

Florida's 2004 Hurricane Season

Structural Impacts on the FDOT System

Hurricane Wind Speed versus Design Wind Speed

Wind Speeds

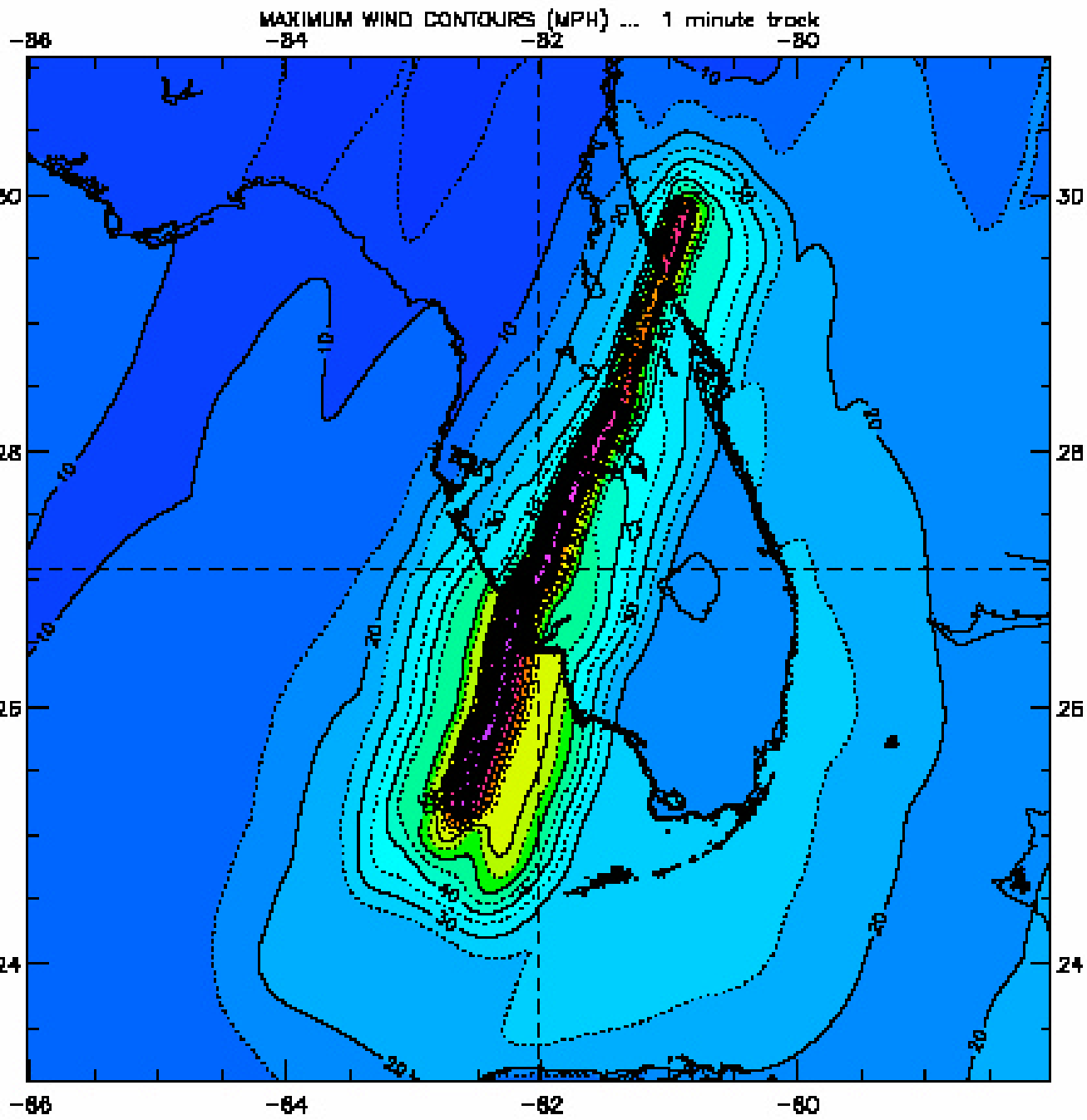
- Sustained Wind Speed
 - 60 second measurement duration
 - National Weather Service
- Fastest Mile
 - measurement duration varies
 - 1994 AASHTO
- Gust Wind Speed
 - 3 second measurement duration
 - National Weather Service and 2001 AASHTO

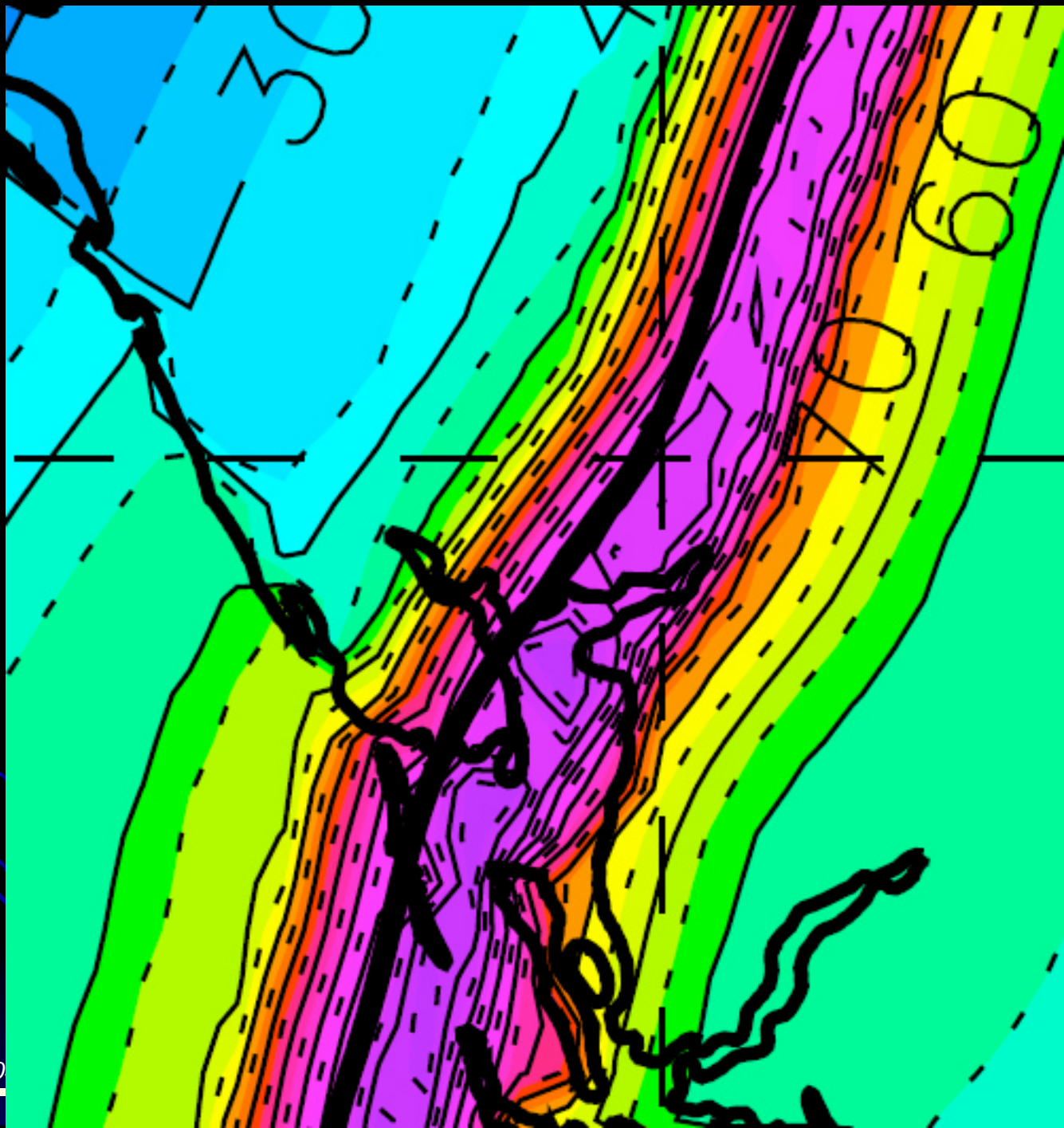
Maps from NOAA

www.aoml.noaa.gov/hrd/data_sub/wind.html

Charley

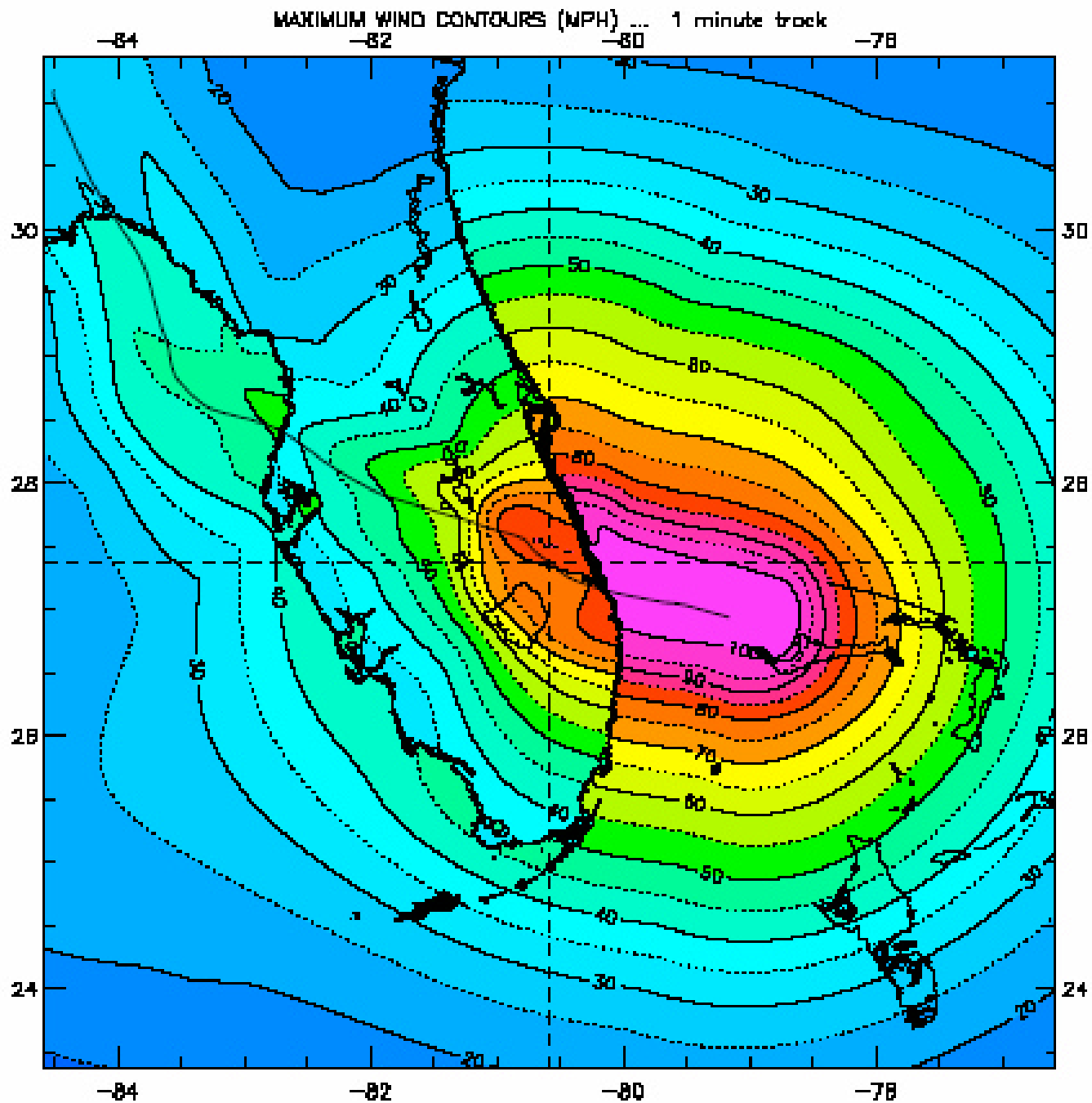
- Sustained Winds - 110/120 mph (map)

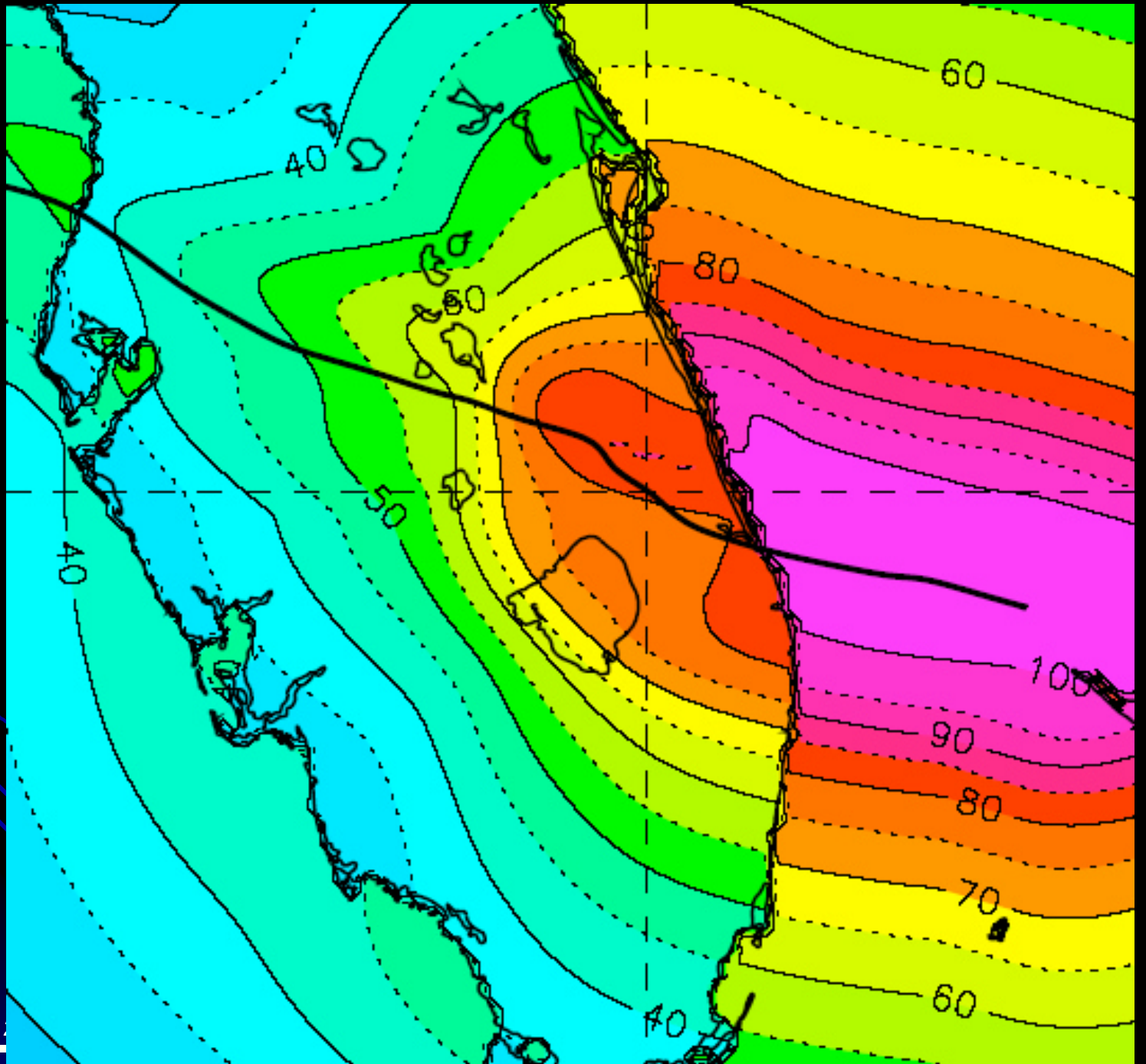


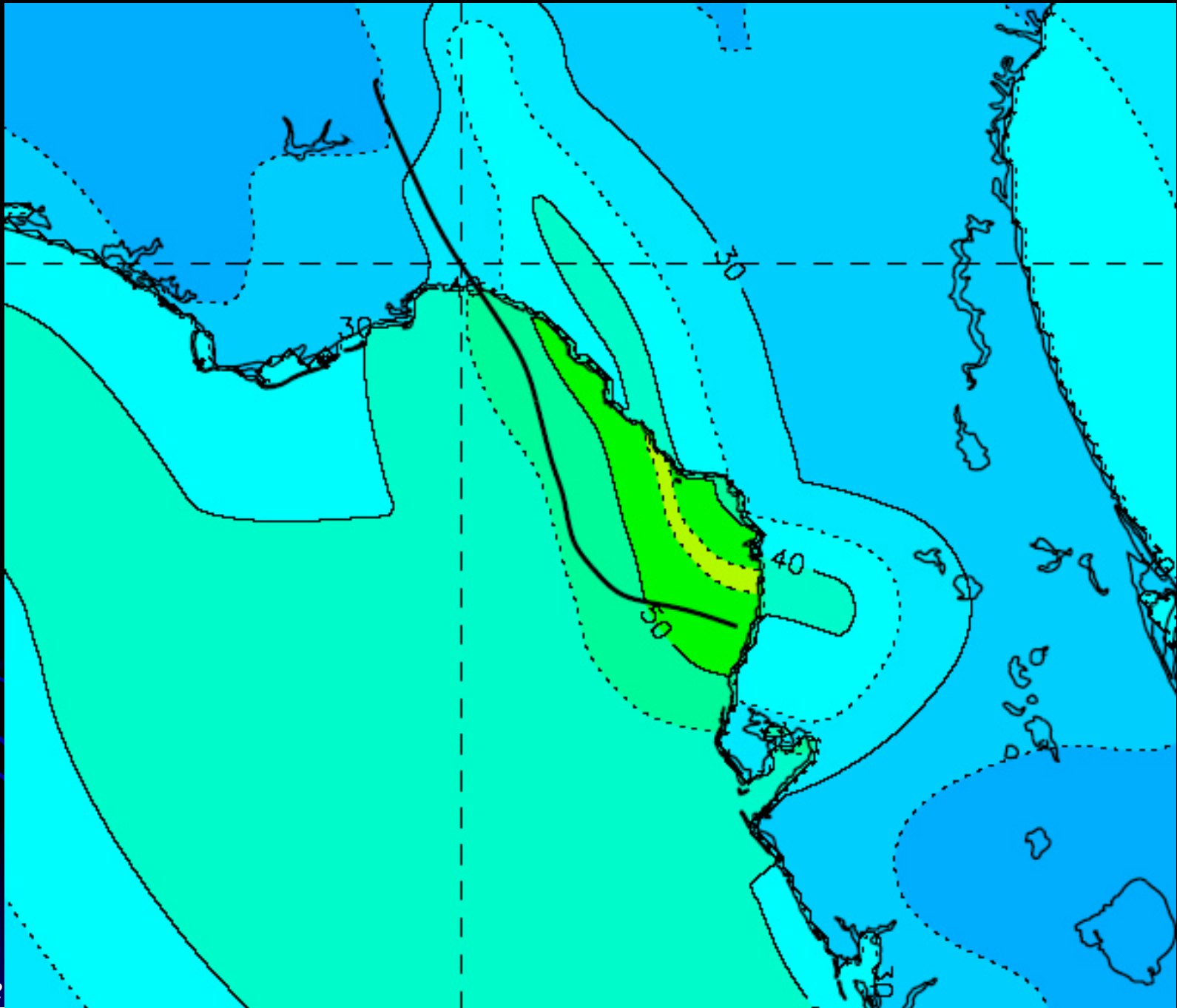


Frances

- Sustained Winds – 80 (map)



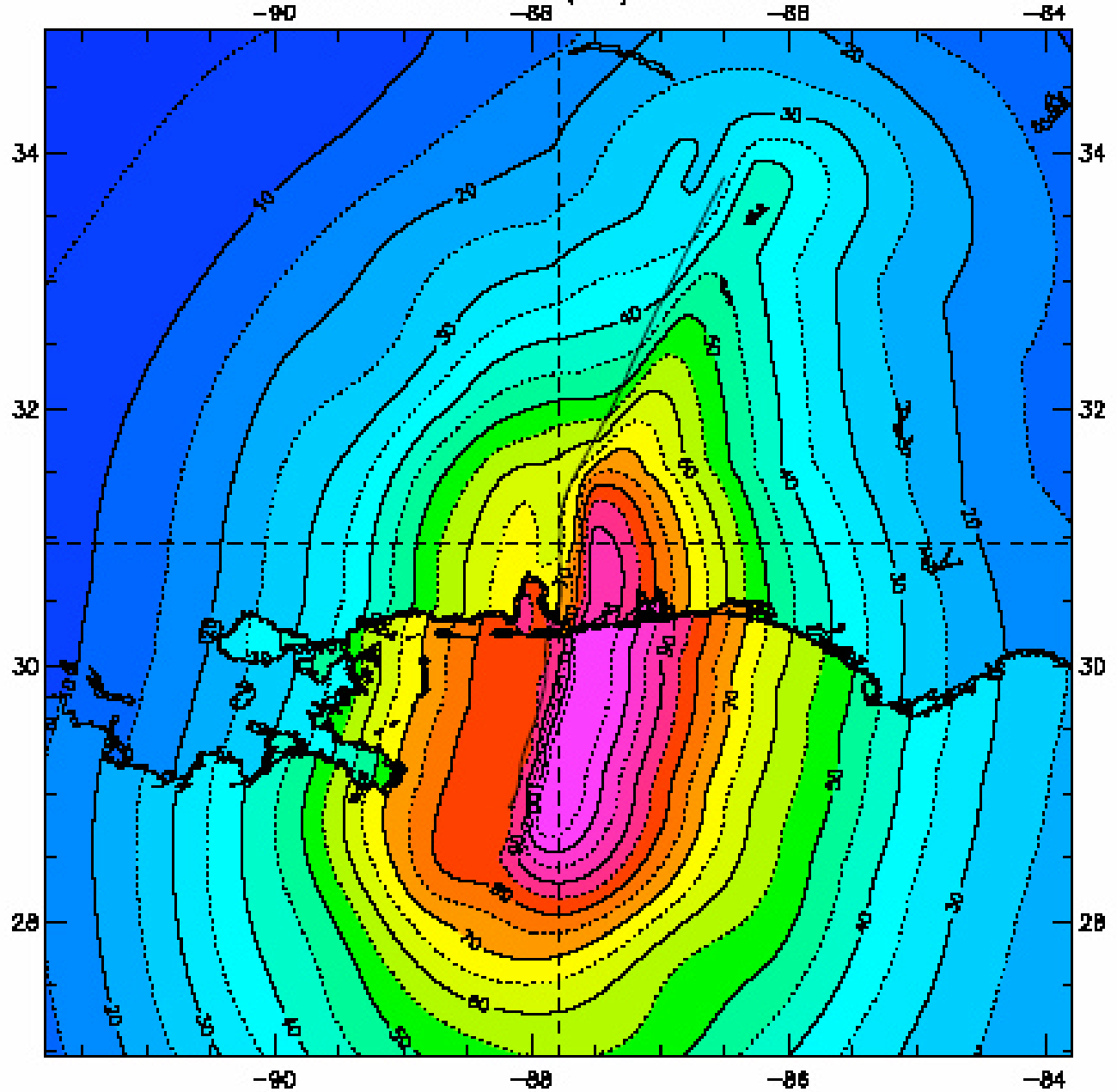


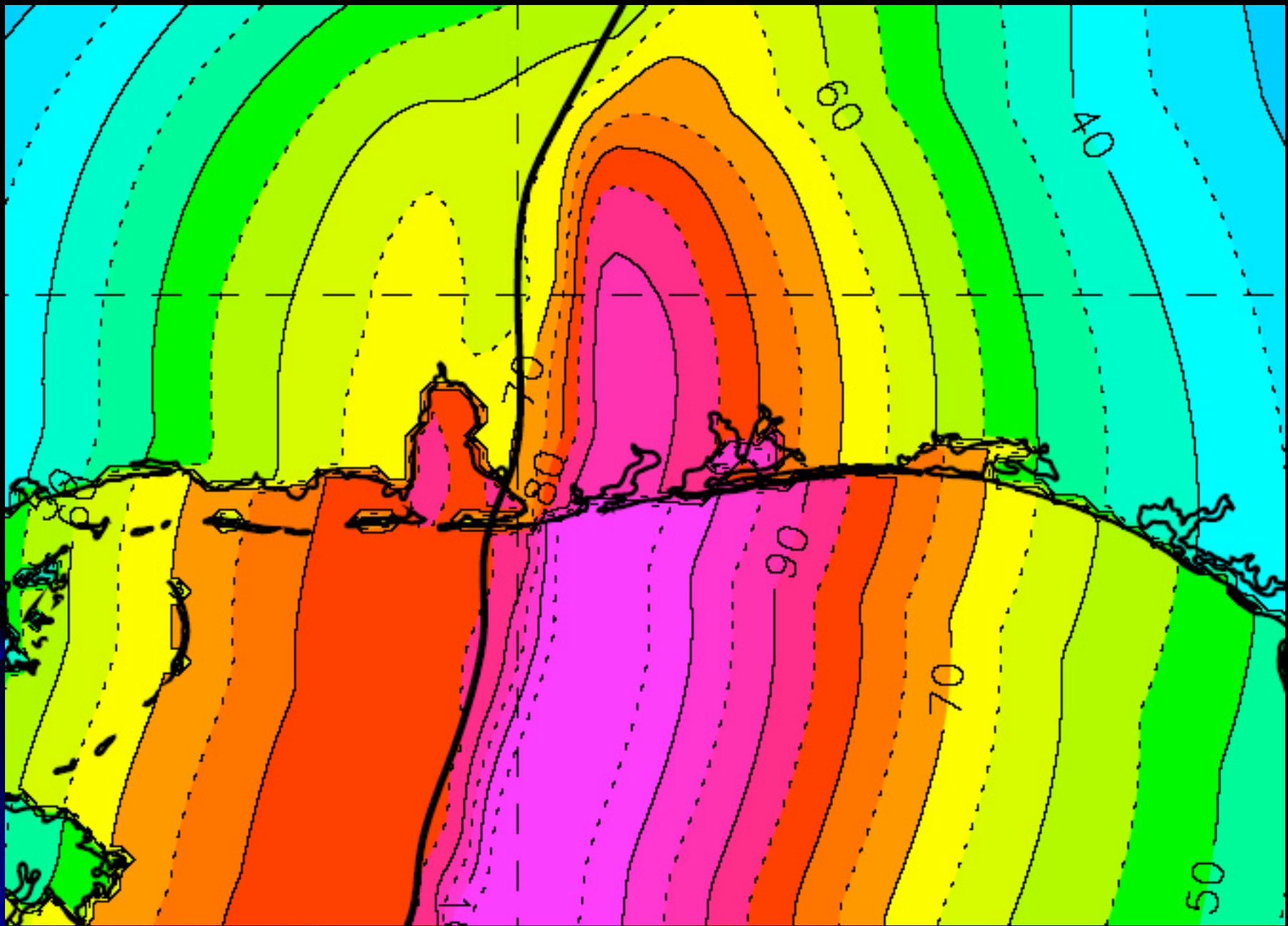


Ivan

- Sustained Winds - 90 mph (map)

MAXIMUM WIND CONTOURS (MPH) ... 1 minute track

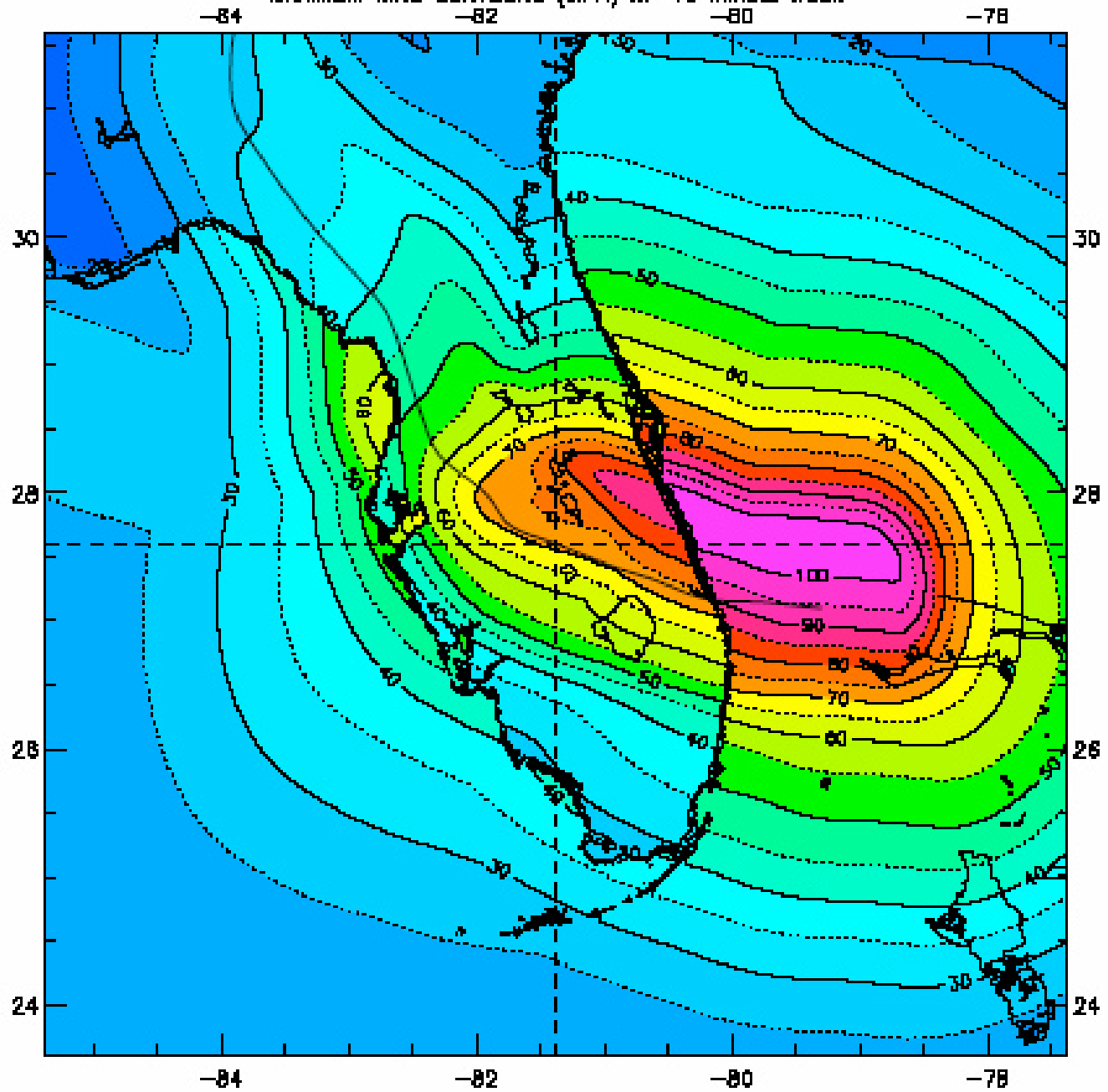


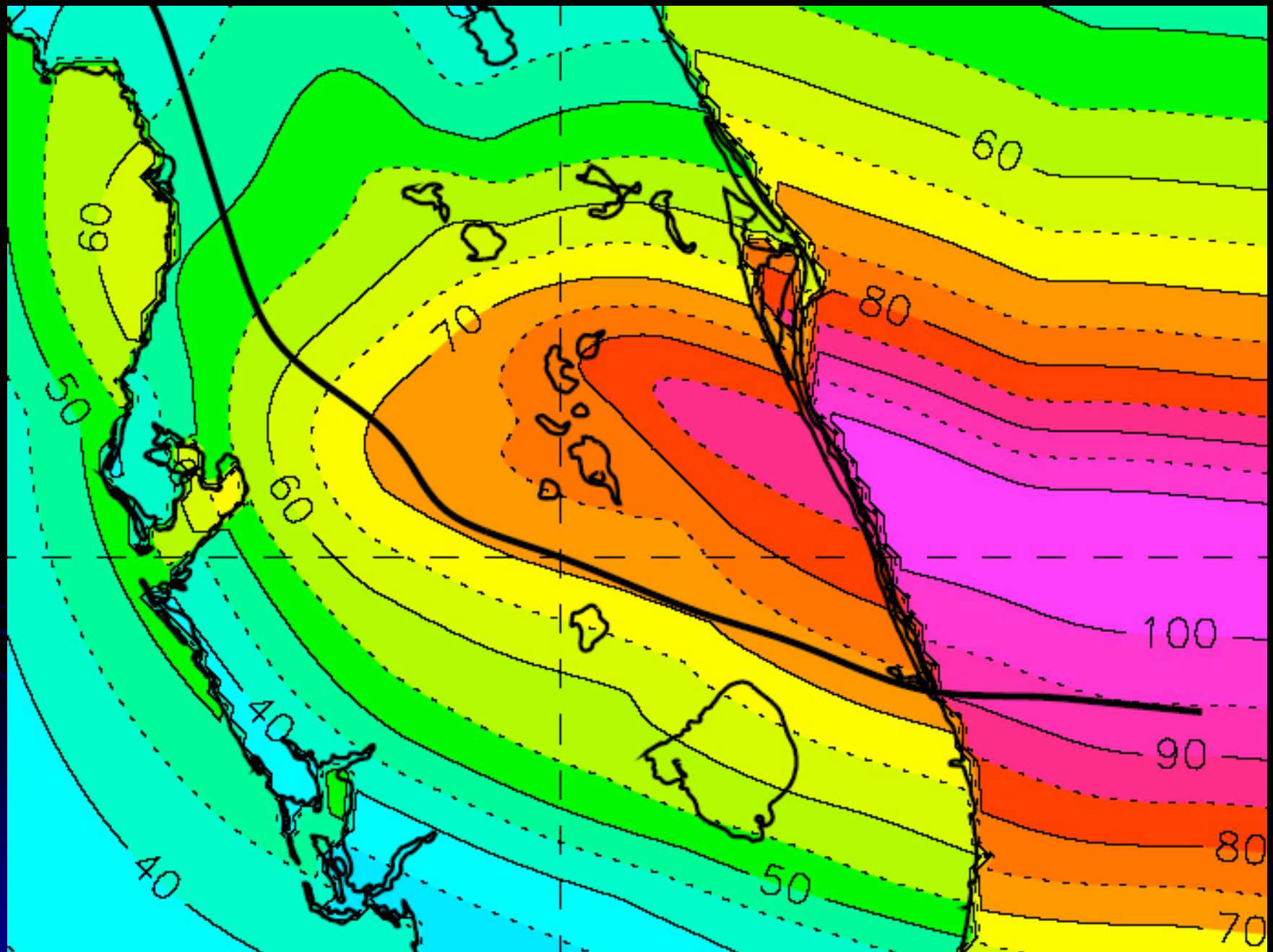


Jeanne

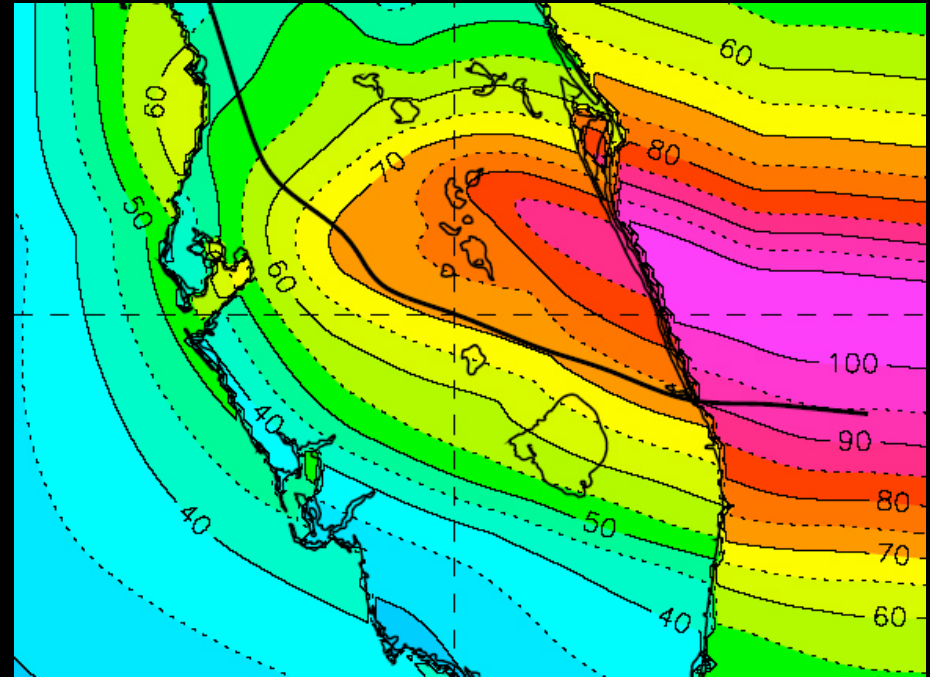
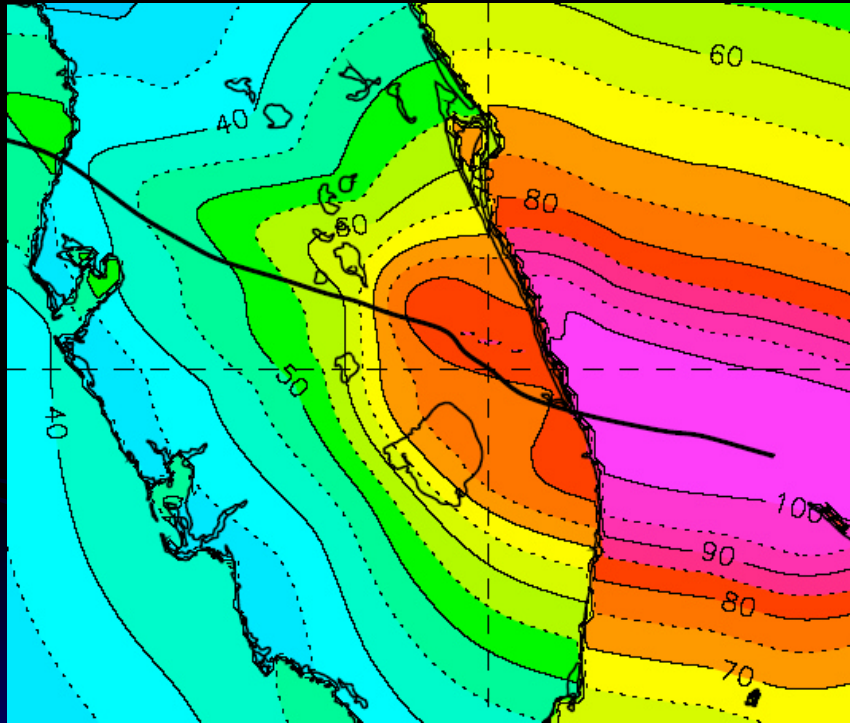
- Sustained Winds - 85 mph (map)

MAXIMUM WIND CONTOURS (MPH) ... 10 minute track





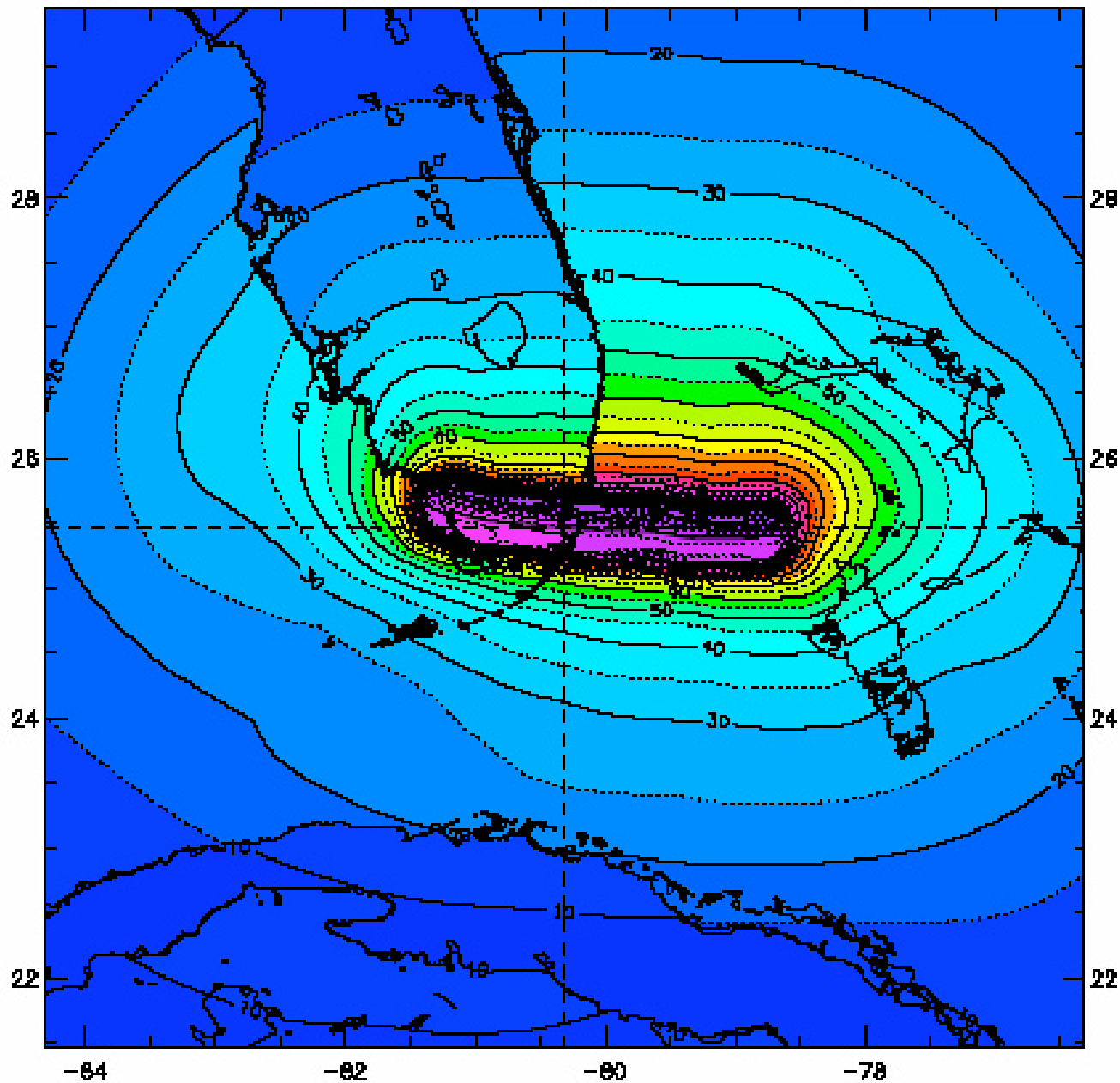
Frances / Jeanne

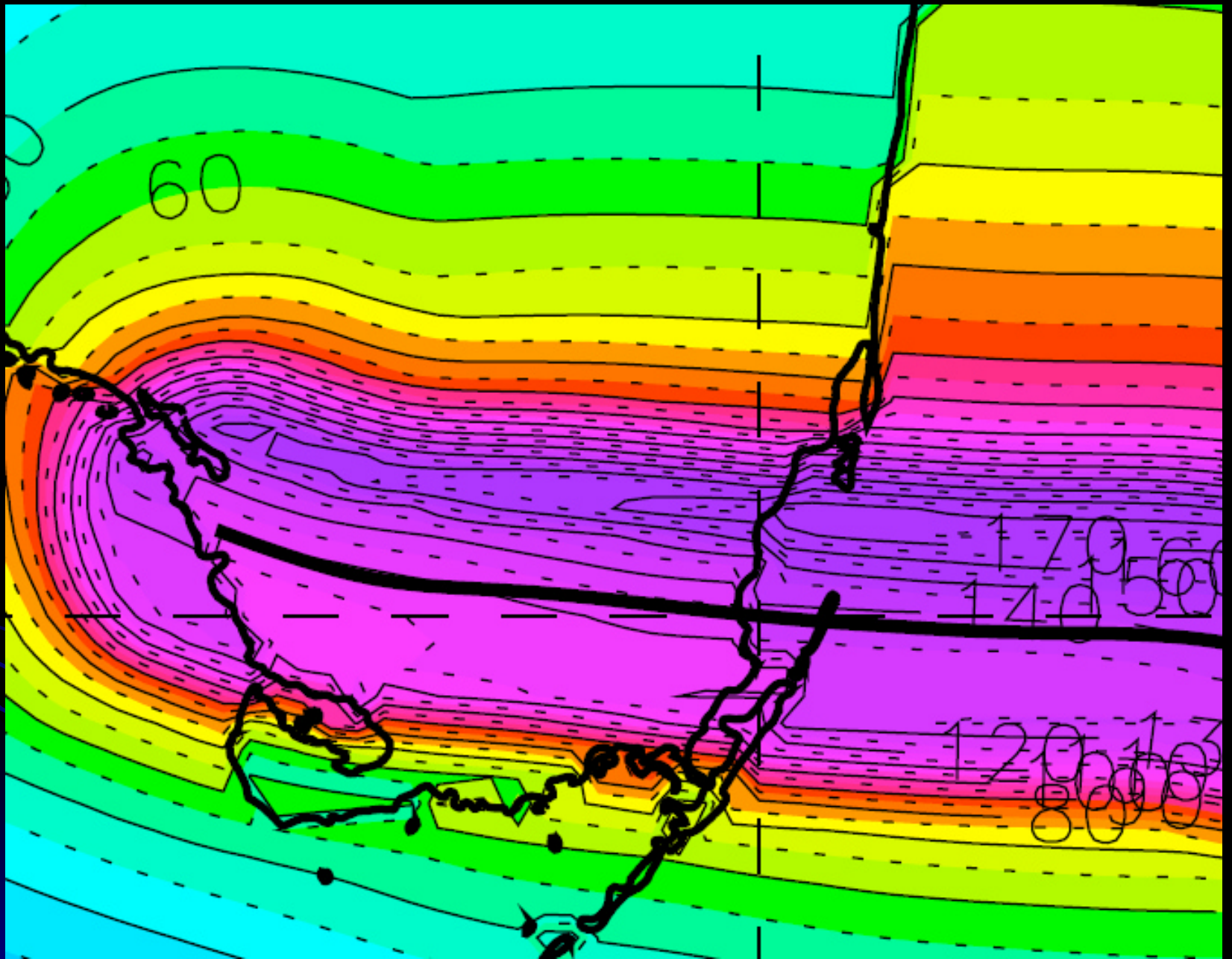


Andrew

- Sustained Winds - 150 mph (map)

MAXIMUM WIND CONTOURS (MPH) ... 1 minute track
-84 -82 -80 -78





Sustained Wind Speeds

Charley 120 mph

Frances 80 mph

Ivan 90 mph

Jeanne 85 mph

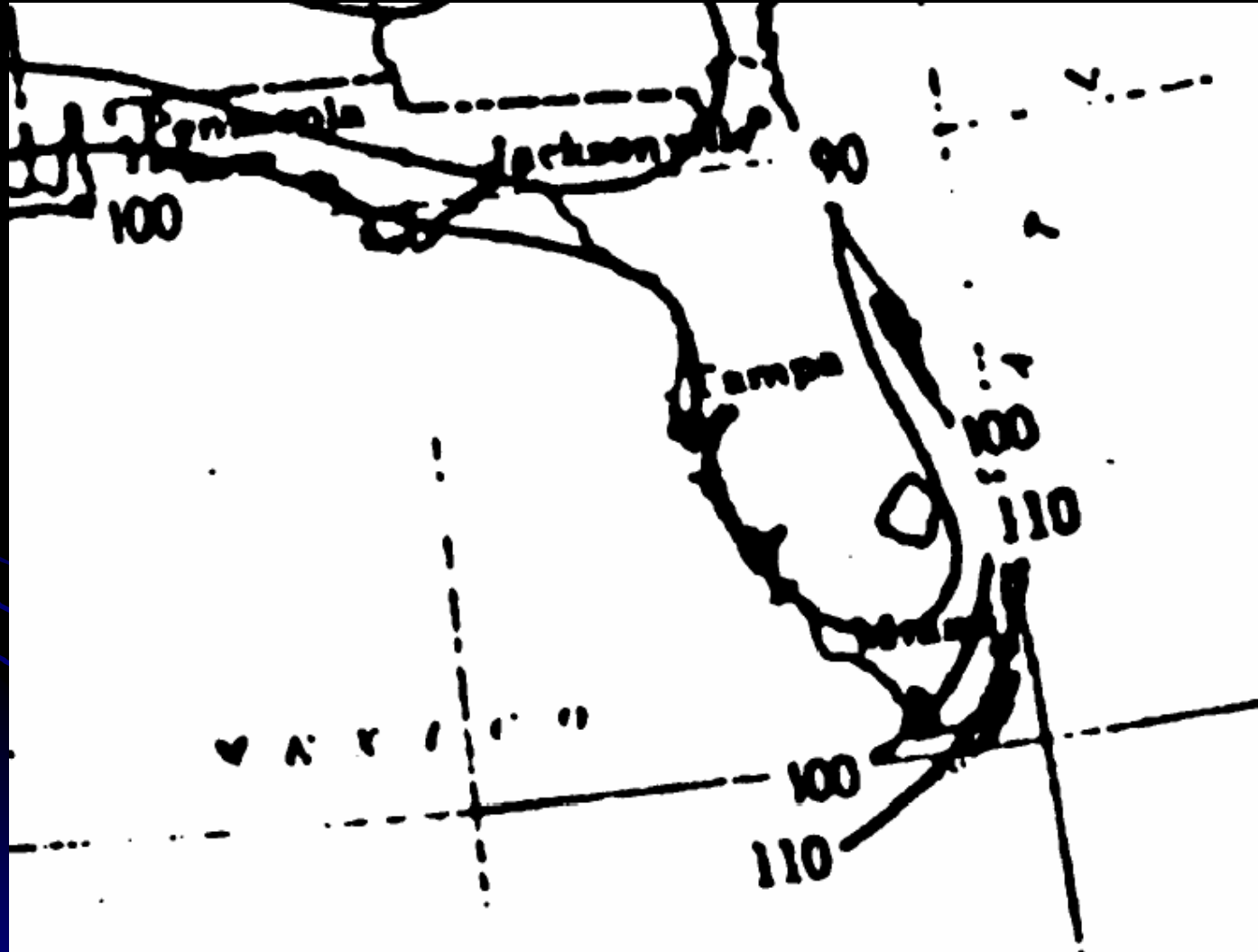
$$f_{\text{SustainedToFastestMile}} \left(\begin{pmatrix} 120 \\ 80 \\ 90 \\ 85 \end{pmatrix} \right) = \begin{pmatrix} 128.5 \\ 82.1 \\ 93.5 \\ 87.8 \end{pmatrix} \text{ mph}$$

$$f_{\text{SustainedTo3SecGust}} \left(\begin{pmatrix} 120 \\ 80 \\ 90 \\ 85 \end{pmatrix} \right) = \begin{pmatrix} 145.9 \\ 97.3 \\ 109.4 \\ 103.4 \end{pmatrix} \text{ mph}$$

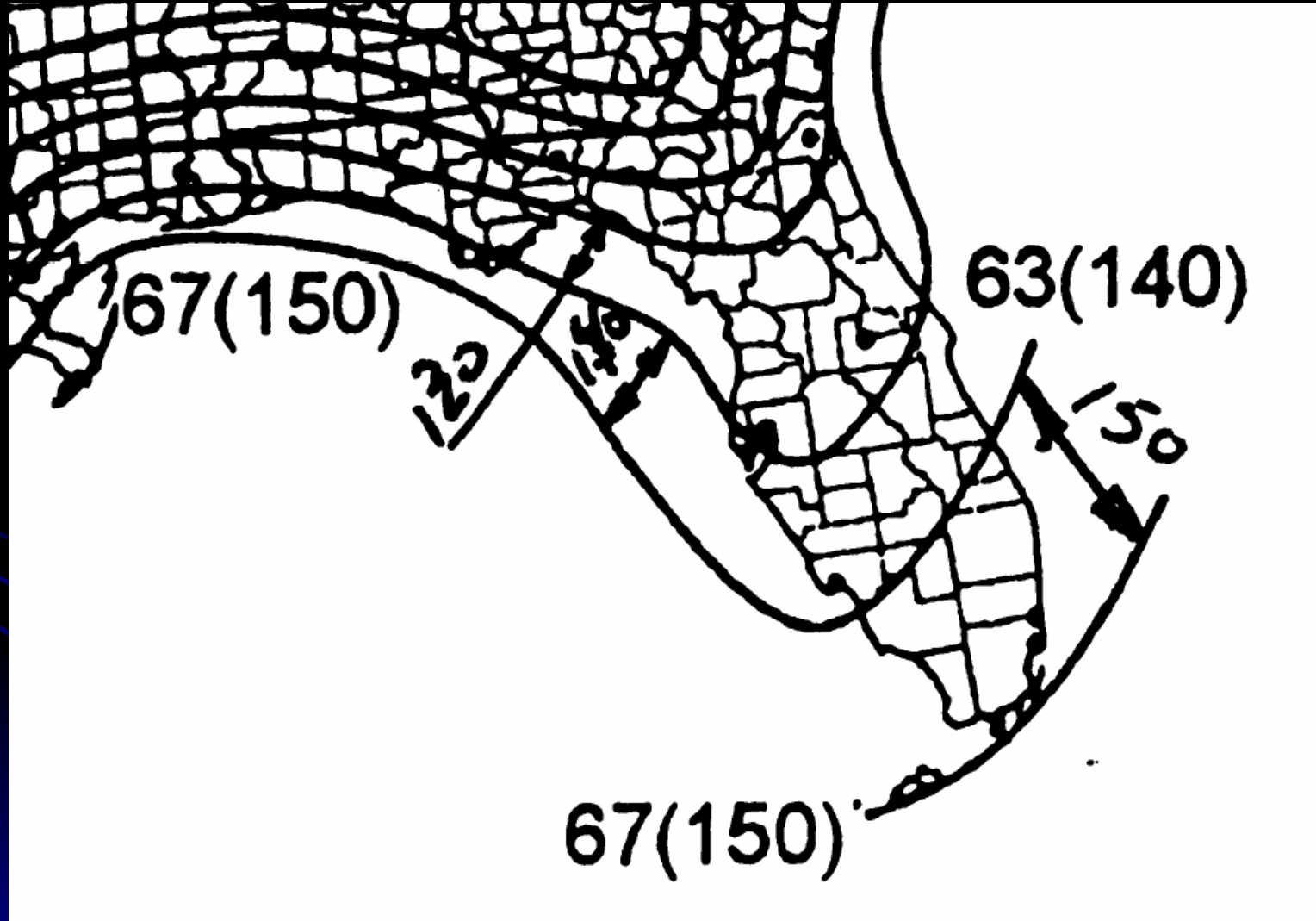
Actual Winds vs. Design Winds

Hurricane	Wind	County	10 year	25 year
Charley	128 mph	Charlotte	80 mph	90 mph
Frances	84 mph	Brevard	80 mph	90 mph
Ivan	94 mph	Escambia	60 mph	90 mph
Jeanne	88 mph	Martin	80 mph	90 mph

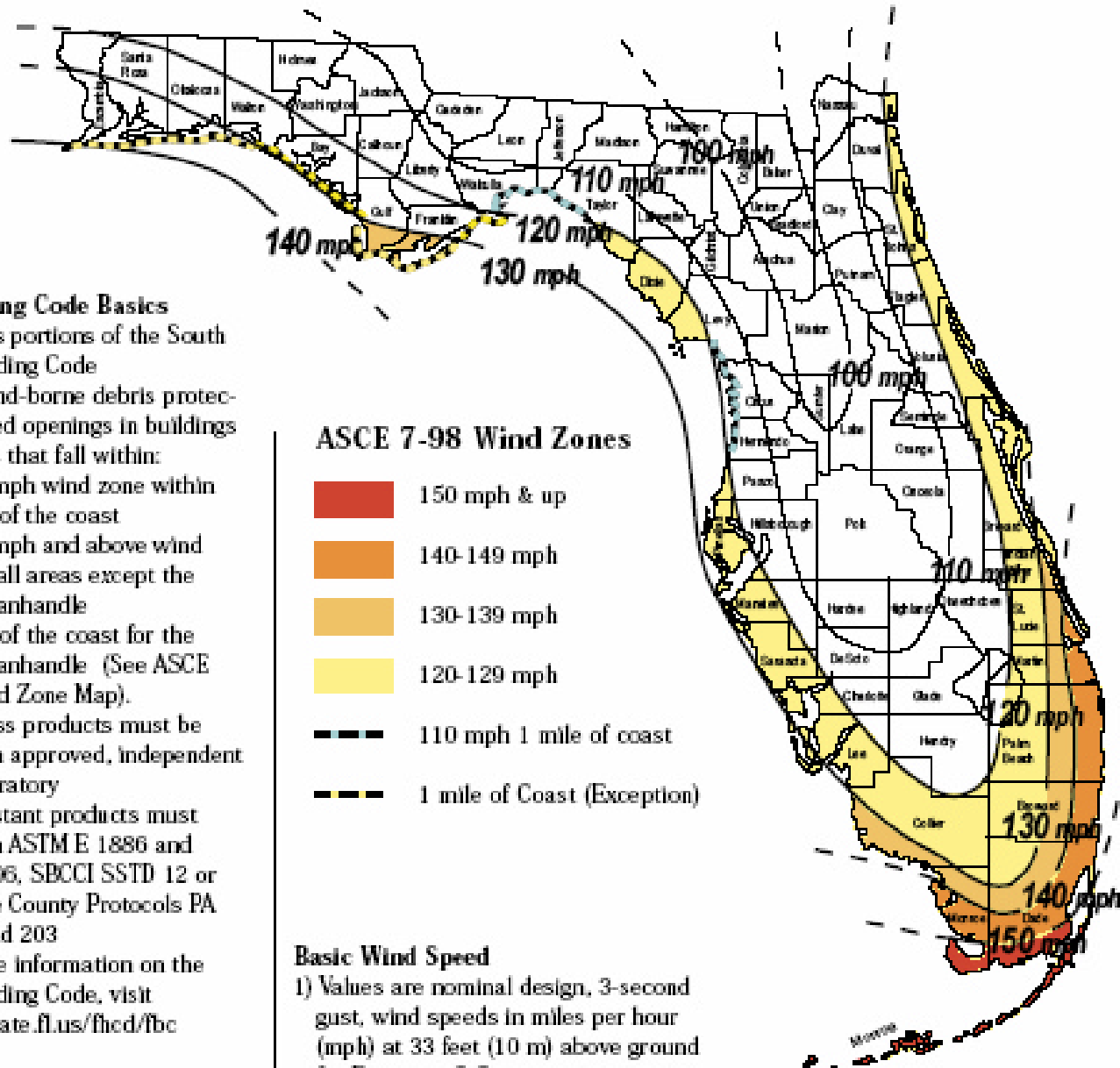
1994 AASHTO – Fastest Mile₅₀



2001 AASHTO – 3 Sec Gust



State of Florida Wind-Borne Debris Region



ASCE 7-98 Wind Zones

- 150 mph & up
- 140-149 mph
- 130-139 mph
- 120-129 mph
- 110 mph 1 mile of coast
- 1 mile of Coast (Exception)

Basic Wind Speed

1) Values are nominal design, 3-second gust, wind speeds in miles per hour (mph) at 33 feet (10 m) above ground for Exposure C Category.

Building Code Basics

states portions of the South Building Code

wind-borne debris protected openings in buildings areas that fall within:

100 mph wind zone within 1 mile of the coast

120 mph and above wind for all areas except the Florida Panhandle

1 mile of the coast for the Florida Panhandle (See ASCE Wind Zone Map).

glass products must be by an approved, independent laboratory

resistant products must with ASTM E 1886 and 1996, SBCCI SSTD 12 or Trade County Protocols PA 2 and 203

complete information on the Building Code, visit www.state.fl.us/fhcd/fbc

additional information on wind-

District 1 Traffic Signals & Supports

Considerable Damage to
Traffic Signal Hangers,
Disconnect Boxes, Clamps.

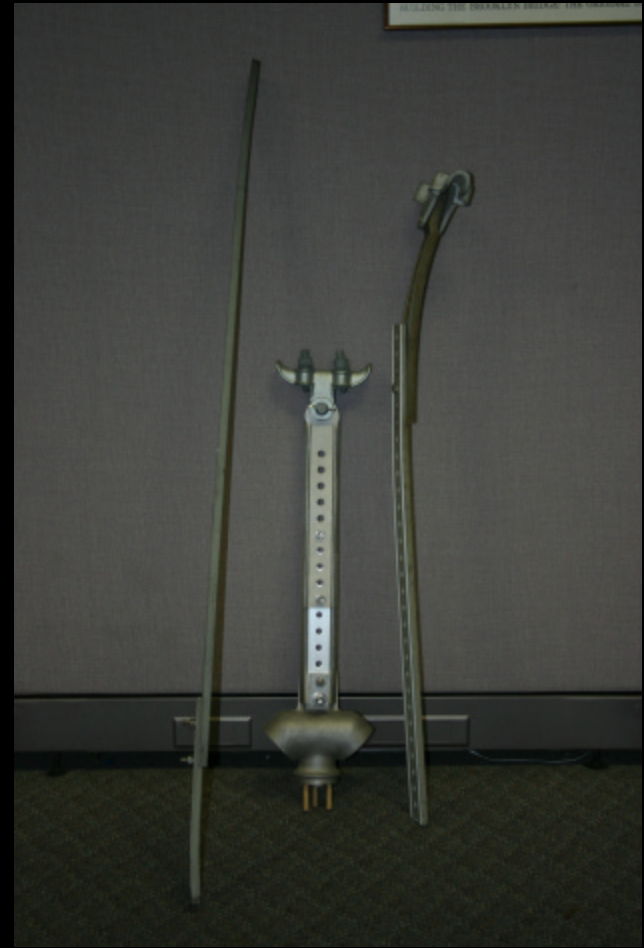
Some Damage to Strain
Wires (connections).



Mast Arm & Span Wire Inventory

District No.	No. Signals	No. Masts	Masts Damage	No. Wires	Other Damage
1	1,778	802	2	976	496
2	1,585	537	0	1,048	40
3	987	300	2	687	265
4	3,329	1,180	14	2,149	735
5	2,972	458	2	2,514	1,885
6	2,640	1,848	0	660*	0
7	2,151	518	0	1,633	102
Sum	15,442	5,643	20	9,667	3,523

Component Failures: Hangers



Component Failures: Disconnect Boxes



District 4 Mast Arm Failures



14 Failures

- All pre-standard structures.
- 3 base failures
- 4 anchor bolt failures
- 7 pole @ flange failures



Structural Successes



New Mast Arm - Punta Gorda



Strain Poles – Punta Gorda

I-10 over Escambia Bay



Escambia Bay on 9/16/2004

I-10 over Escambia Bay



Bridge Looking from West Bank

I-10 over Escambia Bay



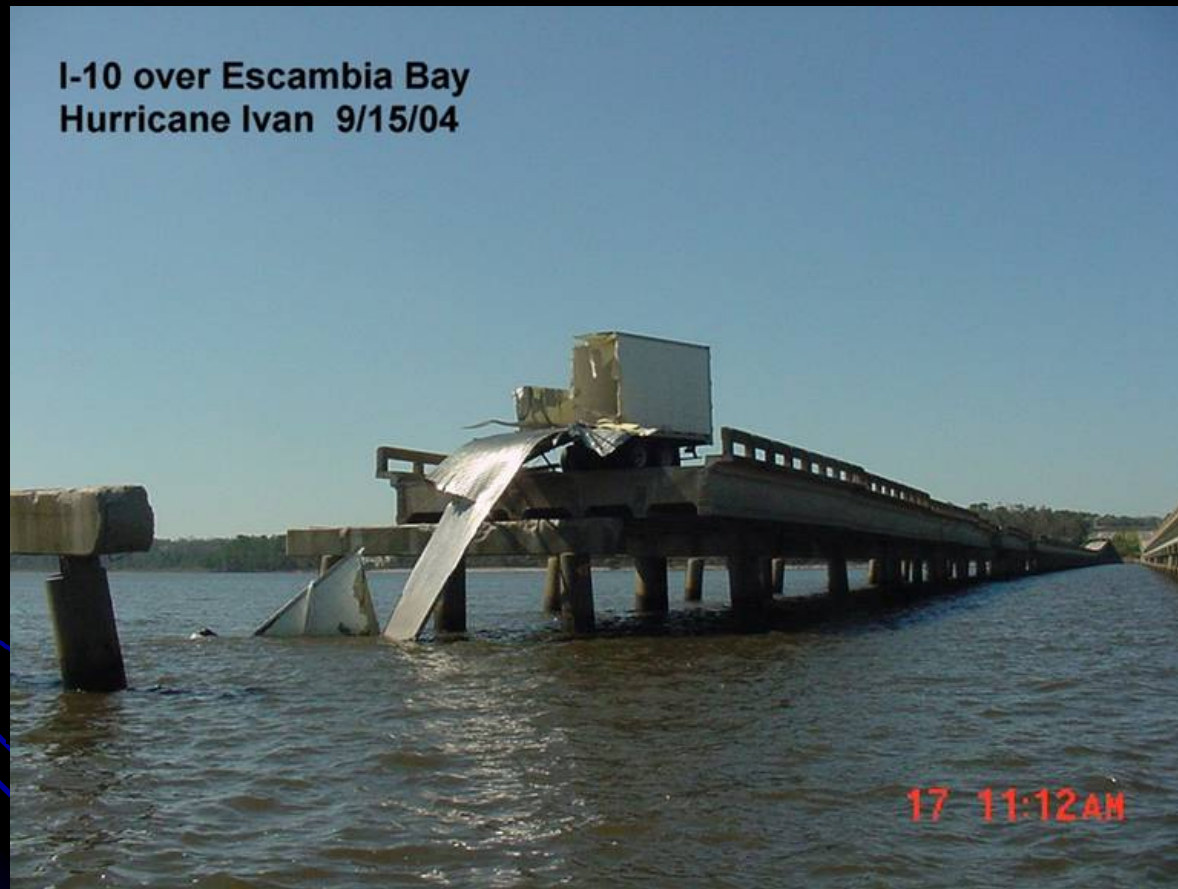
Bridge Looking from East Bank

I-10 over Escambia Bay



60' Trestle Spans Missing: 46 EB & 12 WB

I-10 over Escambia Bay



One Known Fatality

I-10 over Escambia Bay



Misaligned Spans: 50 EB & 16 WB

I-10 over Escambia Bay



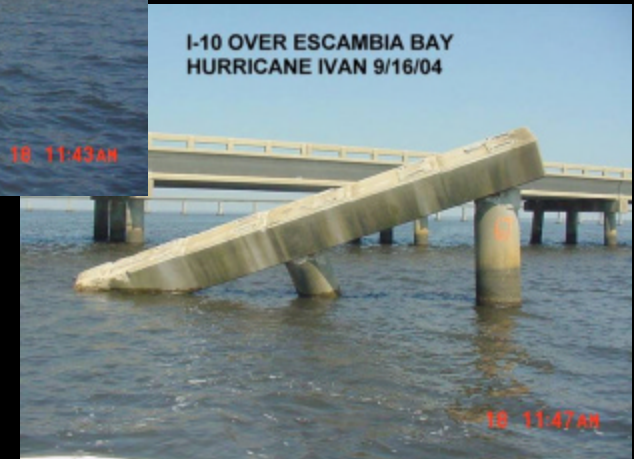
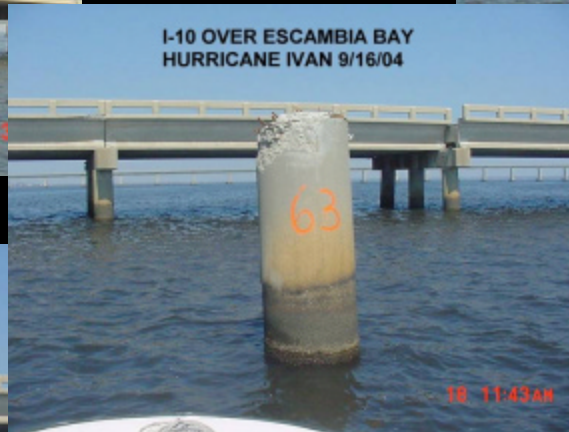
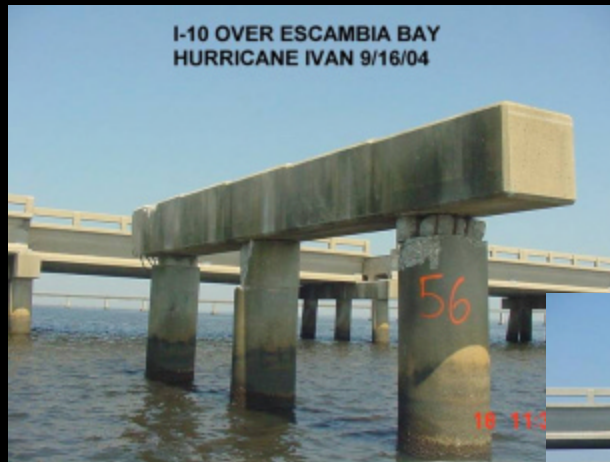
Hold-Down Bolts Sheared

I-10 over Escambia Bay



Hold-Down Bolts & Embedded Studs Sheared

I-10 over Escambia Bay



I-10 over Escambia Bay



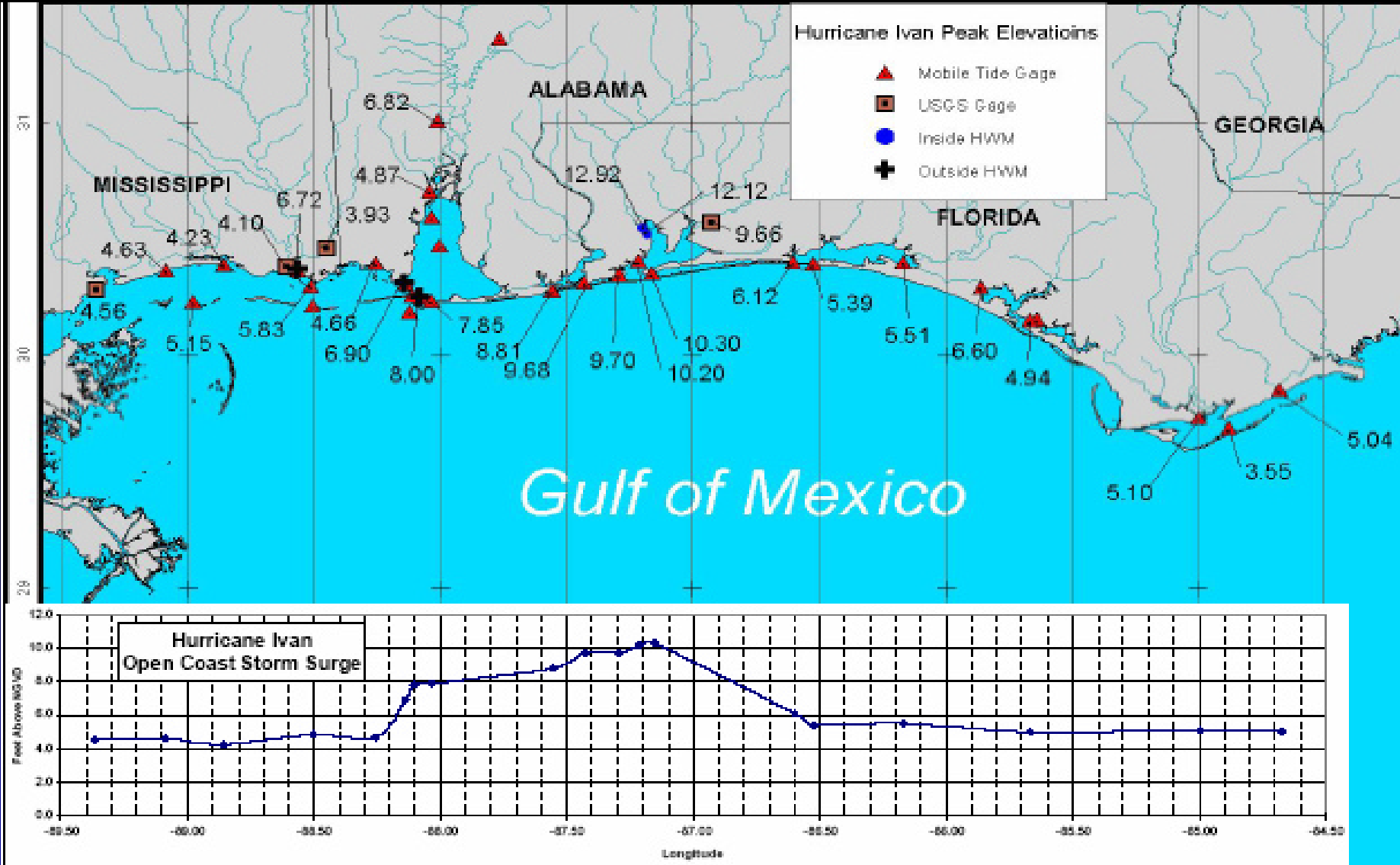
East Abutment of EB Bridge

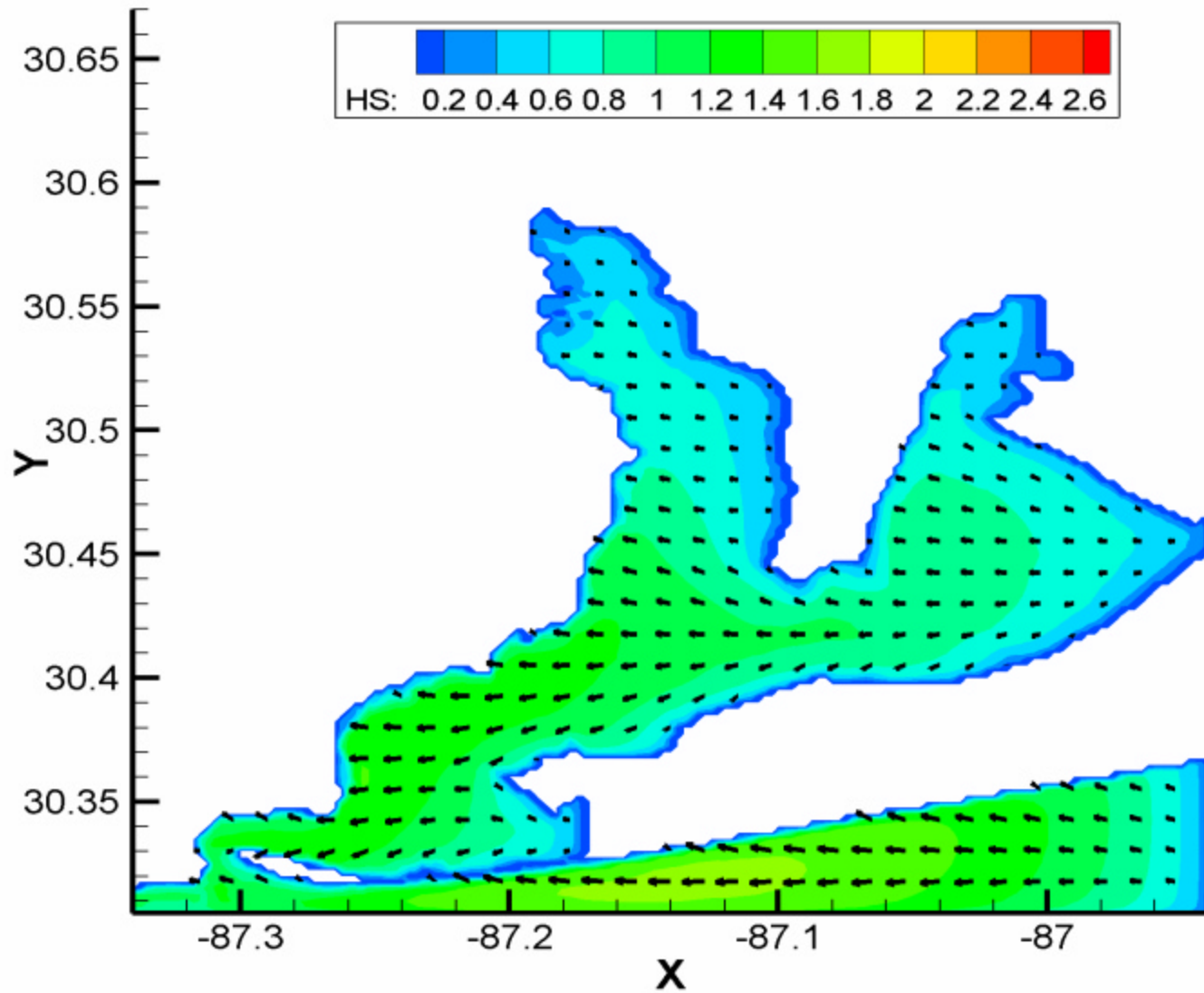
I-10 over Escambia Bay



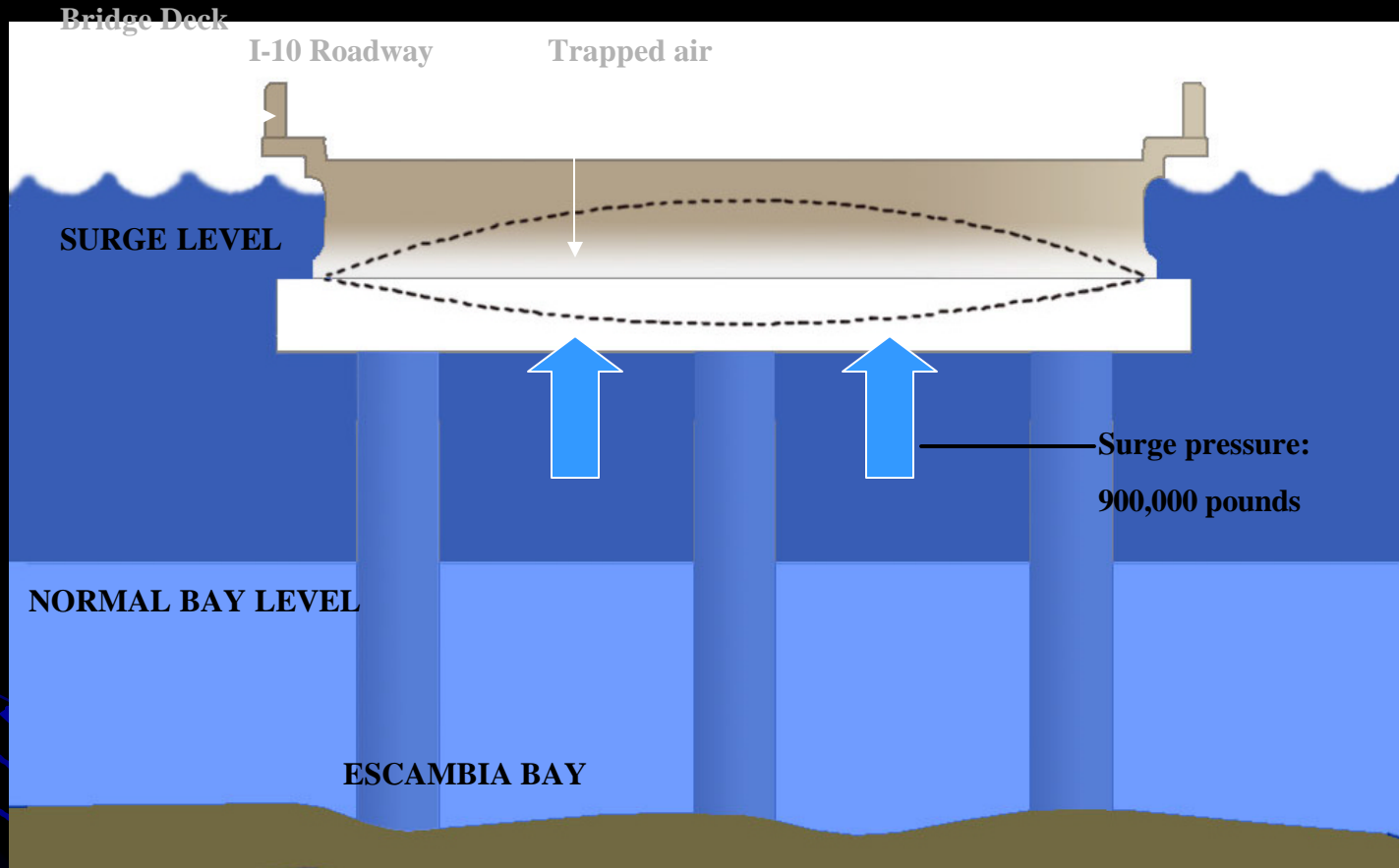
East Abutment of WB Bridge

Regional Peak Surge Elevations





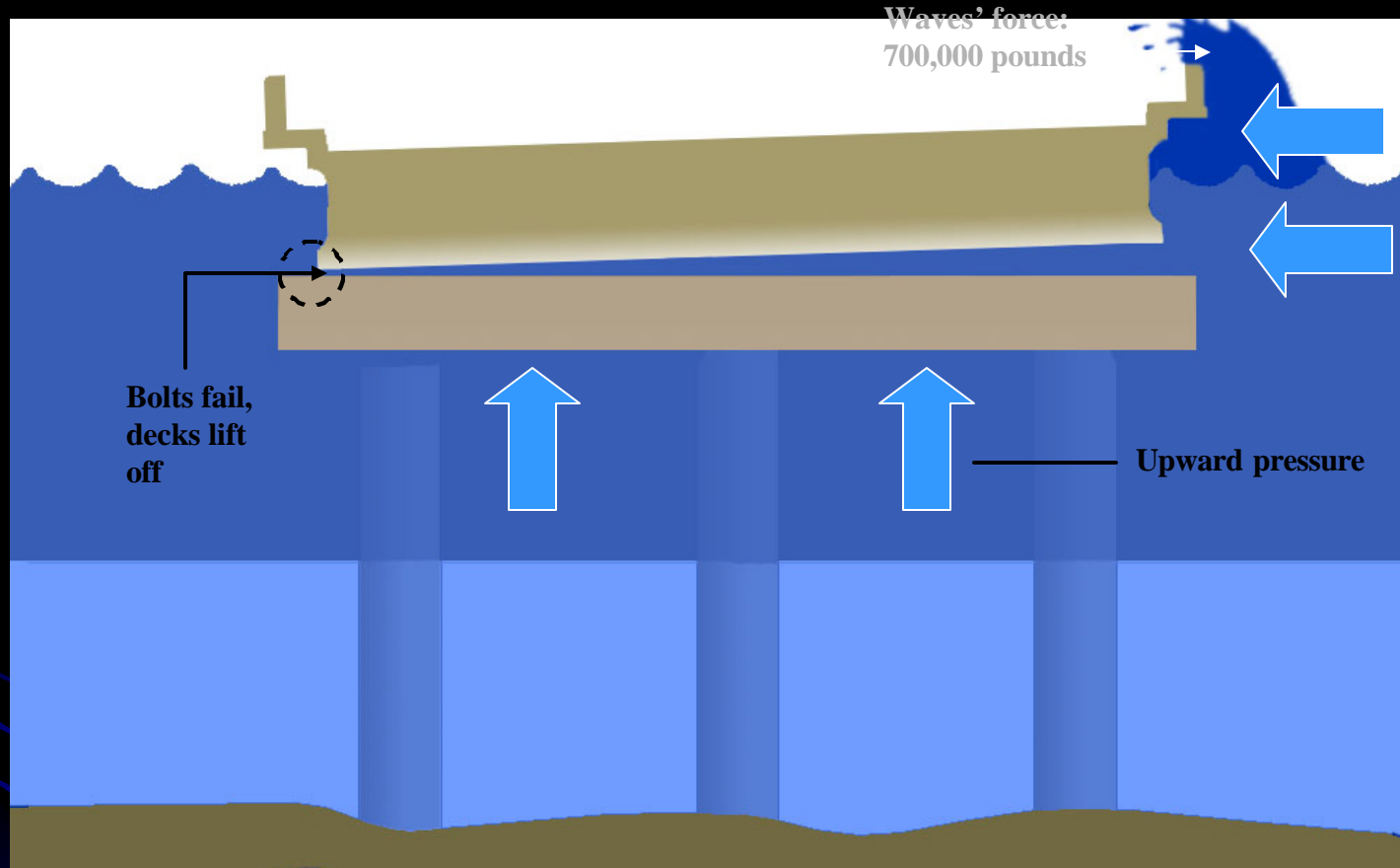
WATER HAMMER



1. The Lifting

Storm surge rose to 14 to 16 feet above sea level beneath the bridge decks, where beams captured air beneath them, increasing the upward force to 900,000 pounds.

WATER HAMMER

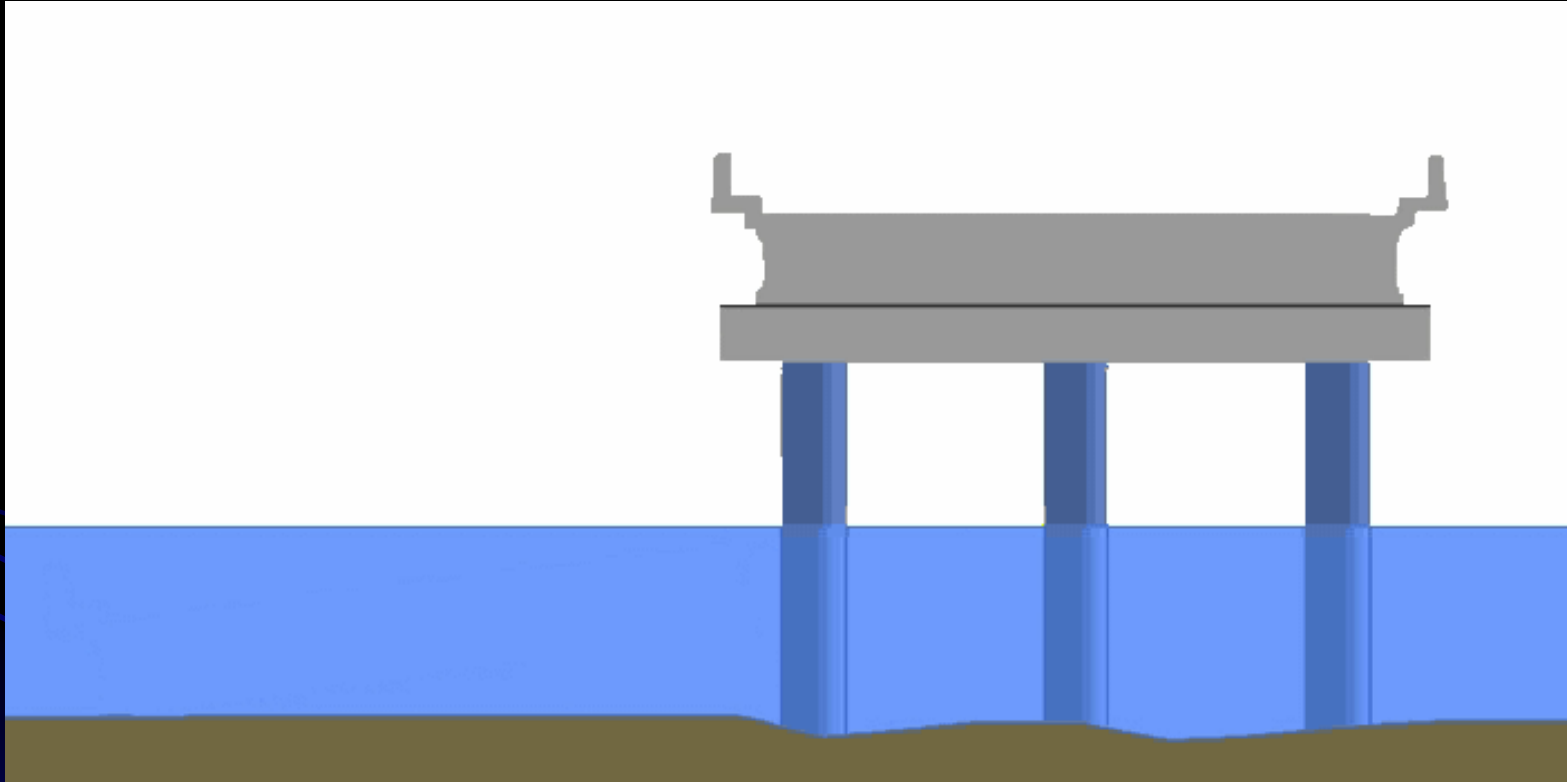


2. The Pounding

At the same time, waves of 13 feet atop the surge hit the sides of the bridge decks with 700,000 pounds of force every 6.5 seconds at the height of the storm.

WATER HAMMER

Some sections of
roadway slide over



3. The Breaking

The water's lifting and pounding broke the connections between 150-foot-deep pilings and piers supporting the bridge decks, allowing the decks to slide sideways or fall into the water.

Other Bridges

Jensen Beach Causeway – Under Construction
East Relief Bridge

Hurricane Francis



Hurricane Jeanne



Other Bridges

Jensen Beach Causeway – Under Construction
Fishing Pier (under Main Bridge)

Hurricane Francis



Hurricane Jeanne



Two spans lost – 14" piles shattered

Other Bridges

Jensen Beach Causeway – Under Construction
Existing Bascule Bridge

Hurricane Jeanne



Existing fishing pier – lost X spans

Hurricane Jeanne



Existing bridge closed for good –
New bridge to open in 3 weeks

Other Bridges

Typical Slope failures around end bents at three bridges

E. Lyons Bridge
Lake Worth Bridge
Roosevelt Bascule Bridge



JENSEN BEACH CAUSEWAY

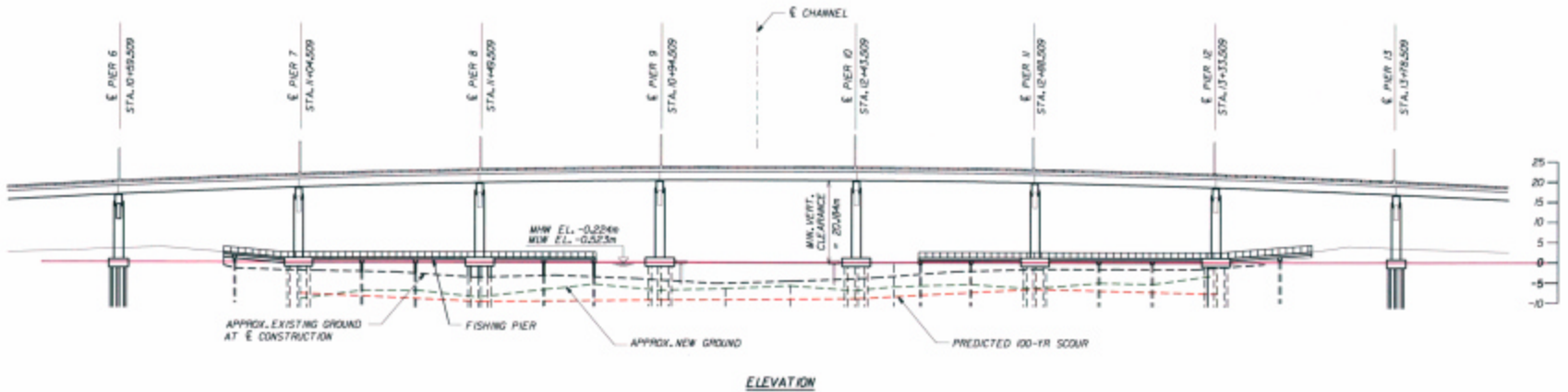


EAST RELIEF BRIDGE AFTER HURRICANES FRANCES AND JEANNE

INSTALLATION CRITERIA									DESIGN CRITERIA								PILE CUT-OFF ELEVATIONS (ft)	** STATE PLANE COORDINATES & STATIONS			
BEAT	PILE SIZE (in)	ULTIMATE BEARING CAPACITY (kN)	TENSION CAPACITY (kN)	* MINIMUM TIP ELEVATION (ft)	ACTUAL TIP ELEVATION (ft)	TEST PILE LENGTH (ft)	REQUIRED JET ELEVATION (ft)	REQUIRED PREFORM ELEVATION (ft)	FACTORED DESIGN LOAD (kN)	DMN DRAG (kN)	TOTAL SCOUR RESISTANCE (kN)	NET SCOUR RESISTANCE (kN)	LONG-TERM SCOUR ELEVATION (ft)	100-YEAR SCOUR ELEVATION (ft)	PRESENT SCOUR ELEVATION (ft)	100-YEAR SCOURABLE DEPTH (ft)		φ	NORTH (X) COORDINATE	EAST (Y) COORDINATE	BEGIN OR END BRIDGE OR INT. BEAT STATION
End Pier No. 1	60	2000	N/A	-12.0	-12.1	17.5	N/A	N/A	1900	0	N/A	N/A	N/A	N/A	N/A	0.7	149	# 323,893,565	E 277,800,276	Sta 18+08.500	
Int. Pier No. 2	60	2780	N/A	-12.0	-12.0	N/A	N/A	N/A	800	0	330	330	N/A	-7.20	-6.20	+0.20	0.7	147	# 323,893,345	E 277,812,191	Sta 18+21.000
Int. Pier No. 3	60	2760	N/A	-12.0	-12.0	33.1	N/A	N/A	800	0	330	330	N/A	-7.20	-5.70	+0.50	0.7	154	# 323,897,126	E 277,824,105	Sta 18+33.500
Int. Pier No. 4	60	2780	N/A	-12.0	-11.8	N/A	N/A	N/A	800	0	330	330	N/A	-7.20	-5.36	+0.84	0.7	161	# 323,900,907	E 277,836,020	Sta 18+46.000
Int. Pier No. 5	60	2760	N/A	-12.0	-12.1	N/A	N/A	N/A	800	0	330	330	N/A	-7.20	-6.39	+0.81	0.7	168	# 323,904,688	E 277,847,934	Sta 18+58.500
Int. Pier No. 6	60	2780	N/A	-12.0	-11.9	N/A	N/A	N/A	800	0	330	330	N/A	-7.20	-6.42	+0.78	0.7	175	# 323,908,469	E 277,859,849	Sta 18+71.000
Int. Pier No. 7	60	2760	N/A	-12.0	-12.0	27.1	N/A	N/A	800	0	330	330	N/A	-7.20	-6.45	+0.75	0.7	182	# 323,912,250	E 277,871,763	Sta 18+83.500
Int. Pier No. 8	60	2780	N/A	-12.0	-11.7	N/A	N/A	N/A	800	0	330	330	N/A	-7.20	-5.29	+0.91	0.7	189	# 323,916,030	E 277,883,678	Sta 18+96.000
Int. Pier No. 9	60	2760	N/A	-12.0	-12.8	N/A	N/A	N/A	800	0	330	330	N/A	-7.20	-5.37	+0.83	0.7	190	# 323,919,811	E 277,895,592	Sta 19+08.500
Int. Pier No. 10	60	2780	N/A	-12.0	-12.7	N/A	N/A	N/A	800	0	330	330	N/A	-7.20	-6.18	+0.02	0.7	189	# 323,923,592	E 278,007,507	Sta 19+21.000
Int. Pier No. 11	60	2760	N/A	-12.0	-12.5	31.4	N/A	N/A	800	0	330	330	N/A	-7.20	-6.02	+0.18	0.7	185	# 323,927,373	E 278,019,421	Sta 19+33.500
Int. Pier No. 12	60	2780	N/A	-12.0	-12.4	N/A	N/A	N/A	800	0	330	330	N/A	-7.20	-6.49	+0.71	0.7	178	# 323,931,154	E 278,031,336	Sta 19+46.000
Int. Pier No. 13	60	2760	N/A	-12.0	-12.5	N/A	N/A	N/A	800	0	330	330	N/A	-7.20	-6.46	+0.74	0.7	171	# 323,934,935	E 278,043,254	Sta 19+58.500
Int. Pier No. 14	60	2780	N/A	-12.0	-12.5	N/A	N/A	N/A	800	0	330	330	N/A	-7.20	-6.43	+0.77	0.7	164	# 323,938,716	E 278,055,205	Sta 19+71.000
Int. Pier No. 15	60	2760	N/A	-12.0	-11.2	33.4	N/A	N/A	800	0	330	330	N/A	-7.20	-6.30	+0.90	0.7	157	# 323,942,497	E 278,067,194	Sta 19+83.500
Int. Pier No. 16	60	2780	N/A	-12.0	-12.8	N/A	N/A	N/A	800	0	330	330	N/A	-7.20	-6.27	+0.93	0.7	150	# 323,946,278	E 278,079,219	Sta 19+96.000
End Pier No. 17	60	2000	N/A	-12.0	-11.4	46.7	N/A	N/A	1900	0	N/A	N/A	N/A	N/A	N/A	0.7	143	# 323,948,026	E 278,091,279	Sta 20+08.500	

East Relief Bridge

JENSEN BEACH CAUSEWAY



ELEVATION

AFTER HURRICANES FRANCES AND JEANNE

MAIN BRIDGE

PILE DATA TABLE

INSTALLATION CRITERIA										DESIGN CRITERIA										Pile cap-off elevations (m)	Site plane coordinates & stationing		
Pier or Bent	Pile Size (mm)	Ultimate Bearing Capacity (MN)	Function Capacity (MN)	MW. Tip Elev. (m) ±	Actual Tip Elev. (m)	Fast Pile Length (m)	Required Int. Elev. (m)	Required Pilehead Elev. (m)	Factorial Design Load (MN)	Overdrag (MN)	Total Scour Resist. (MN)	Net Scour Resist. (MN)	Long-Term Scour Elev. (m)	100-Year Scour Elev. (m) (1)	Present Scour Elev. (m) (2)	100-Year Scourable Depth (m) (1-2)	φ	North (N) Coordinate	East (E) Coordinate		Begin or end of pier station		
End bent 1	60	250	N/A			24.3	N/A	N/A	086	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.7	+4.70	# 323,583,007 E 276,872,780	Sta. 8+34.509			
Pier 2	60	3079	N/A	-5.0		23.0	N/A	N/A	2295	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.7	-0.800	# 323,608,625 E 277,014,980	Sta. 8+79.509			
Pier 3	60	3079	N/A	-5.0		22.0	N/A	N/A	2295	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.7	-0.800	# 323,623,306 E 277,057,275	Sta. 9+24.509			
Pier 4	60	3079	N/A	-5.0		25.3	N/A	N/A	2295	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.7	-0.800	# 323,639,340 E 277,099,658	Sta. 9+69.509			
Pier 5	60	3079	N/A	-5.0		23.3	N/A	N/A	2295	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.7	-0.800	# 323,655,667 E 277,142,049	Sta. 10+14.509			
Pier 6	60	3079	N/A	-5.0		23.0	N/A	N/A	2295	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.7	-0.800	# 323,668,607 E 277,184,686	Sta. 10+59.509			
Pier 7	760	4530	N/A	-15.5	-7.6	25.3	N/A	N/A	2746	N/A	425	425.0	N/A	-7.79	-9.9	-1.40	0.7	+0.200	# 323,680,889 E 277,227,329	Sta. 11+04.509			
Pier 8	760	4403	N/A	-15.5	-7.2	30.4	N/A	N/A	2746	N/A	336	325.6	N/A	-8.77	-8.79	+0.88	0.7	+0.200	# 323,697,26 E 277,270,054	Sta. 11+49.509			
Pier 9	760	4177	N/A	-6.0	-7.1	3.2	N/A	N/A	2764	N/A	60	60.0	N/A	-9.4	-6.8	+2.48	0.7	+0.200	# 323,710,889 E 277,312,882	Sta. 11+94.509			
Pier 10	760	4363	N/A	-6.0	-6.2	27.1	N/A	N/A	2764	N/A	290	287.7	N/A	-9.00	-7.1	+1.89	0.7	+0.200	# 323,725,080 E 277,355,567	Sta. 12+43.509			
Pier 11	760	4339	N/A	-15.5	-15.7	23.4	N/A	N/A	2746	N/A	29	289.5	N/A	-6.75	-6.54	+0.21	0.7	+0.200	# 323,739,58 E 277,400,542	Sta. 12+88.509			
Pier 12	760	4138	N/A	-15.5	-15.7	26.0	N/A	N/A	2746	N/A	130	130.0	N/A	-7.77	-3.28	+4.40	0.7	+0.200	# 323,750,254 E 277,445,094	Sta. 13+33.509			
Pier 13	60	3079	N/A	-5.0		24.3	N/A	N/A	2295	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.7	-0.800	# 323,765,088 E 277,489,732	Sta. 13+78.509			
Pier 14	60	3079	N/A	-5.0		25.0	N/A	N/A	2295	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.7	-0.800	# 323,777,688 E 277,531,025	Sta. 14+23.509			
Pier 15	60	3079	N/A	-5.0		25.8	N/A	N/A	2295	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.7	-0.800	# 323,790,036 E 277,575,098	Sta. 14+68.509			
Pier 16	60	3079	N/A	-5.0		25.6	N/A	N/A	2295	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.7	-1.300	# 323,802,480 E 277,618,443	Sta. 15+13.509			
Pier 17	60	3079	N/A	-5.0		26.3	N/A	N/A	2295	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.7	-0.800	# 323,815,277 E 277,661,014	Sta. 15+58.509			
End bent 18	60	255	N/A			26.8	N/A	N/A	086	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.7	+4.70	# 323,830,748 E 277,704,710	Sta. 16+03.509			

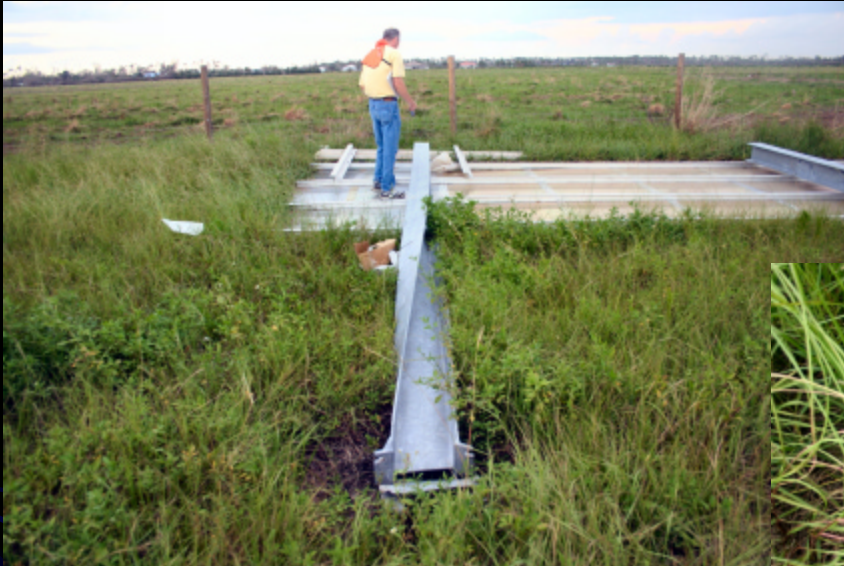
323,828,028 E 277,704,710 Sta. 16+03.509

Main Bridge Scour

Multi-Post Ground Signs



Multi-Post Ground Sign



I-75 Cantilever Signs Structure



I-75 Cantilever Sign Structure



I-4 Cantilever Sign Structure

- Hurricane Jeanne
- Location I-4 near John Young Parkway
- Rush Hour 3:00 pm
- Damage to foundation identified by inspector and structure removed



I-95 Cantilever Sign Structure



I-75 High Mast Lighting

19 High Mast Lights Failed in District 1

2 High Mast Lights Failed in District 4

Following Charley, Policy Issued to
Lower Lights when Category 2 or
Higher Threaten.



Lighting Structures

164 of 1,559 (10%) Poles Damaged
on 4 District 4 Projects.

Damage: Frangible aluminum bases,
support arms, light fixtures
(connections).



Lighting Structures

PGA – West Palm Beach



55 failures out of 186 lights

Other Bridges - Erosion

