.35	0.00	0.00	0.01	0.00	0.00	0.04	0.54	0.09	0.88	0.86	0.00	0.00	0.00
SOI	0.93	0.43	0.00	0.00	0.00	0.00	0.00	0.34	0.00	0.00	0.00	0.00	0.00	0.00
TPI	0.31	0.31	0.00	0.00	0.00	0.00	0.00	0.12	0.00	0.00	0.00	0.00	0.00	0.00

b

Osillation	AMO	AMO (tre	DMI	Niño 1+2	Niño 3	Niño 3.4	Niño 4	NAO	NPI	PDO	PNA	SAM	SOI	TPI
AMO	1.00	0.21	0.03	-0.05	-0.01	0.02	0.07	-0.08	0.04	0.02	0.02	0.02	0.00	-0.02
AMO (trend)	0.21	1.00	0.00	-0.66	-0.34	-0.07	0.15	-0.07	0.32	-0.03	0.01	0.06	-0.02	-0.02
DMI	0.03	0.00	1.00	0.08	0.11	0.12	0.13	-0.03	-0.02	-0.05	-0.02	0.07	-0.12	0.08
Niño 1+2	-0.05	-0.66	0.08	1.00	0.61	0.30	0.03	0.05	-0.20	0.14	0.03	-0.06	-0.11	0.20
Niño 3	-0.01	-0.34	0.11	0.61	1.00	0.66	0.32	-0.01	0.00	0.24	0.10	-0.06	-0.26	0.40
Niño 3.4	0.02	-0.07	0.12	0.30	0.66	1.00	0.61	-0.04	0.09	0.27	0.16	-0.08	-0.39	0.57
Niño 4	0.07	0.15	0.13	0.03	0.32	0.61	1.00	-0.05	0.06	0.27	0.16	-0.04	-0.43	0.58
NAO	-0.08	-0.07	-0.03	0.05	-0.01	-0.04	-0.05	1.00	-0.01	-0.01	-0.06	-0.01	0.02	-0.03
NPI	0.04	0.32	-0.02	-0.20	0.00	0.09	0.06	-0.01	1.00	-0.11	-0.28	0.04	0.06	-0.09
PDO	0.02	-0.03	-0.05	0.14	0.24	0.27	0.27	-0.01	-0.11	1.00	0.27	0.00	-0.22	0.43
PNA	0.02	0.01	-0.02	0.03	0.10	0.16	0.16	-0.06	-0.28	0.27	1.00	0.00	-0.14	0.22
SAM	0.02	0.06	0.07	-0.06	-0.06	-0.08	-0.04	-0.01	0.04	0.00	0.00	1.00	0.07	-0.08
SOI	0.00	-0.02	-0.12	-0.11	-0.26	-0.39	-0.43	0.02	0.06	-0.22	-0.14	0.07	1.00	-0.46
TPI	-0.02	-0.02	0.08	0.20	0.40	0.57	0.58	-0.03	-0.09	0.43	0.22	-0.08	-0.46	1.00

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