

A Framework for Tropical Cyclone-Induced Compound Flood Modelling: Demonstrated in New Orleans

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Background & Study Area

- Compound flooding is the spatial and/or temporal interaction (simultaneous or concurrent) of multiple flood processes
- In coastal-estuarine regions globally, compound flooding is typically due to processes including:
 - coastal (tide, surge, waves, relative sea level rise)
 - fluvial (river discharge)
 - pluvial (rainfall runoff)
 - groundwater
- In this study we investigate TC driven compound flooding in the Greater New Orleans Metropolitan Area and the surrounding Mississippi River Delta, a region of significant population and economic importance
- New Orleans is a unique site of compounding for a number of reasons:
 - situated entirely at or below sea level
 - highly coastally influenced, with the largest system of wetlands, lakes, and estuaries in the US
 - highly fluvially influenced, bisected by the Mississippi River, the largest average discharge river in the US
 - extensive network of engineered and managed artificial canals and flood defense, the largest defense system in the US

Modelling

We simulate TC-induced flood scenarios involving the 7 unique flood driver combination scenarios (C, F, P, CF, CP, FP, CFP) for 9 historical TC events that pass within 100km of New Orleans

- Synthetic TC data is modelled for each of the historical events using a physics-based machine learning approach (based on WRF, IBTrACS, and satellite observations) to generate wind velocity, atmospheric pressure, and rainfall fields
- River discharge is simulated using the hydrological model FUSE and the routing model MizuRoute
- Total coastal water levels are simulated using the coupled hydrodynamic and wind wave model SCHISM-WWMIII, the hydrodynamic compound flood model SFINCS, the tidal atlas FES2014, and the CMEMS sea level anomaly dataset
- Total compound flood water levels are simulated with the 2D hydraulic model Lisflood-FP employing a 1D subgrid fluvial network, using boundary condition water level inputs derived from each of the coastal, fluvial, and pluvial flood components

Research Questions

This research showcases the novel development of a continental US applicable physics-based compound flood modelling framework for simulating the interaction of TC driven coastal (C), fluvial (F), and pluvial (P) dynamics

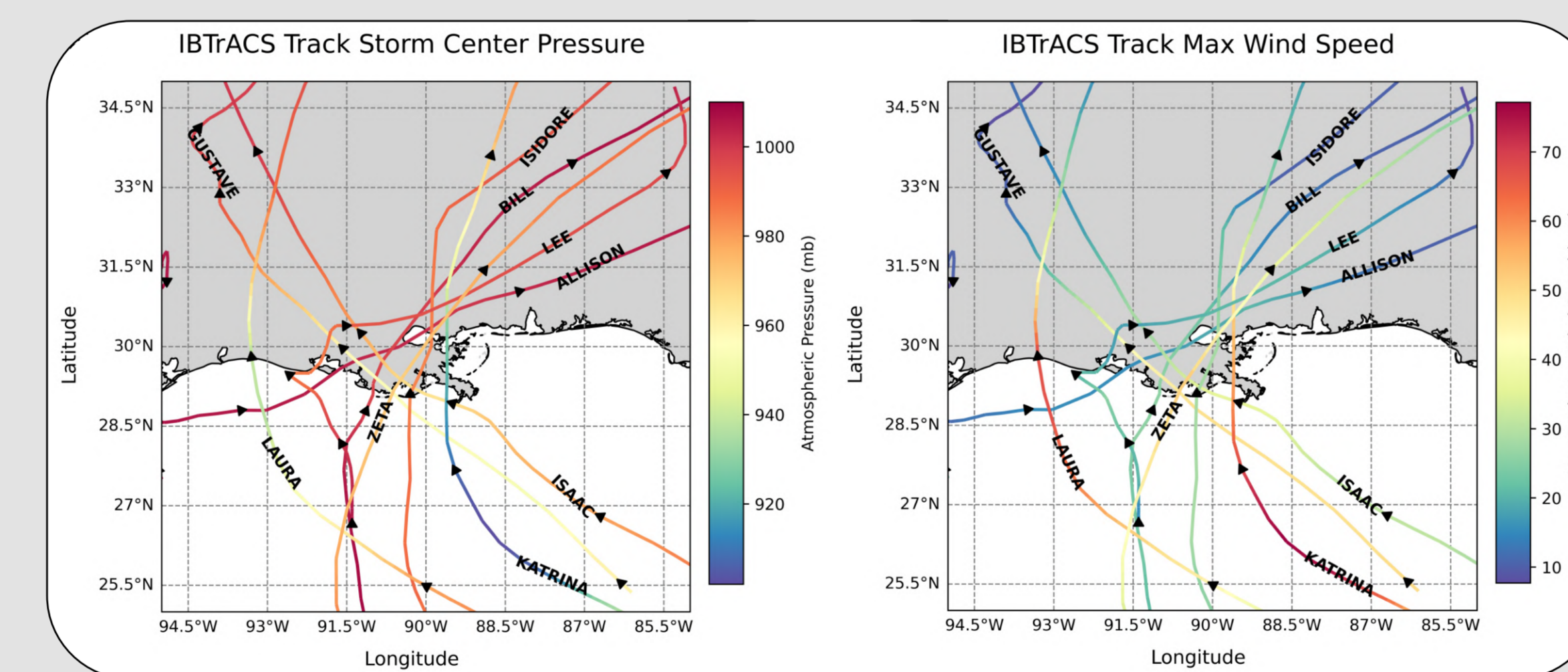
As part of this study, we outline four key research questions:

- 1) What is the magnitude of inundation for each of the TC events under different flood driver scenarios?
- 2) Where is flooding the result of compound interactions and how is flooding misestimated by not considering nonlinear interactions?
- 3) What are the relative contributions and spatial distribution dominated by the three individual flood drivers?
- 4) What characteristics of TC events are associated with greater compound flooding?

Analysis

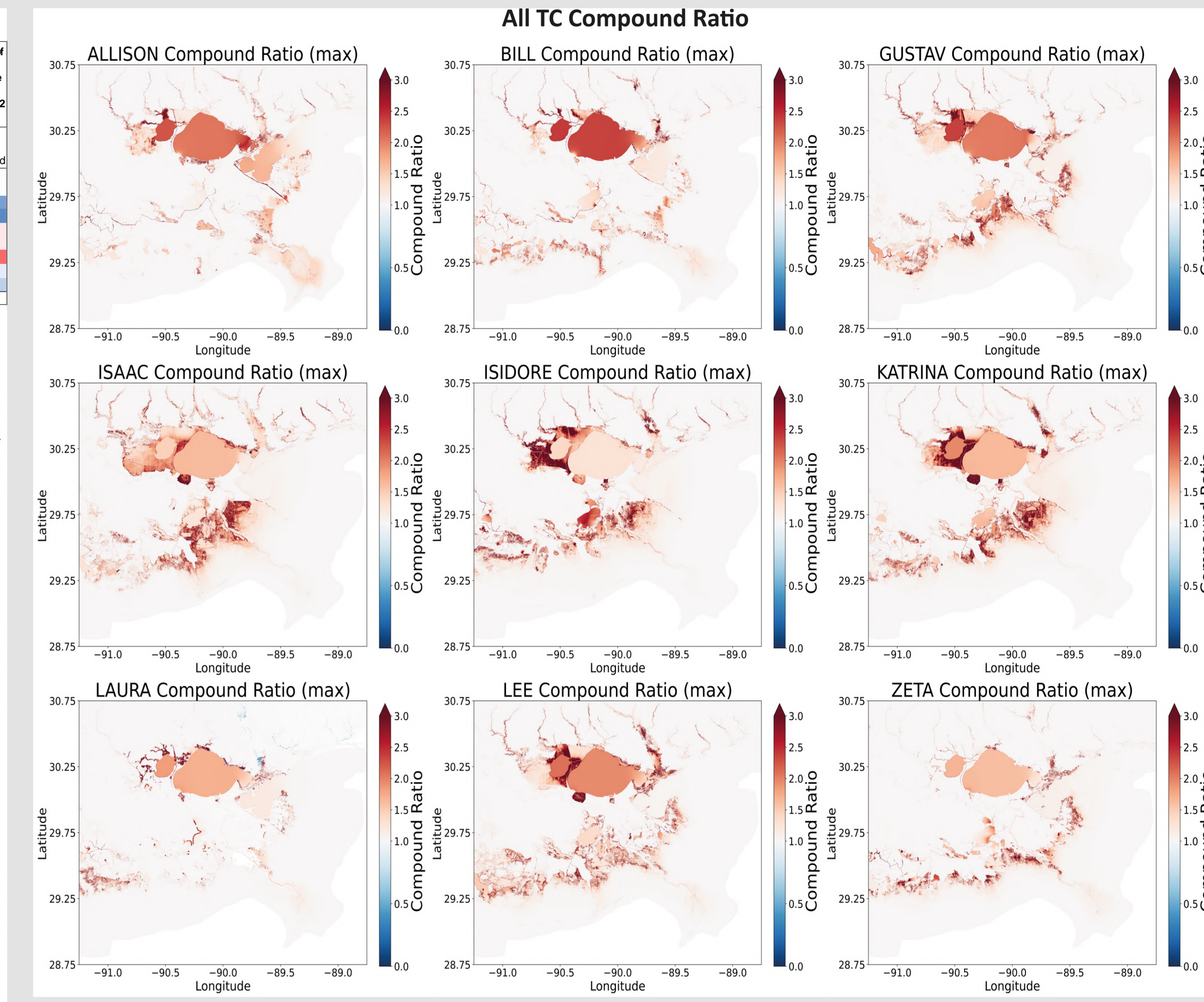
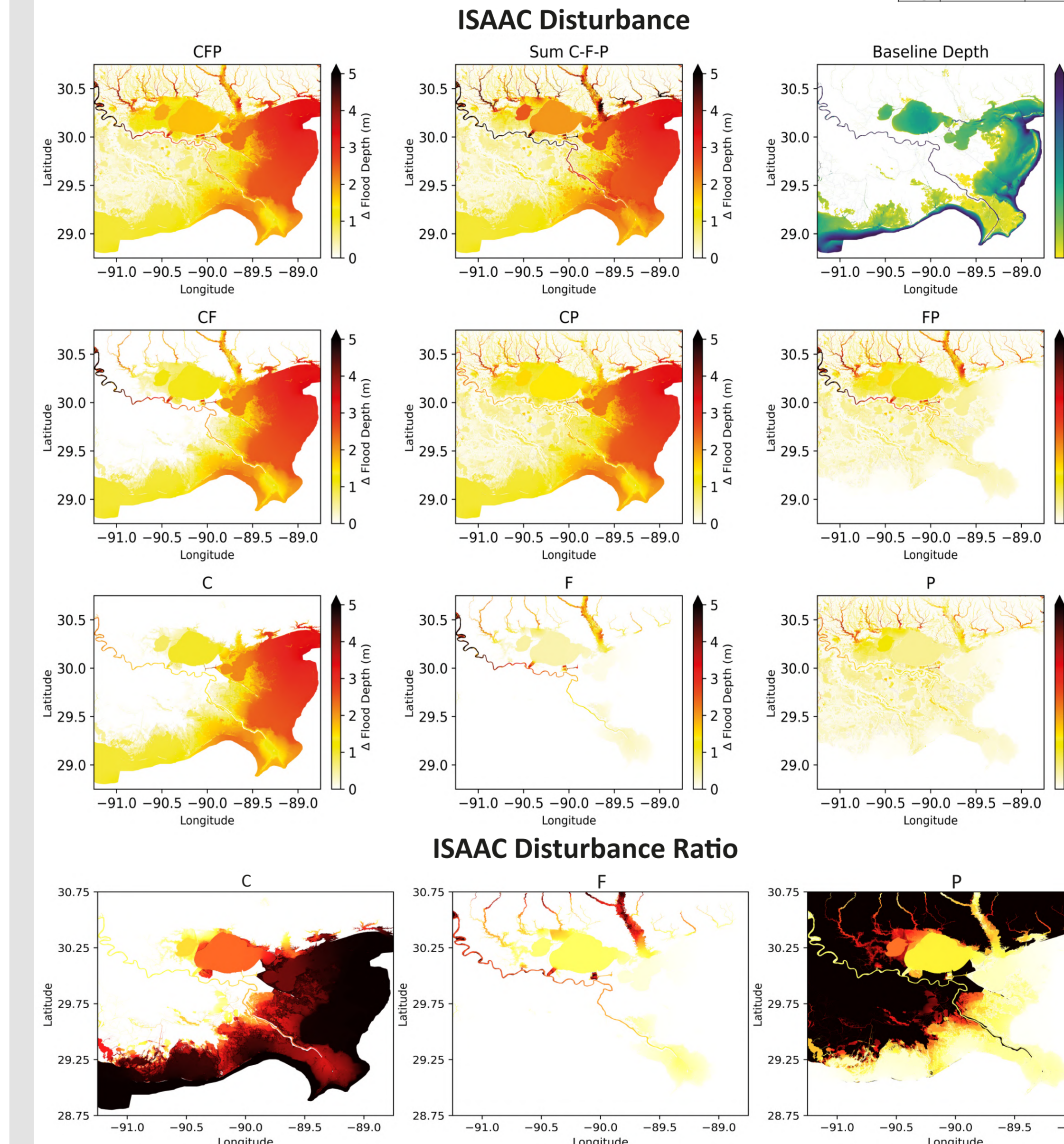
- Flood disturbance** - change in water depth, maximum water depth minus baseline initial inundation layer water depth
- Flood area** - percentage study area with disturbance > 0.1 m
- Compound ratio (Cr)** - CFP scenario disturbance divided by max (C, F, and P disturbances); where a Cr value > 1 indicates nonlinear compound driver interactions that result in greater flooding than any individual driver
- Relative driver disturbance (Dr)** - disturbance of an individual driver divided by sum (C, F, and P disturbances)
- Driver dominance zones** - individual driver dominated where Dr > 0.5; compound dominant where all drivers Dr < 0.5

Event	Year
Allison	2001
Bill	2003
Gustave	2008
Isaac	2012
Isidore	2002
Katrina	2005
Laura	2020
Lee	2011
Zeta	2020



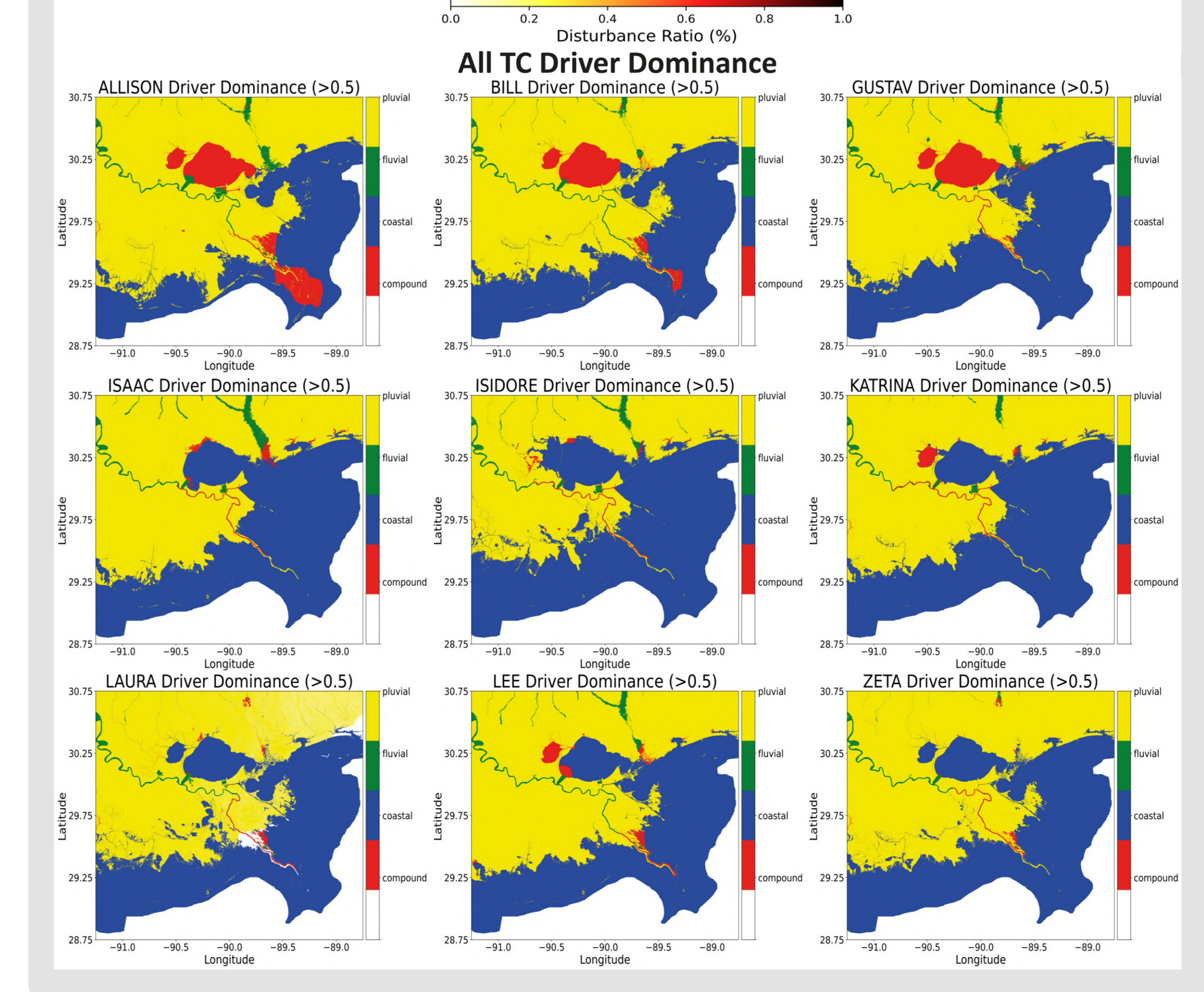
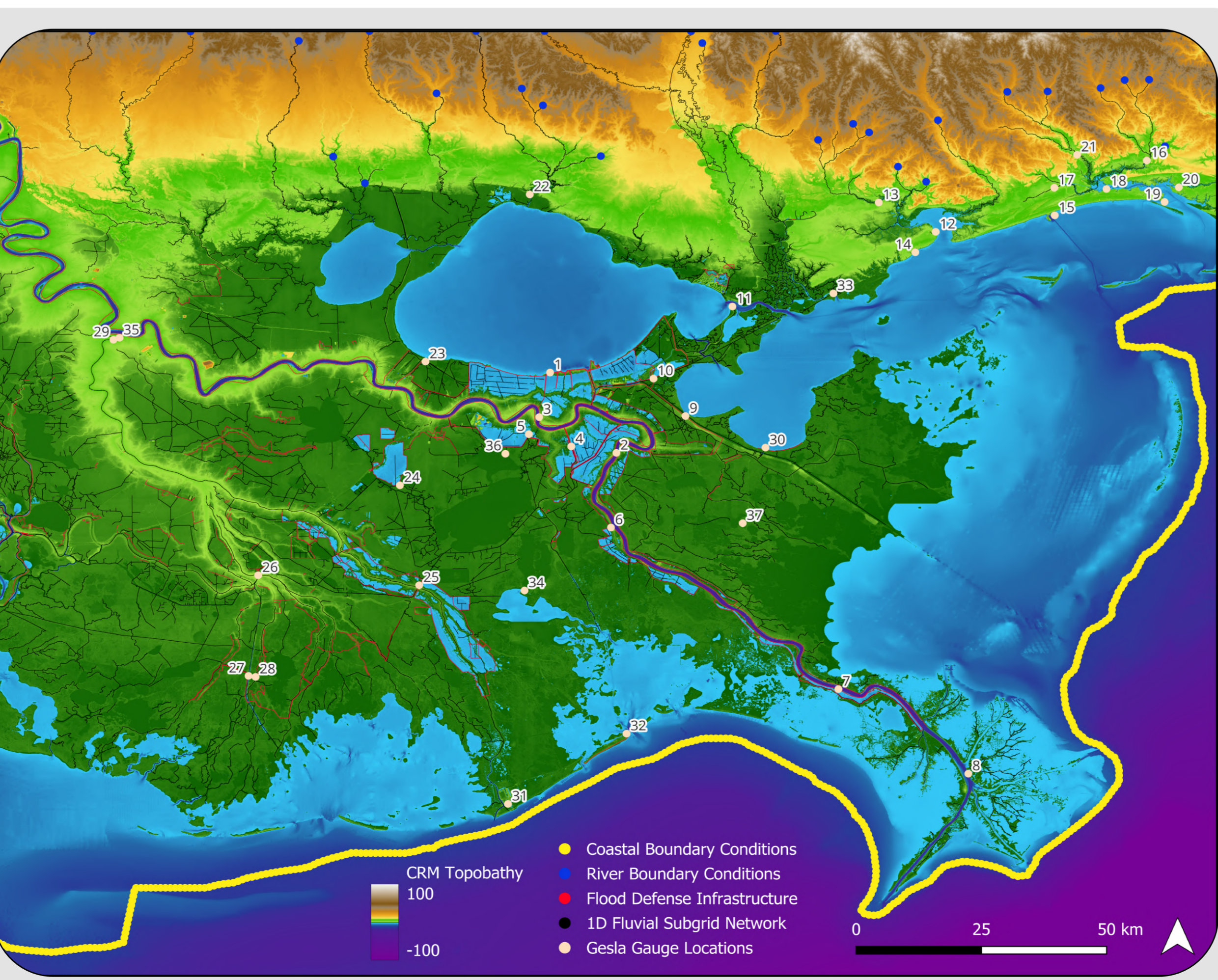
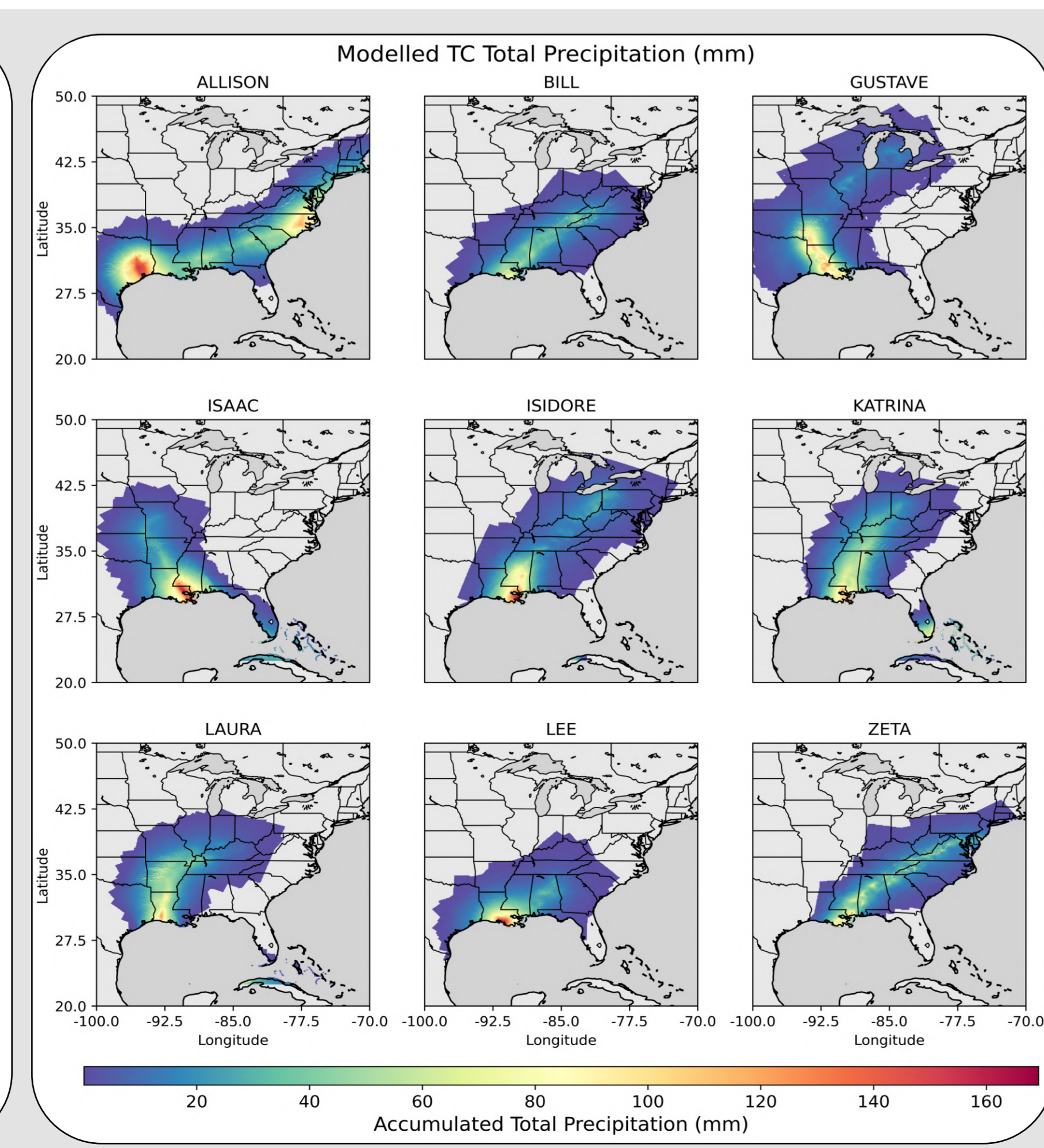
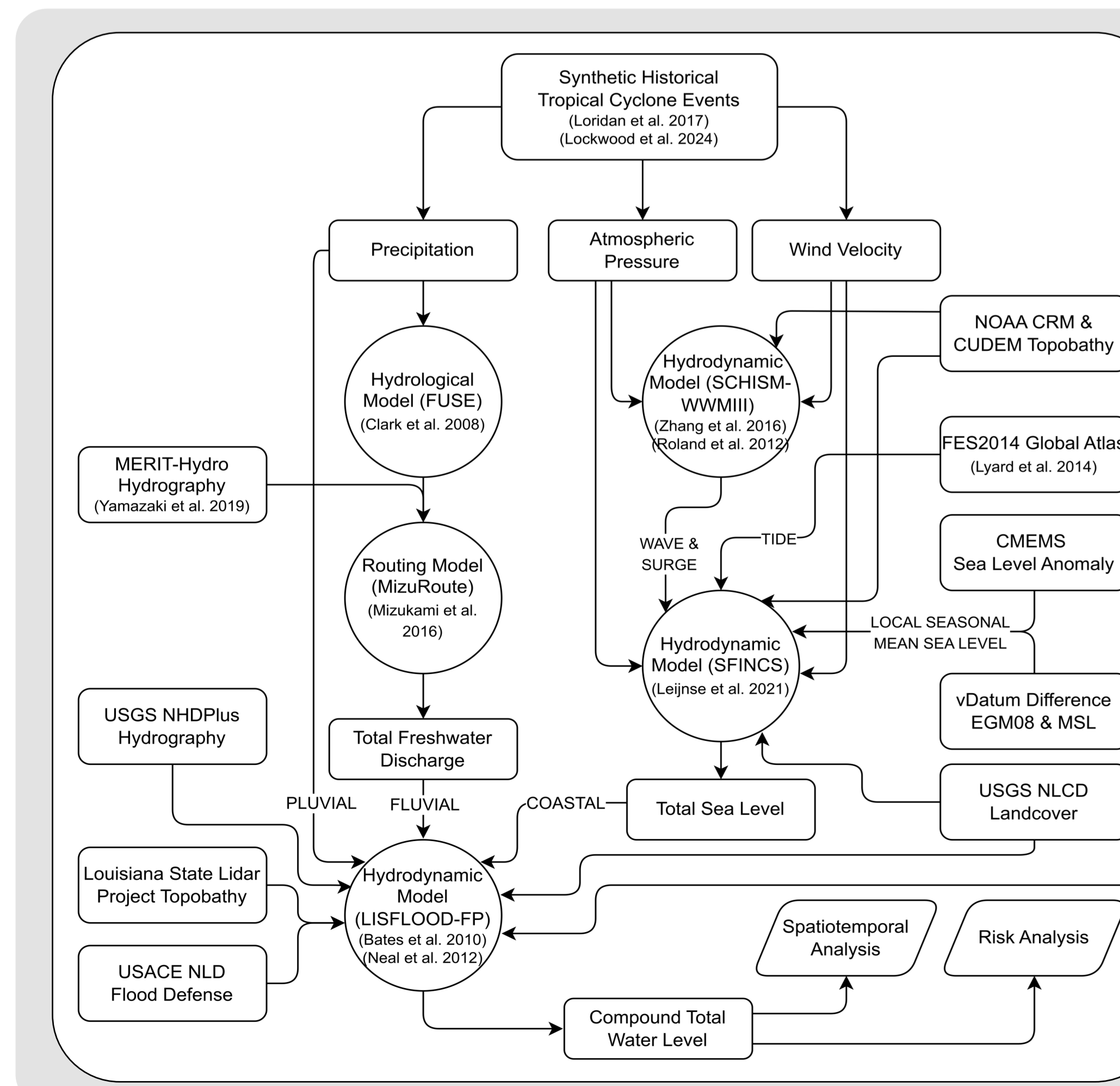
Results

Scenario	Percentage Study Area with Water Depth > 0.1m (%)							Average Disturbance of the Study Area (m)							Missestimate of CFP vs Sum of C-F-P Average Disturbance of the Study Area (%)		
	C	F	P	CF	CP	FP	CFP	C	F	P	CF	CP	FP	CFP	Compound Overestimated	Compound Underestimated	
ALLISON	10.77	1.21	1.13	1.17	10.81	30.77	8.01	0.34	0.08	0.08	0.08	0.08	0.01	0.02	0.11	0.25	1.14
BILL	8.90	1.33	1.13	1.15	5.41	33.49	7.43	1.74	48.17	0.24	0.04	0.07	0.32	0.38	0.02	0.01	0.09
QWEST	11.91	1.63	1.44	1.21	1.77	37.37	9.01	32.45	19.36	0.54	0.06	0.12	0.68	0.72	0.06	0.01	0.15
ISAC	14.34	1.80	1.17	1.31	2.02	40.02	11.55	30.77	62.18	0.71	0.08	0.22	0.94	1.01	0.32	0.06	0.41
ISIDORE	11.89	1.76	1.14	1.17	1.85	43.18	8.50	23.07	55.57	0.67	0.05	0.08	0.77	0.80	0.13	0.01	0.09
KATRINA	12.99	1.91	1.13	1.24	2.07	40.02	8.09	36.26	60.33	0.83	0.05	0.15	0.86	1.00	0.10	0.08	0.18
LAURA	7.96	1.40	1.13	1.11	1.44	35.98	7.20	4.43	38.85	0.32	0.04	0.02	0.35	0.38	0.03	0.00	0.01
LEE	12.50	1.42	1.14	1.23	1.58	35.03	8.70	31.61	58.53	0.34	0.06	0.14	0.55	0.53	0.02	0.01	0.18
ZETA	8.11	1.58	1.12	1.15	1.85	36.01	5.80	13.66	46.84	0.50	0.03	0.06	0.57	0.58	0.06	0.00	0.06
Avg																	



Key Findings

- We locate areas of frequently observed intense compound interactions including:
 - Lake Pontchartrain, Lake Maurepas, and their surrounding wetlands
 - The Barataria, Breton Sound, Pearl, Pontchartrain, and Terrebonne Estuary Basins
- We determine that compound flood driver interactions are nonlinear and that exposure is greatly misestimated by modelling flood drivers individually and summing their peak disturbance.
 - Average flood disturbance at sites of compounding underestimate all TC compound scenarios by 60% or higher (mean ~74%)
- We delineate regions dominated by individual drivers (coastal, fluvial, and pluvial)
- We identify tentative relationships between TC characteristics and compound flood magnitude:
 - Compound area --> atmospheric pressure, max wind radius, max rain rate
 - Compound disturbance --> atmospheric pressure, max wind radius, max wind velocity
 - No relationship observed involving translational velocity
 - Overall results suggest that compound flooding correlates with intense (extreme rainfall, high wind velocity, and low pressure) but concentrated (low max wind radius) TC events



Contact

Abstract Portfolio

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