



Kennedy Space Center

Kennedy Space Center Use of NHC Products – Then and Now

Kathy Rice, 3 March 2021

KSC Weather Office

Spaceport Management & Integration Division

Customer Services & Integration Branch

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Overview



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- ◆ Kennedy Space Center operations overview
- ◆ Current use of NHC product
- ◆ Comparison to past – actual cases
- ◆ Current case -- continued challenges

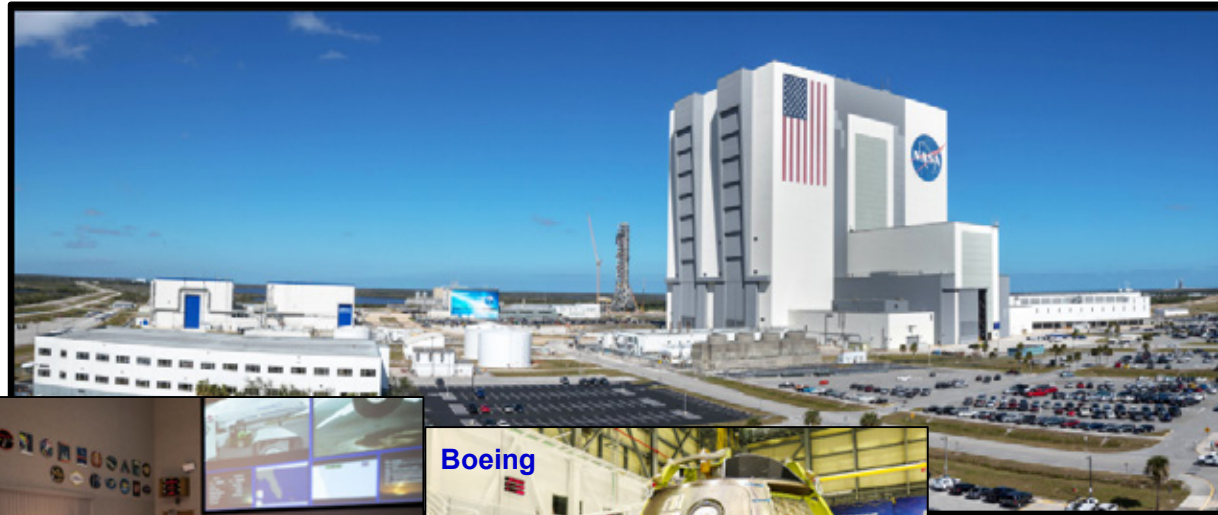


Spaceport Integration & Services



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➤ Kennedy Space Center – Multi-user Spaceport





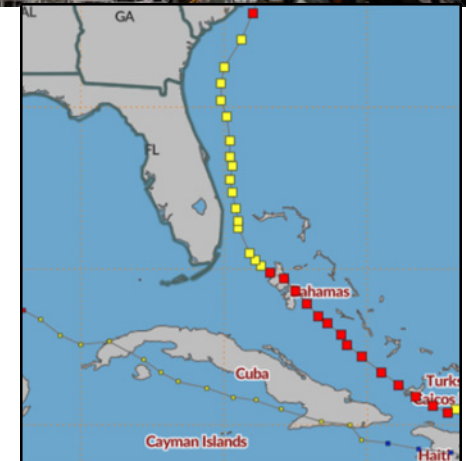
Artemis I



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KSC had near miss with Isaias in August



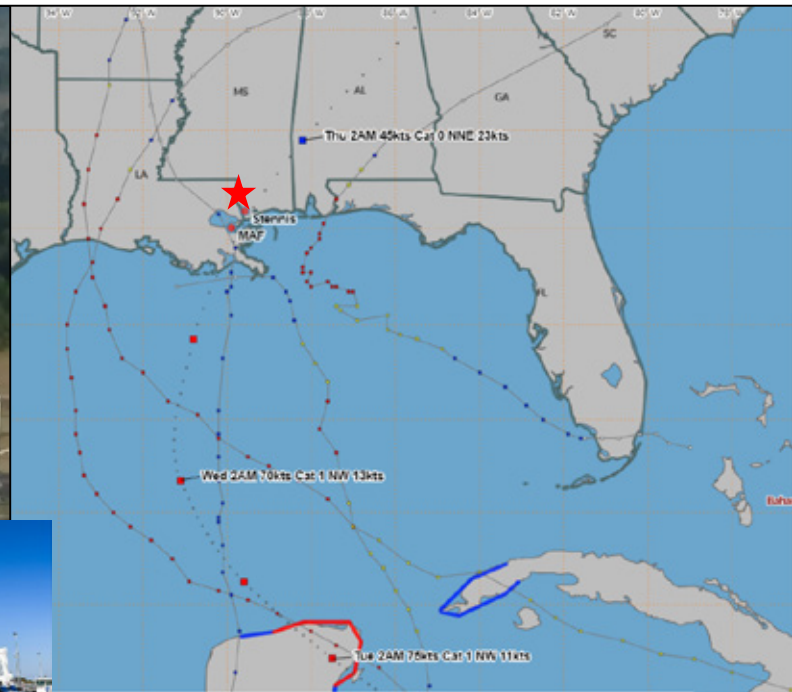


Stennis Space Center



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- **KSC Weather Office providing tropical updates to Green Run Operations at Stennis**
 - Six tropical cyclones threatened Stennis during 2020 season (TS Cristobal, Hurricanes Marco, Laura, Sally, Delta, TS Zeta)

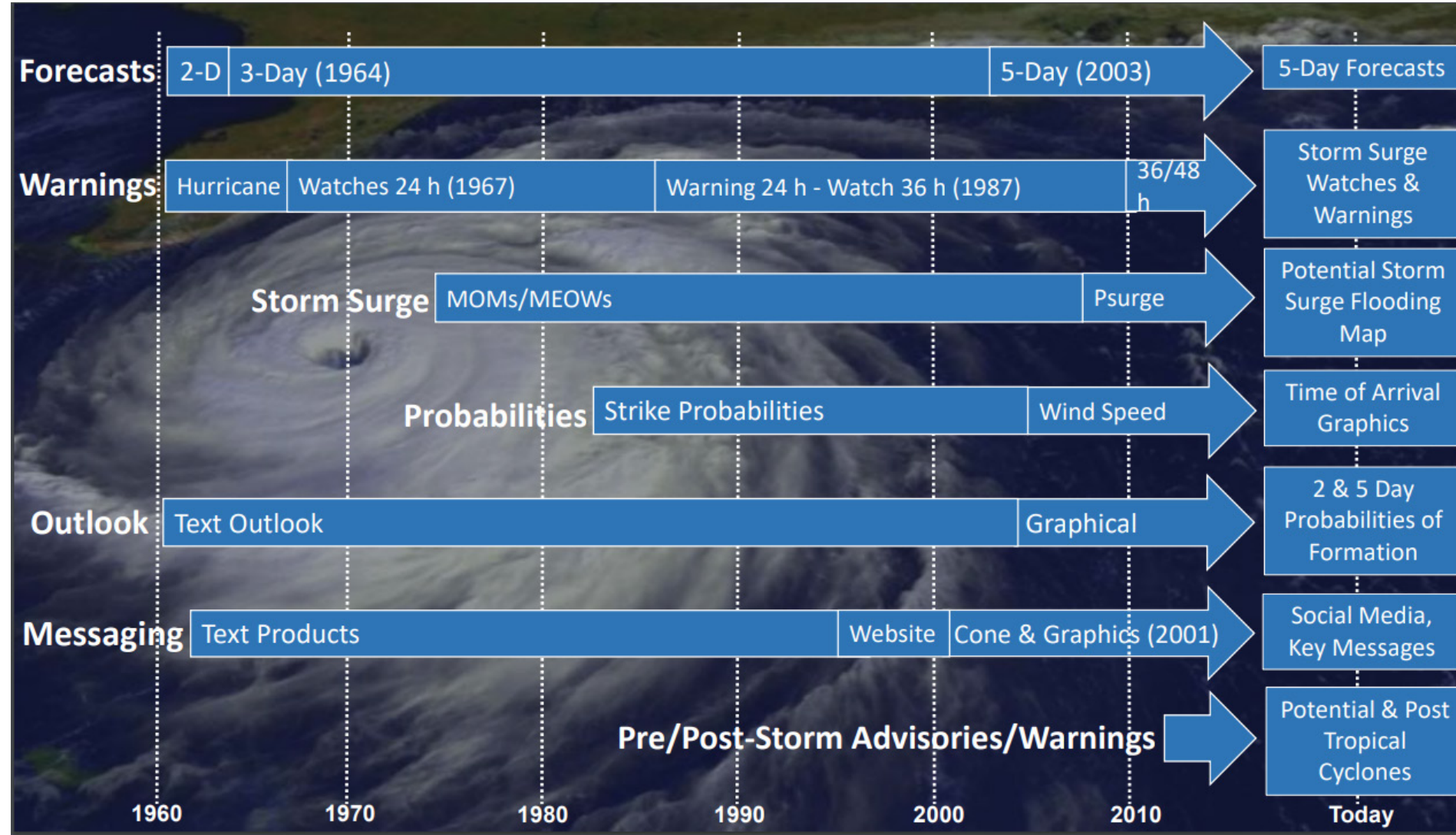




NHC Product Evolution



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KSC – Recent History – Summary



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- ◆ 2004: Charley, Frances, Jeanne – **Busy!**
- ◆ 2005: Katrina, Ophelia, Wilma – **Close Storm Genesis**
- ◆ 2006: Ernesto – **False Alarm**
- ◆ 2008: Fay – **Flooding**
- ◆ 2011: Columbus Day Storm – **Not named but was significant!**
- ◆ 2012: Sandy – **Storm Surge**
- ◆ 2016: Matthew – **Not a 'near miss' for KSC**
- ◆ 2017: Irma – **Entire state in damaging winds—go inland! Tornadoes, too!**
- ◆ 2019: Dorian – **Hurry up and wait – Are we there yet? Coastal winds.**
- ◆ 2020: Isaias – **Another off-shore pass – Good 'hurricane exercise'**



KSC – Recent History



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Highest Peak Wind



	<u>Charley</u> <u>2004</u>	<u>Dorian</u> <u>2019</u>	<u>Wilma</u> <u>2005</u>	<u>Jeanne</u> <u>2004</u>	<u>Frances</u> <u>2004</u>	<u>Irma</u> <u>2017</u>	<u>Matthew</u> <u>2016</u>
KSC <u>< 60'</u>	56 / 75 Knots	44 / 62 Knots	56 / 82 Knots	54 / 76 Knots	59 / 82 Knots*	56 / 76 Knots	68 / 93 Knots
KSC All Towers (≤500ft)	58 / 73 Knots	67 / 77 Knots	65 / 78 Knots	71 / 81 Knots	70 / 89 Knots*	90 / 101 Knots	105 / 121 Knots

* Frances -- Wind System Comm Failure: 0820L, 5 Sep 04



2004 Charley



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Shuttle Hurricane Information

Tropical Storm Charley

Source: National Hurricane Center Advisory #10, 11/1700L

Current Storm Information: Source--NHC

Location:	17.0°N 77.5°W 165° @ 713NM from KSC
Movement:	290° @ 15Kts
Strength:	Winds 65 G 80 Kts (Cat: N/A) Pressure: 993 mb

NHC Storm Forecast: Based on attached NHC forecast plot of storm track.
 - Forecast speed and intensity of storm at each point on attached NHC forecast:

Point	Current - 12/02L	12/02L - 12/14L	12/14L - 13/02L	13/02L - 13/14L	13/14L - 14/14L	14/14L - 15/14L	15/14L - 16/14L
Speed	16 Kts	15 Kts	14 Kts	14 Kts	24 Kts	26 Kts	26 Kts
Wind	65G80Kts	75G90Kts	80G100Kts	80G100Kts	90G110Kts	45G55Kts	35G45Kts
40Kt Radii NE SE SW NW	50 65 60 50	50 65 60 50	50 50 50 50	50 55 50 50	50 60 50 50	50 60 50 50	N/A

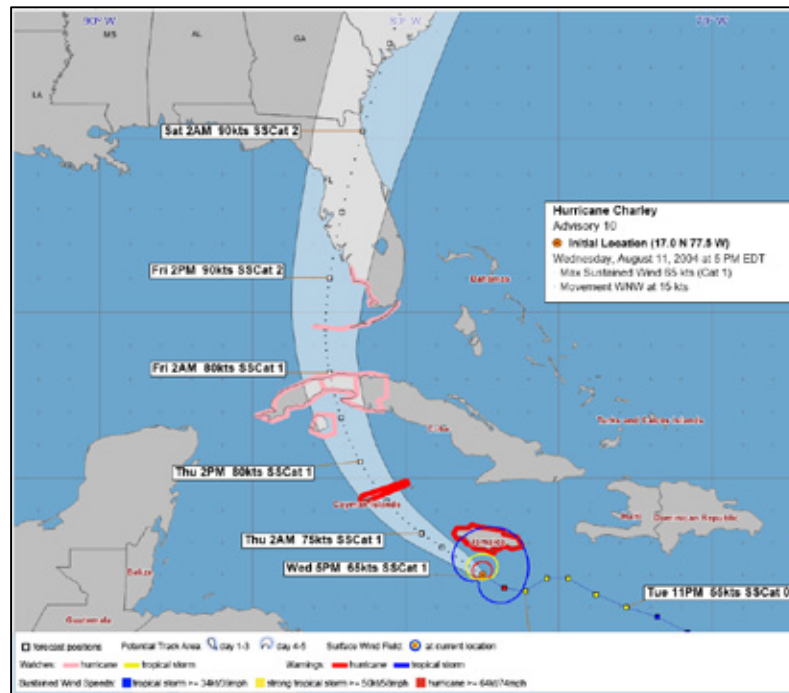
KSC Threat: Based on the NHC's forecast, products, and published forecast errors.

Probability of 40 Kt sustained wind @ LC 39:	75%
Probability of 70 Kt peak wind @ LC 39 within 72 hrs:	40%

40-Knot Simulation: NOTE: This is a simulation. The official forecast is the NHC's current forecast.

Timing/Probability Assumptions
 - Timing assumes the storm follows the NHC forecast for 36 hours then turns sharper and tracks toward KSC.

Given Storm Speed	Arrival Time at given storm speed					
	20 Kts	18 Kts	15 Kts	12 Kts	10 Kts	8 Kts
Time until arrival of 40 Kt winds	38 hrs	43 hrs	51 hrs	64 hrs	77 hrs	96 hrs
Date/Time of arrival of 40 Kt winds	13/0124L Fri	13/0540L Fri	13/1412L Fri	14/0300L Sat	14/1548L Sat	15/1100L Sun



After-the-fact CIRA probabilities (experimental)

- Probability of 34kt sustained: 45%
- Probability of 50kt sustained: 10%
- Probability of 64kt sustained: 3%

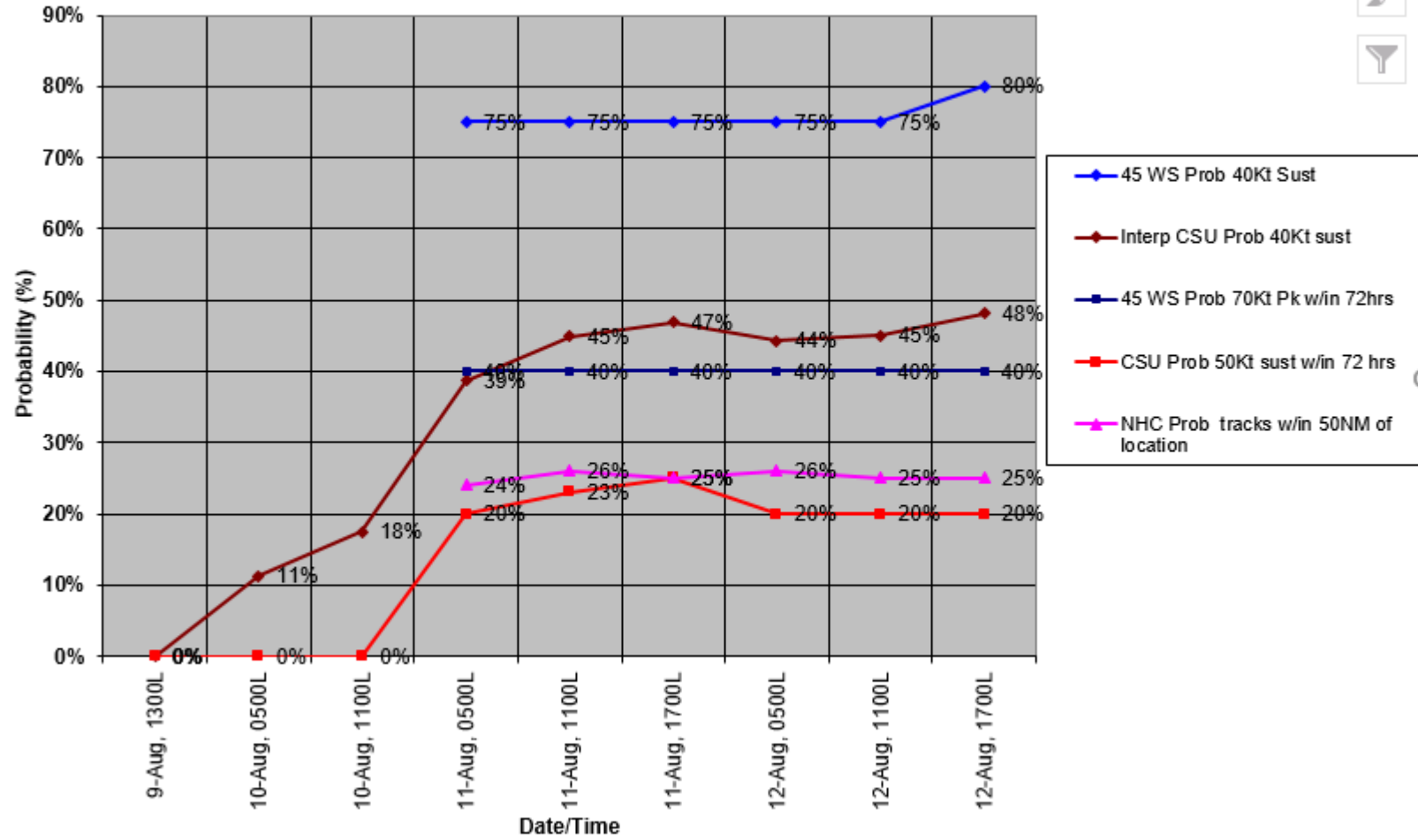


Charley Probability Comparison



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Hurricane Probability Comparisor -- 2004 Charley Occurred



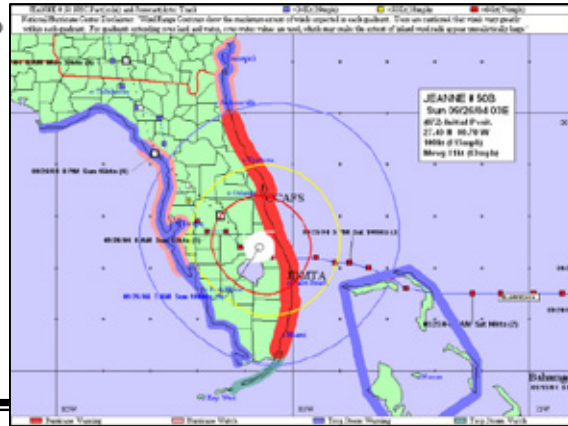
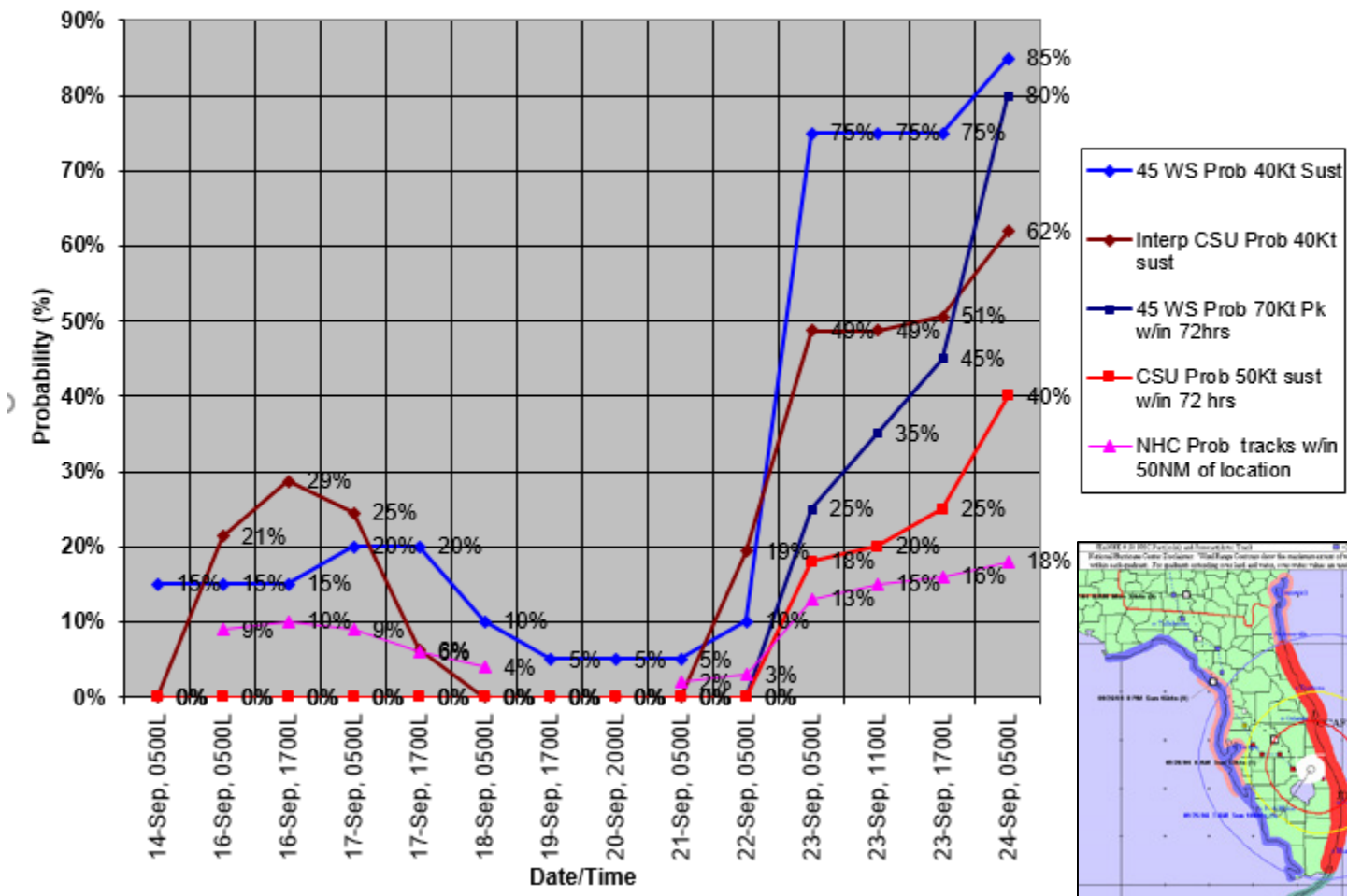


2004 Jeanne



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Hurricane Probability Comparison -- 2004 Jeanne
Occurred

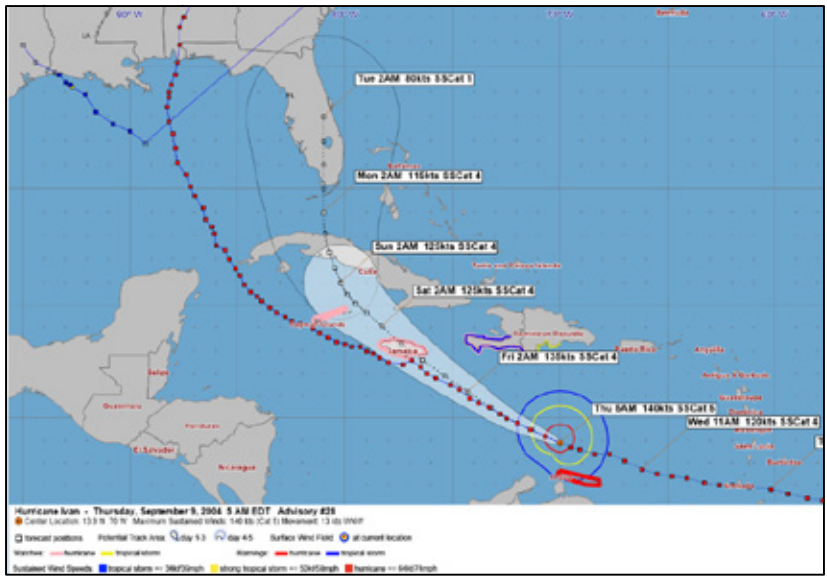
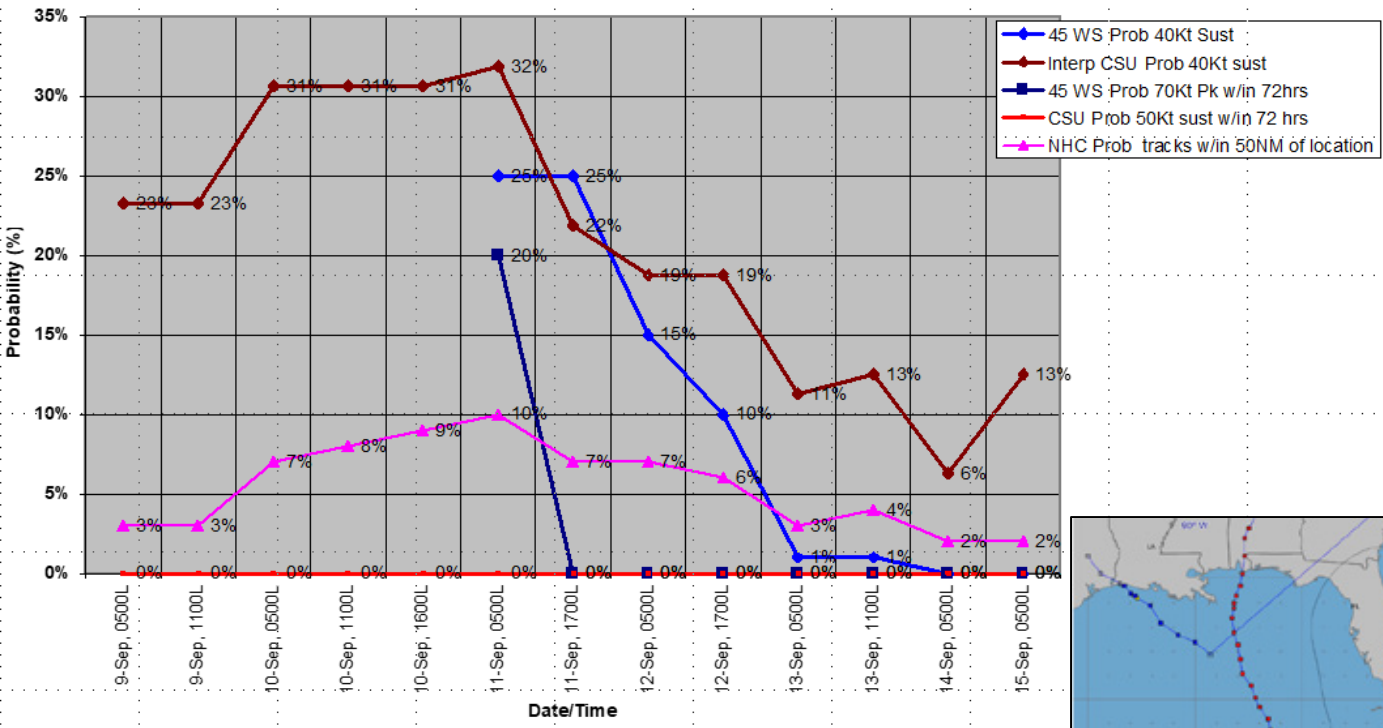




2004 Ivan



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2005 Briefing



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Pros/Cons

Pros	Cons
<ul style="list-style-type: none">- Based on NHC Forecast- 120 hour product vs. NHC 72 hour product- Trends indicated, better start- Tested during active 2004 hurricane season- Probability for WIND SPEED vs distance of eye from location (NHC)- NWS Interested	<ul style="list-style-type: none">- Availability of Product- Tested for only 2 seasons- Not public product- Difficult to determine data if storm overlap- Experimental product – changes?

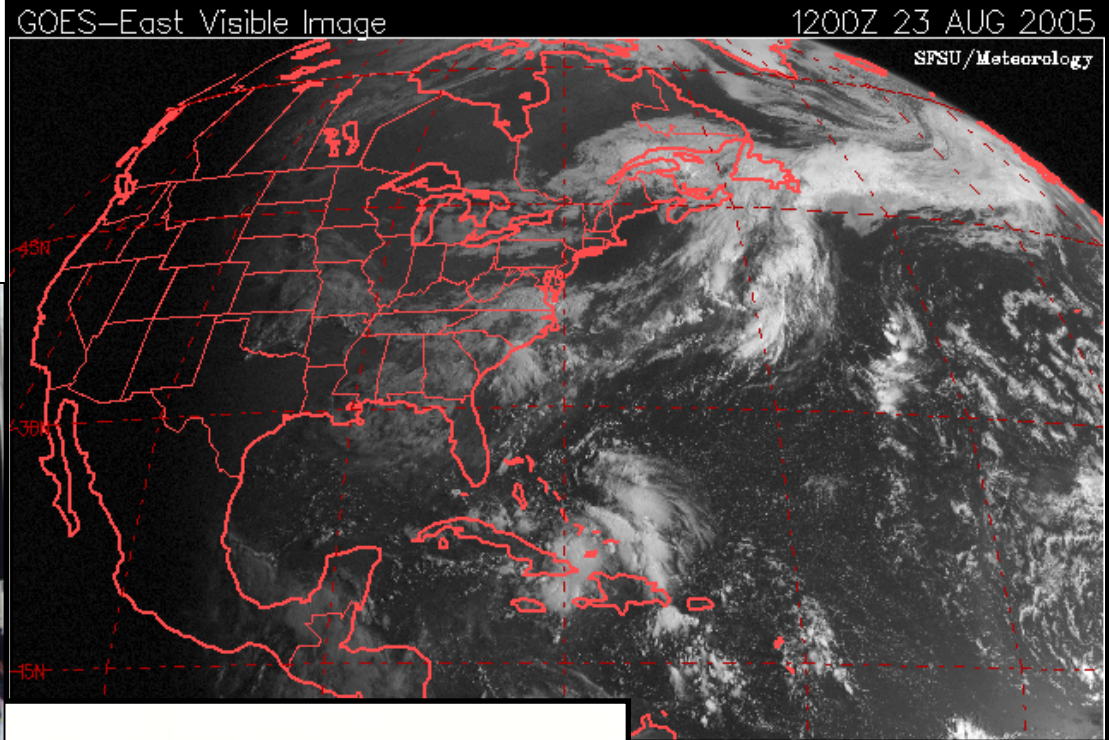
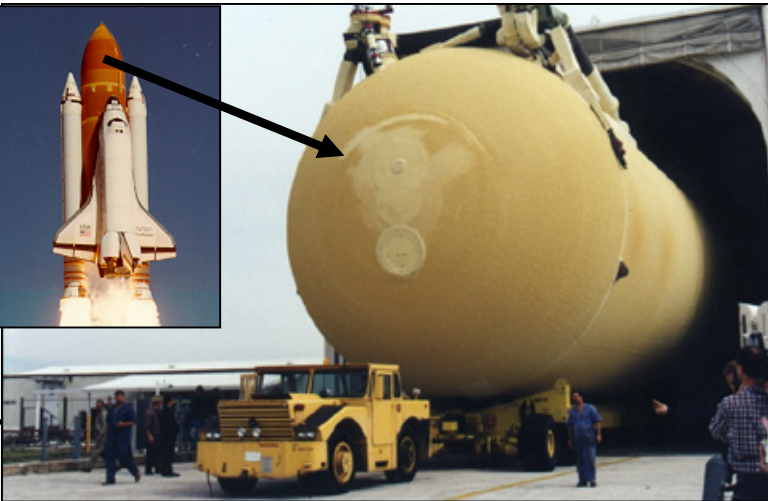


Case Study #1 – ET Barge



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External Tank Barge Transport Planned 23 Aug 05





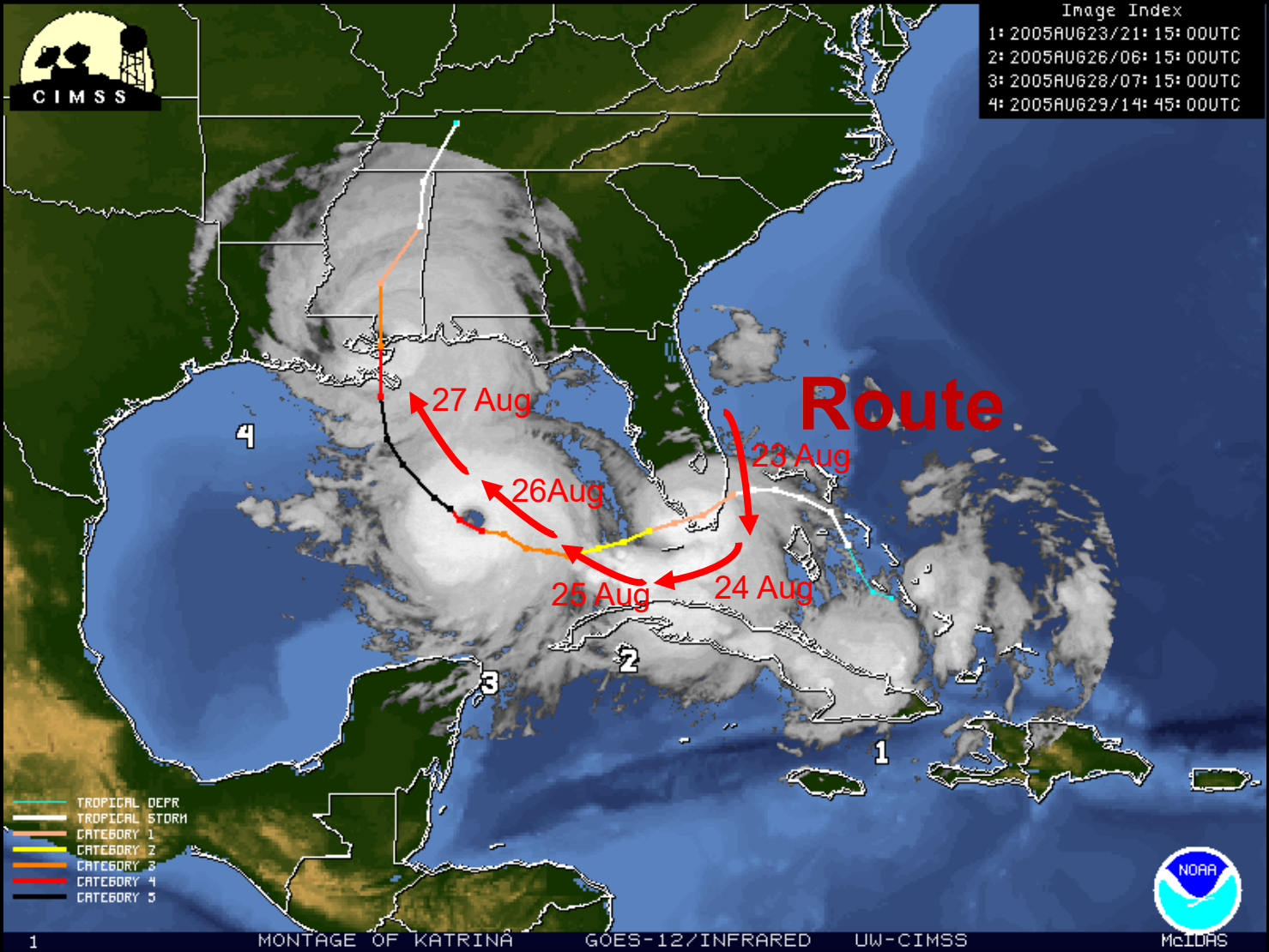
2005 Katrina



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Image Index

1:	2005AUG23/21: 15: 00UTC
2:	2005AUG26/06: 15: 00UTC
3:	2005AUG28/07: 15: 00UTC
4:	2005AUG29/14: 45: 00UTC



- TROPICAL DEPR
- TROPICAL STORM
- CATEGORY 1
- CATEGORY 2
- CATEGORY 3
- CATEGORY 4
- CATEGORY 5

1

MONTAGE OF KATRINA

GOES-12/INFRARED

UW-CIMSS

McIDAS

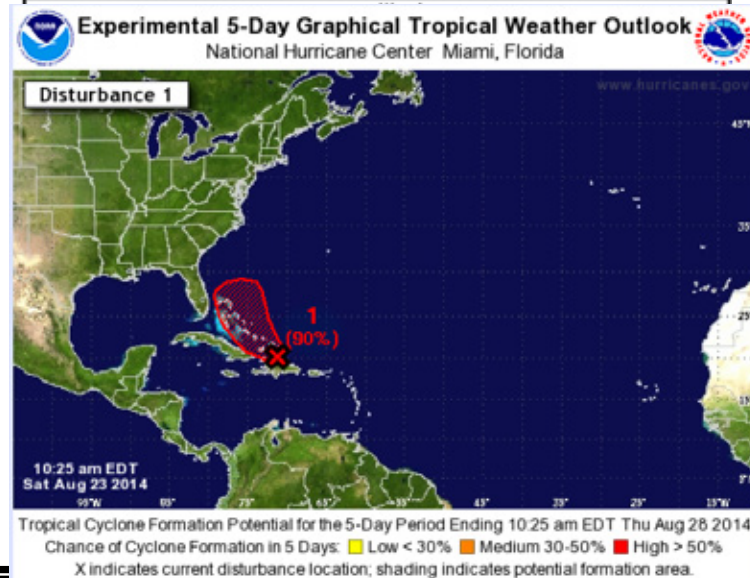
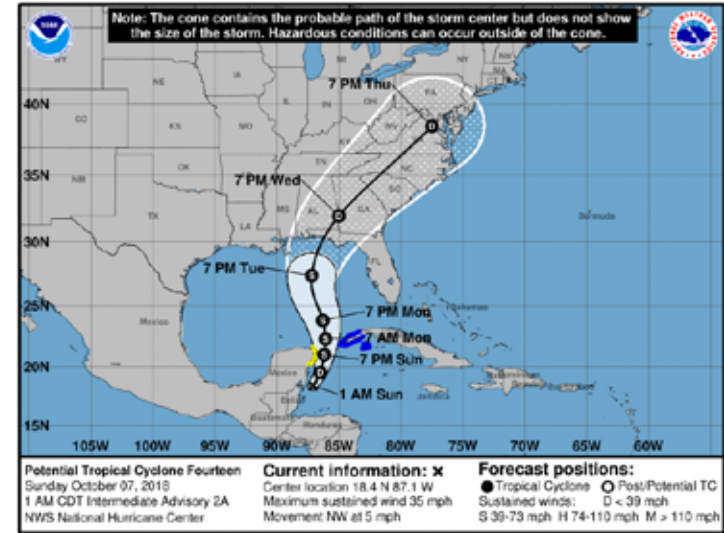


Summary of Case #1 ET Barge



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- ◆ Most Utilized NHC Products
 - Tropical Outlook Discussion (not graphical)
- ◆ Current Products that would have been useful then:
 - Graphical Tropical Weather Outlook
 - Potential Tropical Cyclone Forecast
- ◆ Success Points:
 - Experienced external tank barge marine transport team very aware of tropical cyclone risk and took action on potential for a developing tropical wave.

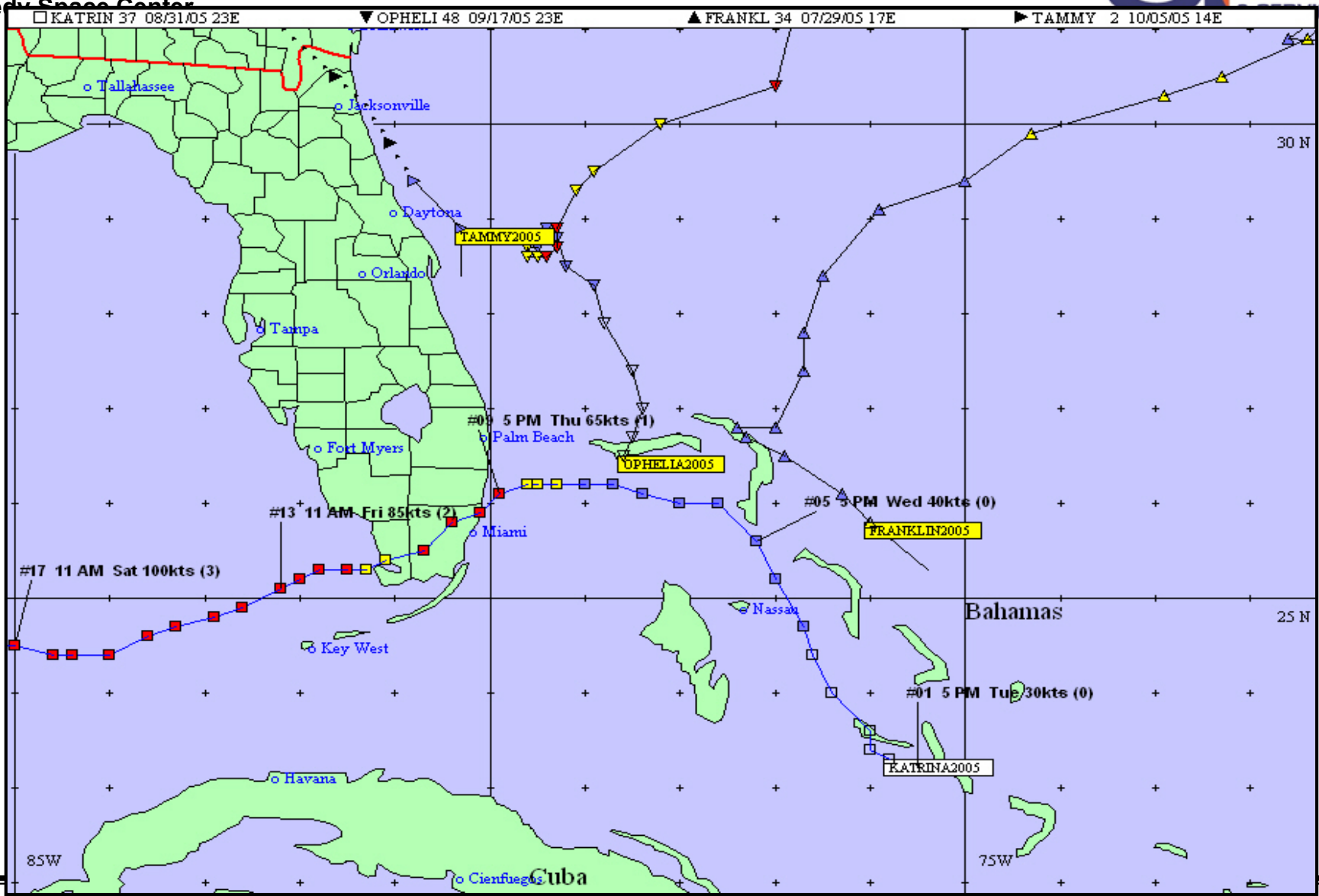




2005 Close Storm Genesis



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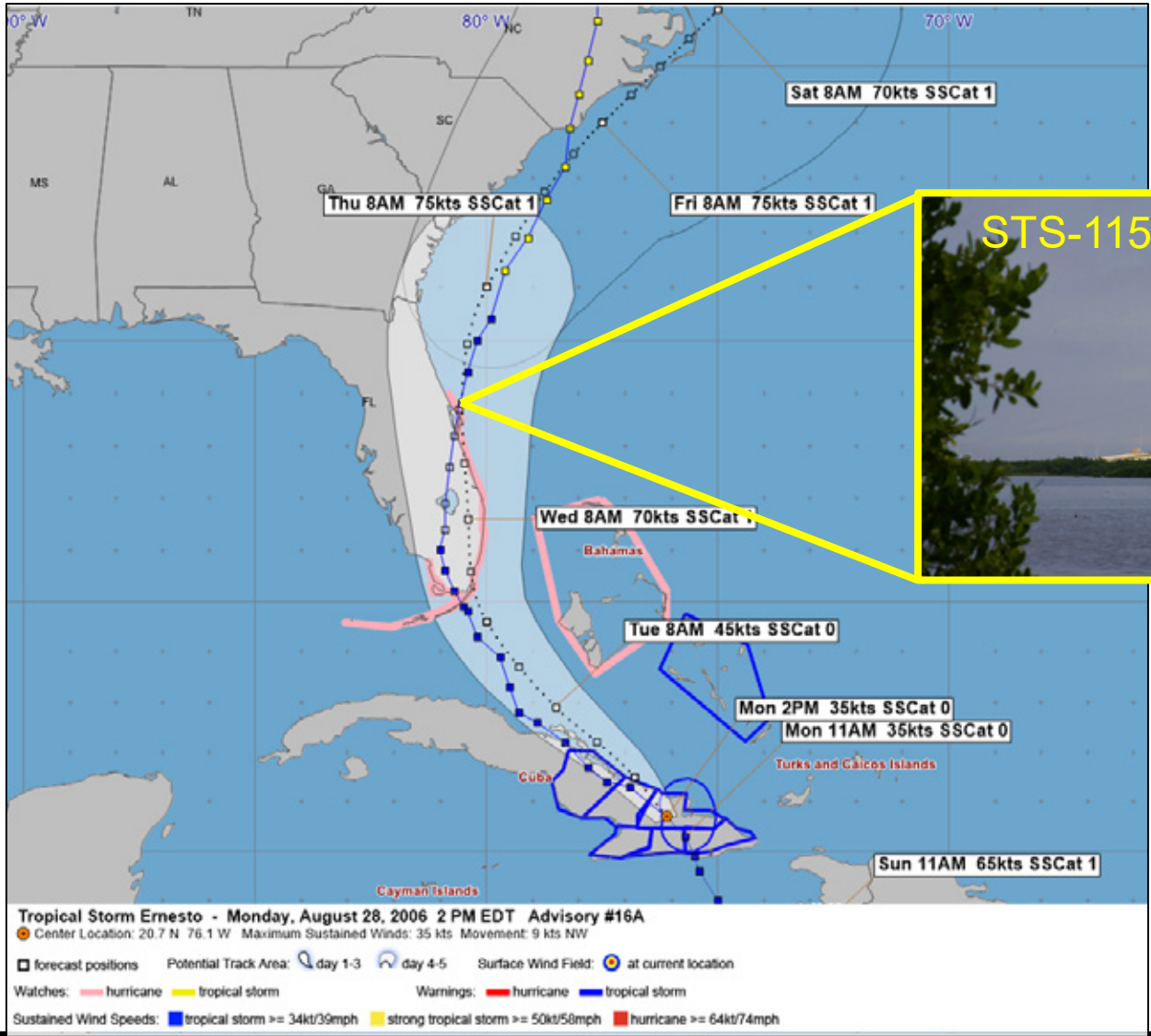




Case #2 – 2006 Ernesto



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Rollback Exposure Forecast



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Exposure Forecast

Monday, 28 Aug 06
VAB / CX 39B

As of 28 Aug, 1300L

<u>Time</u>	<u>Wind</u>	<u>Precip</u>	<u>TSTMS</u>
0900 – 1100L	140 / 8Kt	10%	10%
1100 – 1400L	140 / 12 P 17Kts	20%	10%
1400 – 1800L	140 / 12 P 17Kts	10%	10%
1800 – 2400L	140 / 8Kt	10%	10%

Shuttle Rollback constraints:

- $\leq 10\%$ chance lightning within 20NM
- Winds ≤ 40 knots sustained 60 knots peak



Exposure Forecast

Tuesday, 29 Aug 06
VAB / CX 39B

As of 28 Aug, 1300L

<u>Time</u>	<u>Wind</u>	<u>Precip</u>	<u>TSTMS</u>
0000 – 1100L	140 / 8Kt	30%	20%
1100 – 1400L	120 / 12 P 17Kts	30%	20%
1400 – 1700L	120 / 14 P 20Kts	30%	20%
1700 – 2000L	120 / 14 P 20Kts	40%	30%
2000 – 2200L	120 / 17 P 25Kt	60%	40%
2200 – 2400L	120 / 17 P 25Kt	70%	60%



Parallel Work -- Partial Stack Move



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28 Aug – Rollback preps:
Crawler Failure – added 4 hours
onto Shuttle Rollback timeline



Rollback Decision



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Leroy Cain, Launch Integration Manager

Mike Leinbach, Launch Director

Kathy Rice, Launch Weather Officer

TIME PERIODS	FROM 06Z MON TO 18Z MON	FROM 18Z MON TO 06Z TUE	FROM 06Z TUE TO 18Z TUE	FROM 18Z TUE TO 06Z WED	FROM 06Z WED TO 06Z THU	FROM 06Z THU TO 06Z FRI	FROM 06Z FRI TO 06Z SAT
FORECAST HOUR	(12)	(24)	(36)	(48)	(72)	(96)	(120)
COCOA BEACH FL 34	X	X(X)	3(3)	18(21)	28(49)	4(53)	2(55)
COCOA BEACH FL 50	X	X(X)	X(X)	5(5)	17(22)	2(24)	1(25)
COCOA BEACH FL 64	X	X(X)	X(X)	2(2)	7(9)	2(11)	X(11)

Shuttle Exposure constraint:

- 70 knots peak wind



2006 Ernesto – Shuttle Half Rollback



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0938, Tuesday, August 29, 2006



Turn-Around Decision Point
1330EDT 29 August

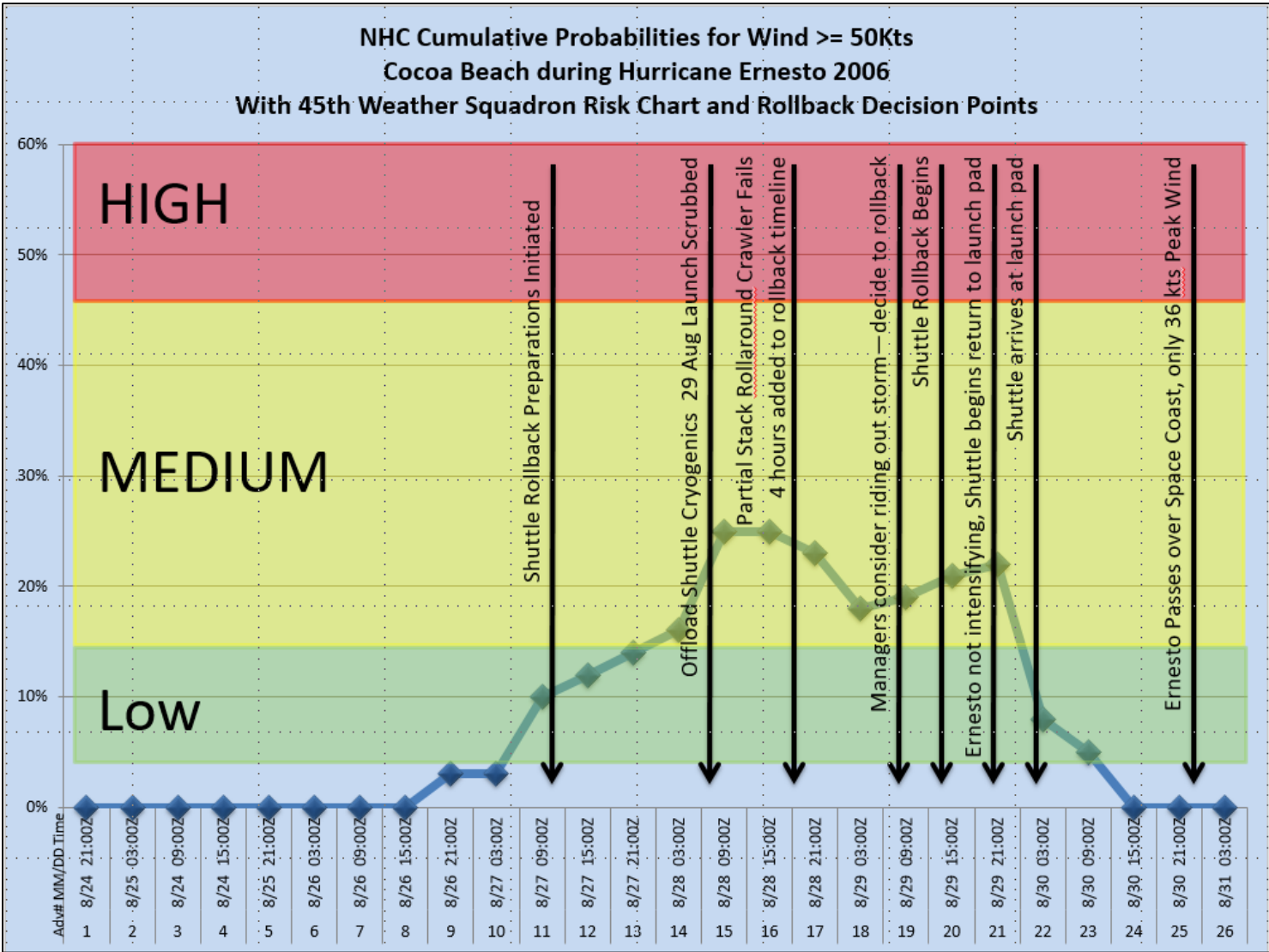




2006 Ernesto Timeline



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STS-115 Atlantis Timeline



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Rollout in preparation for 27 Aug Launch Date



Launch Preps



Strong Lightning Strike to Launch Pad. 27 Aug launch date postponed

Rollback Preps for Ernesto – 29 Aug Launch Date Scrubbed



1st Launch Attempt Scrubbed due to Fuel Cut-Off Sensor

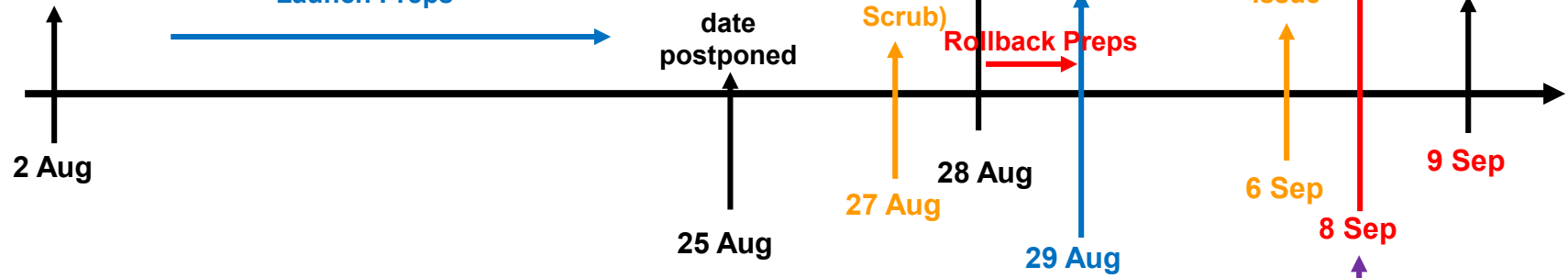
Original Launch Date (Lightning Strike Scrub)

2nd Planned Launch Date (Ernesto Scrub)

3rd Planned Launch Date delayed due to Fuel Cell Issue



LAUNCH!



ISS Launch Window Supposed to End

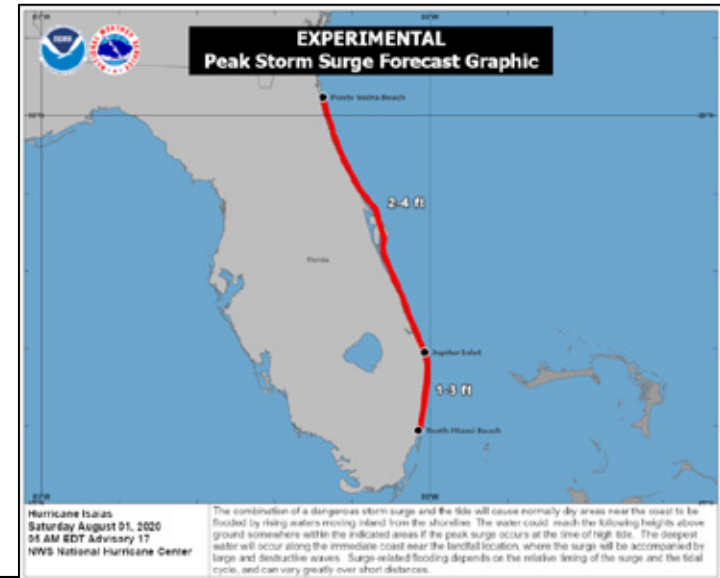
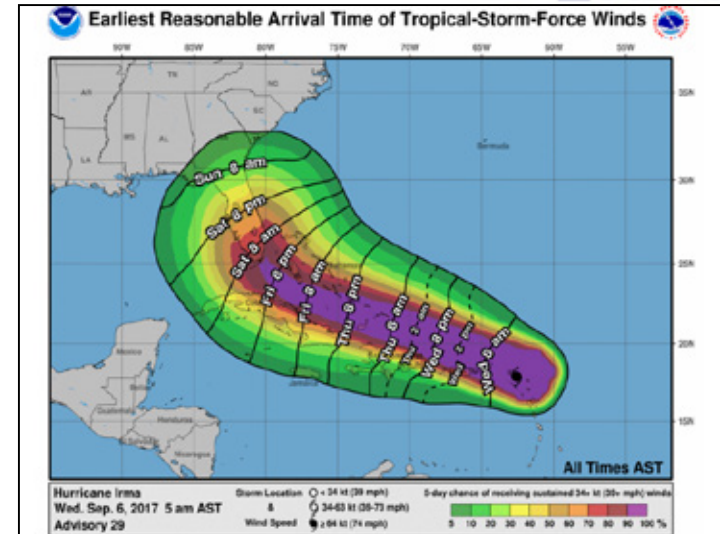


Summary of Case #2 Ernesto



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- ◆ Most Utilized NHC Products
 - 5-Day track/intensity forecast with 66.6% error cone
 - Forecast Discussions – around the clock
 - Probability Products - CRITICAL Decision Making Tool!
- ◆ Current Products that would have been useful then:
 - Time of arrival of tropical storm force winds
 - Current storm surge/inundation products
- ◆ Success Points: Launch Director noted trust and confidence in team due to experience together.





Case Study #3 – Stennis

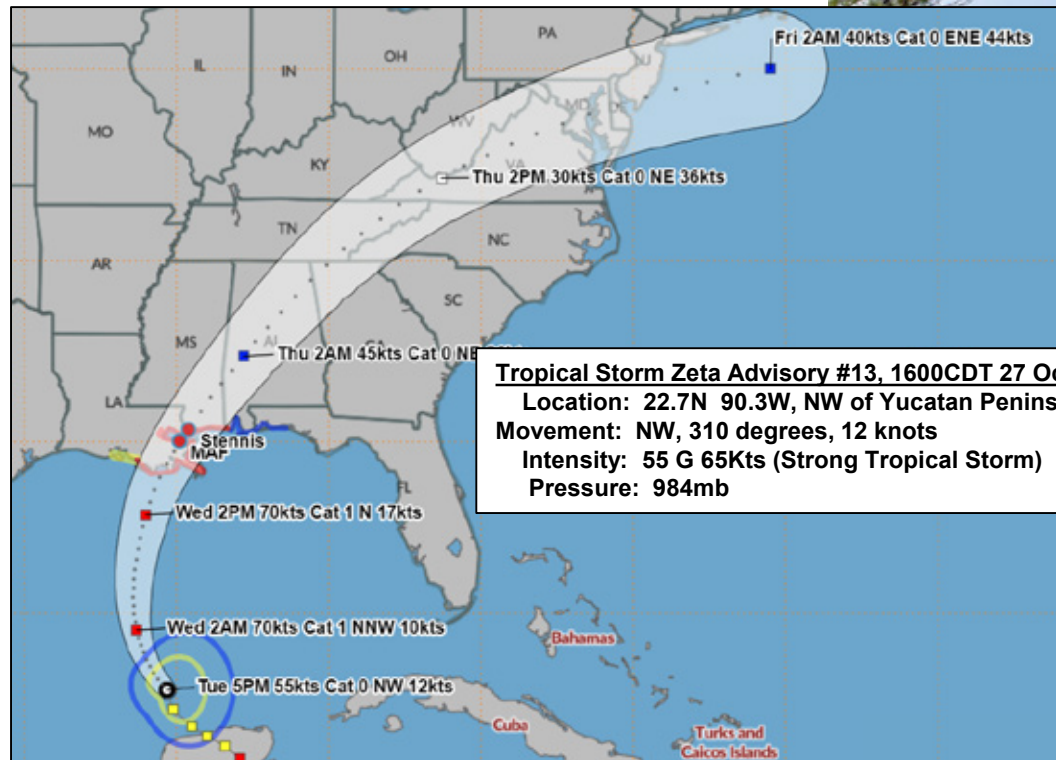


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2020 Zeta



**Space Launch System
Core Stage testing,
a.k.a. “Green Run”**

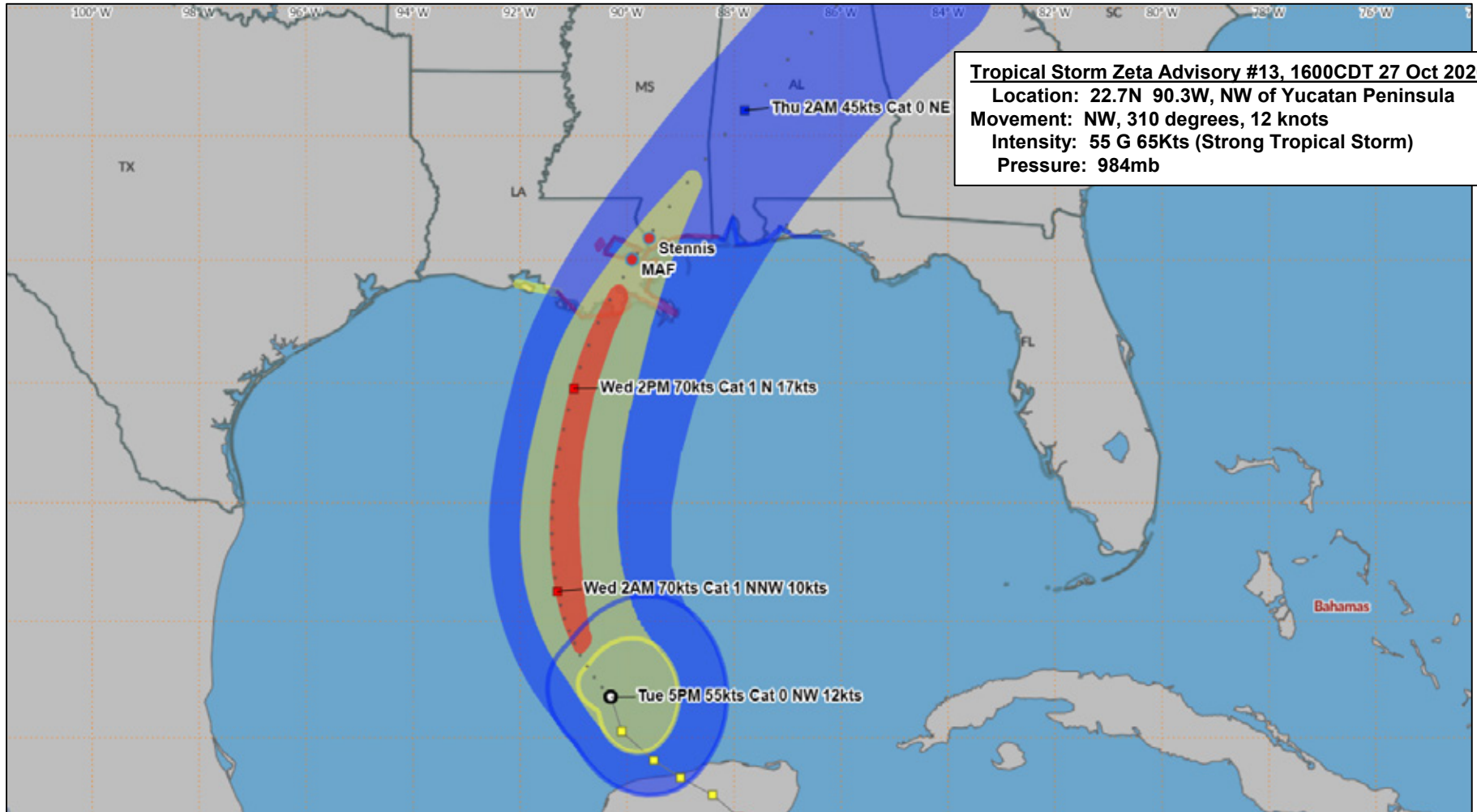




Products Used – 2020 Zeta



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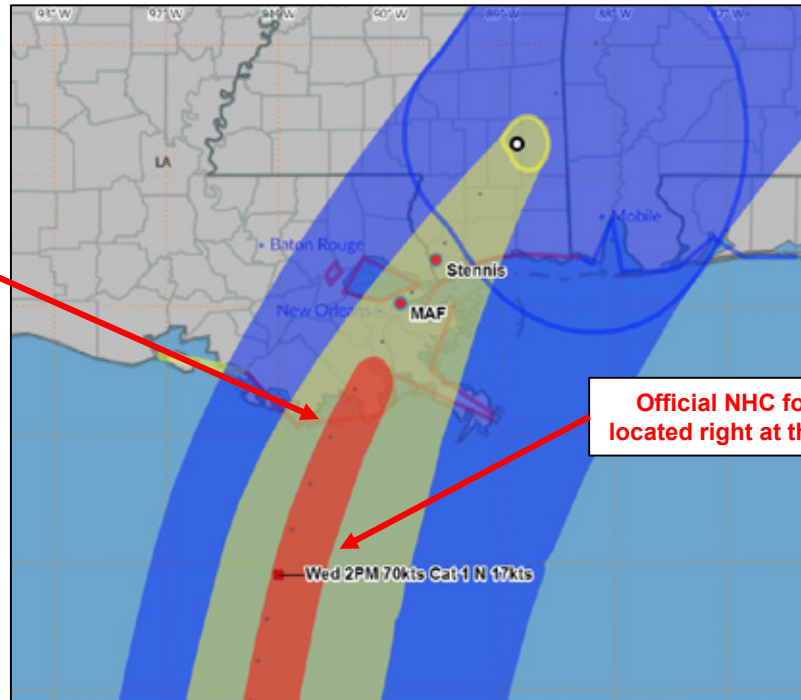


Products Used – 2020 Zeta



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NHC Forecast Wednesday 8pm CDT – Hurricane Force Winds close-by



Hurricane Force Wind Radii in RED

Based on PERFECT NHC forecast – subject to change!

Wind Radii forecast

Official NHC forecast point located right at the coastal area

Note: Slight changes in the wind radii can be due to the interpolation of wind between points on the software—in general, this is showing that category 1 winds are possible

Note: Software uses Eastern Time for storm plot labels



Products Used – 2020 Zeta

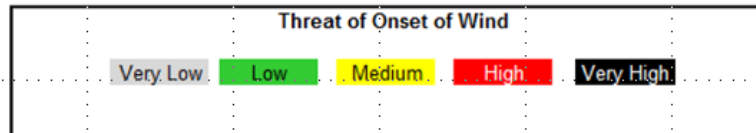


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Wind Speed Probabilities

FCST HR	Timing/Threat of <u>Onset</u> of Winds										Previous (27/1000CDT)	
	0	12	24	36	48	60	72	84	96	108		120
	HURCON I	HURCON II	HURCON III		HURCON IV		OUTLOOK			OVERALL	OVERALL	
KSC												
34Kt	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
50Kt	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
64Kt	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
STENNIS												
34Kt	0%	10%	61%	0%	0%	0%	0%	0%	0%	0%	71%	63%
50Kt	0%	1%	36%	0%	0%	0%	0%	0%	0%	0%	37%	27%
64Kt	0%	0%	5%	0%	0%	0%	0%	0%	0%	0%	5%	6%
MICHOUD												
34Kt	0%	19%	43%	0%	0%	0%	0%	0%	0%	0%	62%	55%
50Kt	0%	3%	29%	0%	0%	0%	0%	0%	0%	0%	32%	26%
64Kt	0%	0%	5%	0%	0%	0%	0%	0%	0%	0%	5%	6%
	HURCON I	HURCON II	HURCON III		HURCON IV		OUTLOOK			OUTLOOK	OVERALL	OVERALL
TIME (EDT)	27/1400L	28/0200L	28/1400L	29/0200L	29/1400L	30/0200L	30/1400L	31/0200L	31/1400L	1/0200L		
TIME (CDT)	27/1300L	28/0100L	28/1300L	29/0100L	29/1300L	30/0100L	30/1300L	31/0100L	31/1300L	1/0100L		
	Tue	Wed	Wed	Thu	Thu	Fri	Fri	Sat	Sat	Sun		

Current Time



General Note: Low probabilities in the long range can still be significant. Use the color-coded threat scale.

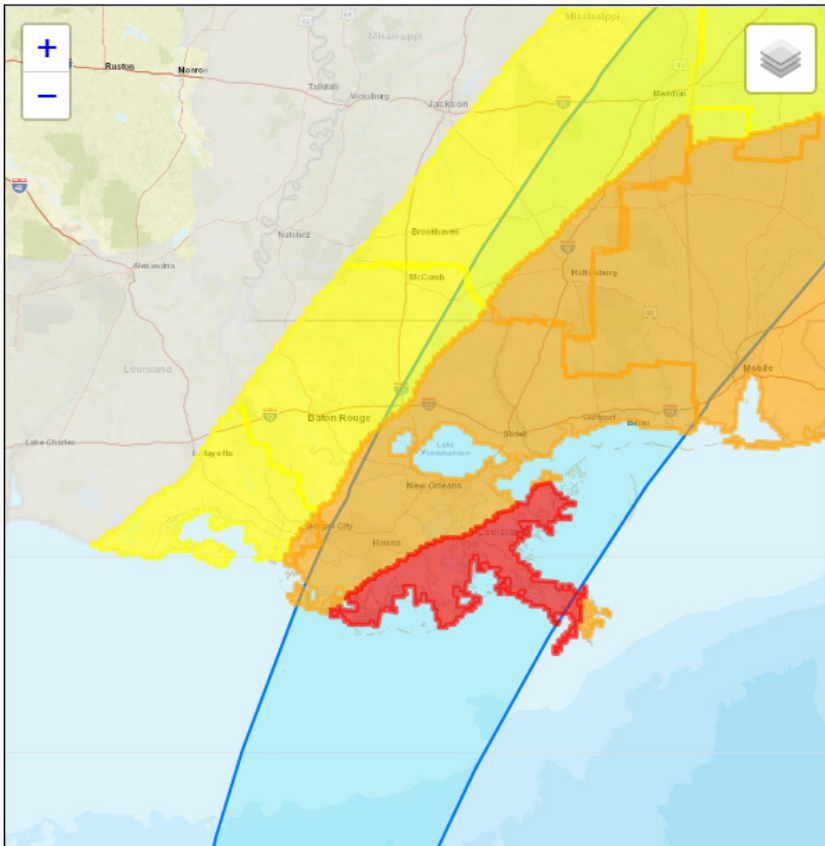


Products Used – 2020 Zeta



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Impact -- Wind



Sustained Wind

Wind Threat	Wind Threat (Kts)
Potential for wind greater than 110 mph	> 96Kts
Potential for wind 74 to 110 mph	64-96Kts
Potential for wind 58 to 73 mph	50-63Kts
Potential for wind 39 to 57 mph	34-49Kts
Wind less than 39 mph	33Kts

Highly dependent on storm size/track/intensity

<https://www.weather.gov/srh/tropical?office=lix#hti>

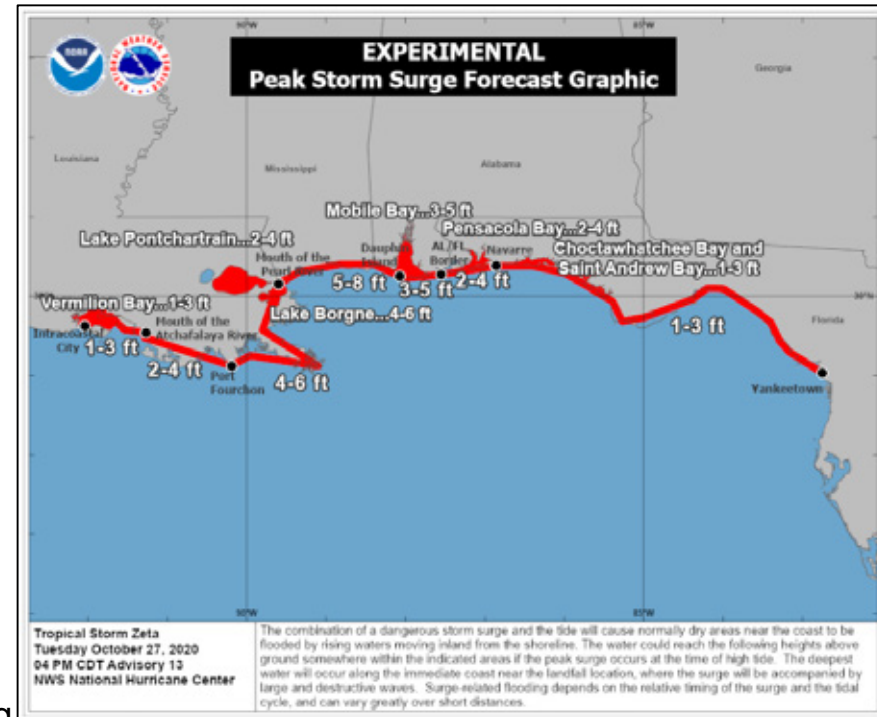
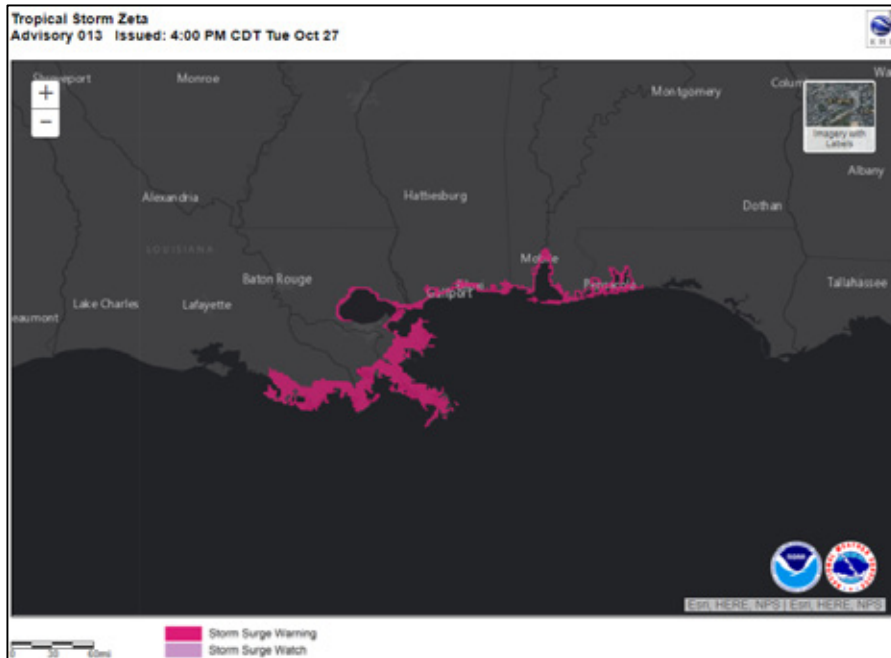


Products Used – 2020 Zeta



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Storm Surge



A Storm Surge **Warning** is in effect for the Mouth of the Atchafalaya River to Navarre Florida Navarre Florida including Lake Borgne, Lake Pontchartrain, Vermilion Bay, Pensacola Bay, and Mobile Bay.

(The storm surge area from Intracoastal City Louisiana to the mouth of the Atchafalaya River has been discontinued.)



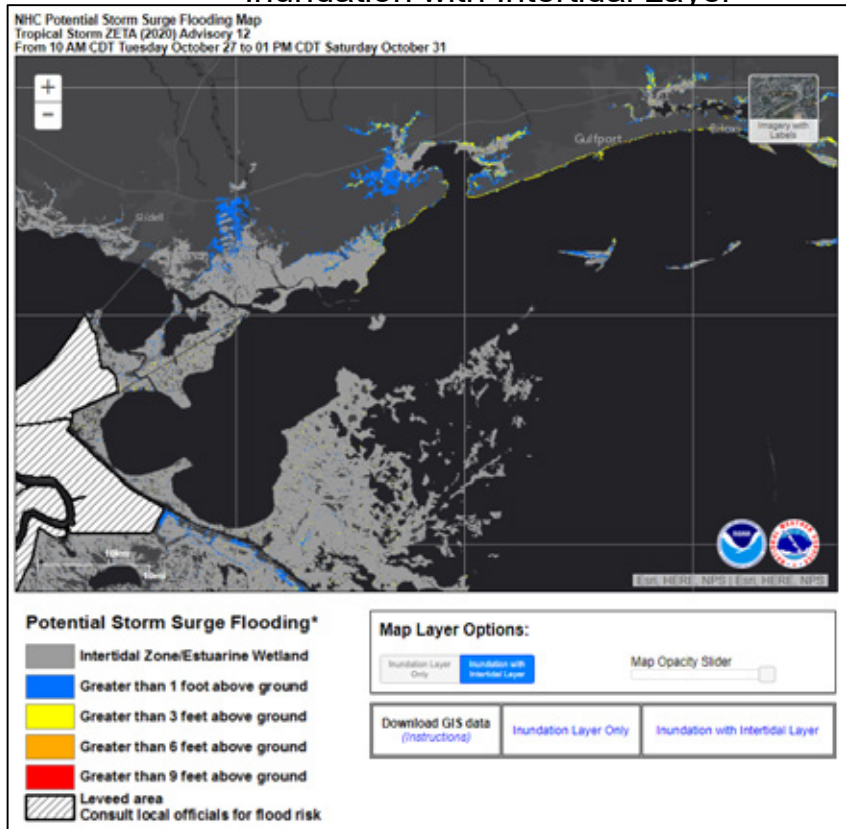
Products Used – 2020 Zeta



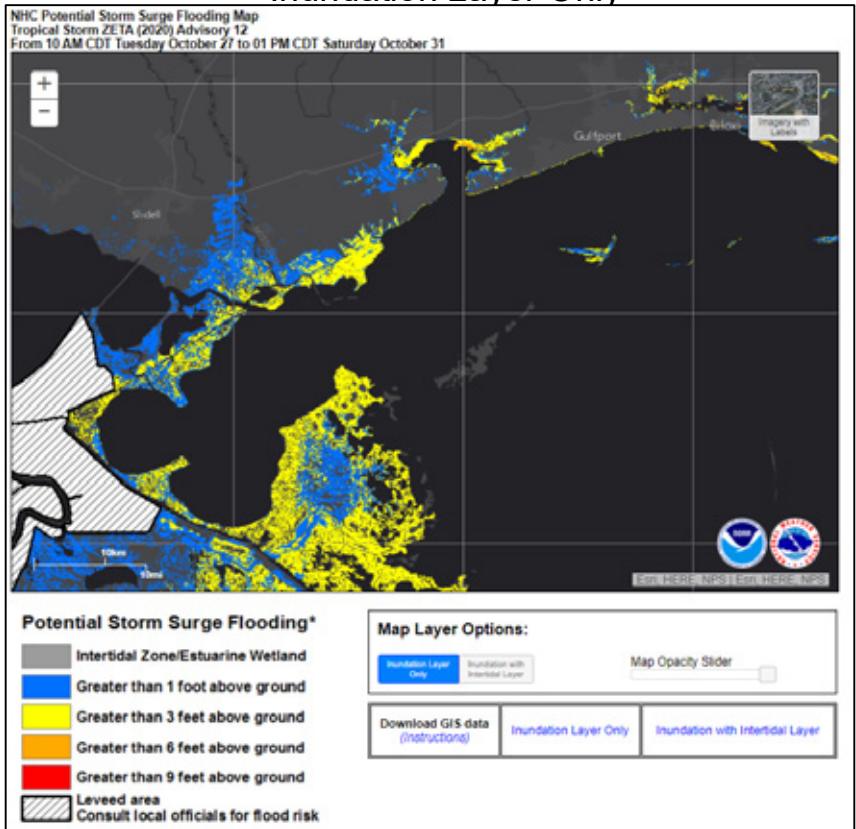
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Impacts -- Inundation

Inundation with Intertidal Layer



Inundation Layer Only





Summary of Case #3 Stennis



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- ◆ Most Utilized NHC Products
 - 5-Day track/intensity forecast with 66.6% error cone
 - Wind speed probability product
 - Time of arrival of tropical storm force winds – earliest and most likely
 - Current storm surge/inundation products
 - Flood / Rainfall Products – WPC and local
 - SPC Tornado Threat
 - Wind radii forecast when within 48 hours of arrival
- ◆ Needs:
 - Clarity between NHC and local warnings (county vs coastal)
 - Display issues
 - Web Based HURREVAC only in Eastern Time (Great customer support)
 - Storm intensity interpolation
- ◆ Success Points: Stennis team very familiar with NHC products.



Summary



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- ◆ KSC Overview – Impacts related to Tropical Cyclones
 - Multiuser spaceport launching on average once per week
 - Preparing for Artemis I mission
- ◆ Current use of NHC product
 - “Newer” products related to storm genesis, timing, and storm surge very helpful
- ◆ Comparison to past -- Reviewed Cases
- ◆ Continued Challenges
 - Need for earlier storm surge products
 - Displaying data