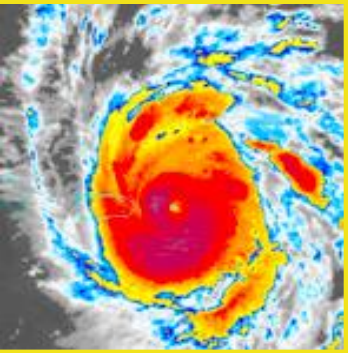
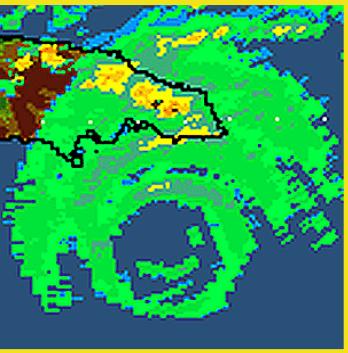
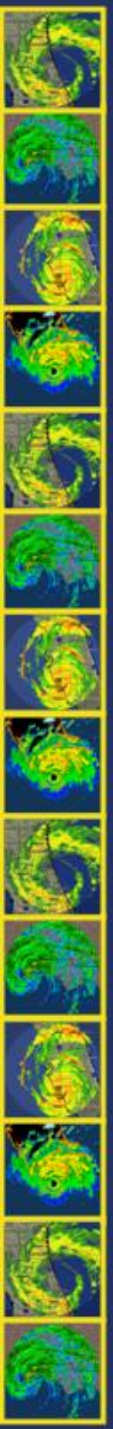




Tropical Cyclone Rainfall

Scott Cordero
Meteorologist In Charge
NWS WFO Jacksonville, FL



Outline

- Factors influencing TC rainfall
- TC rainfall forecasting tools
- TC rainfall forecasting products

Hurricane Flora (1963) Cuba

- Isolated locations in Cuba received over 80 inches (2,000 mm) of rain, with Santiago de Cuba recording 100.39 inches (2,550 mm).
- The highest rainfall total measured on Cuba from any rainfall event on record.
- Hurricane Flora is among the deadliest Atlantic hurricanes in recorded history, with a death total of over 7,000.
- Many citizens were left stranded at the tops of their houses.
- Several entire houses were swept away by the flooding, and many roads and bridges were destroyed, resulting in major disruptions to communications.

Characteristics of TC Precipitation

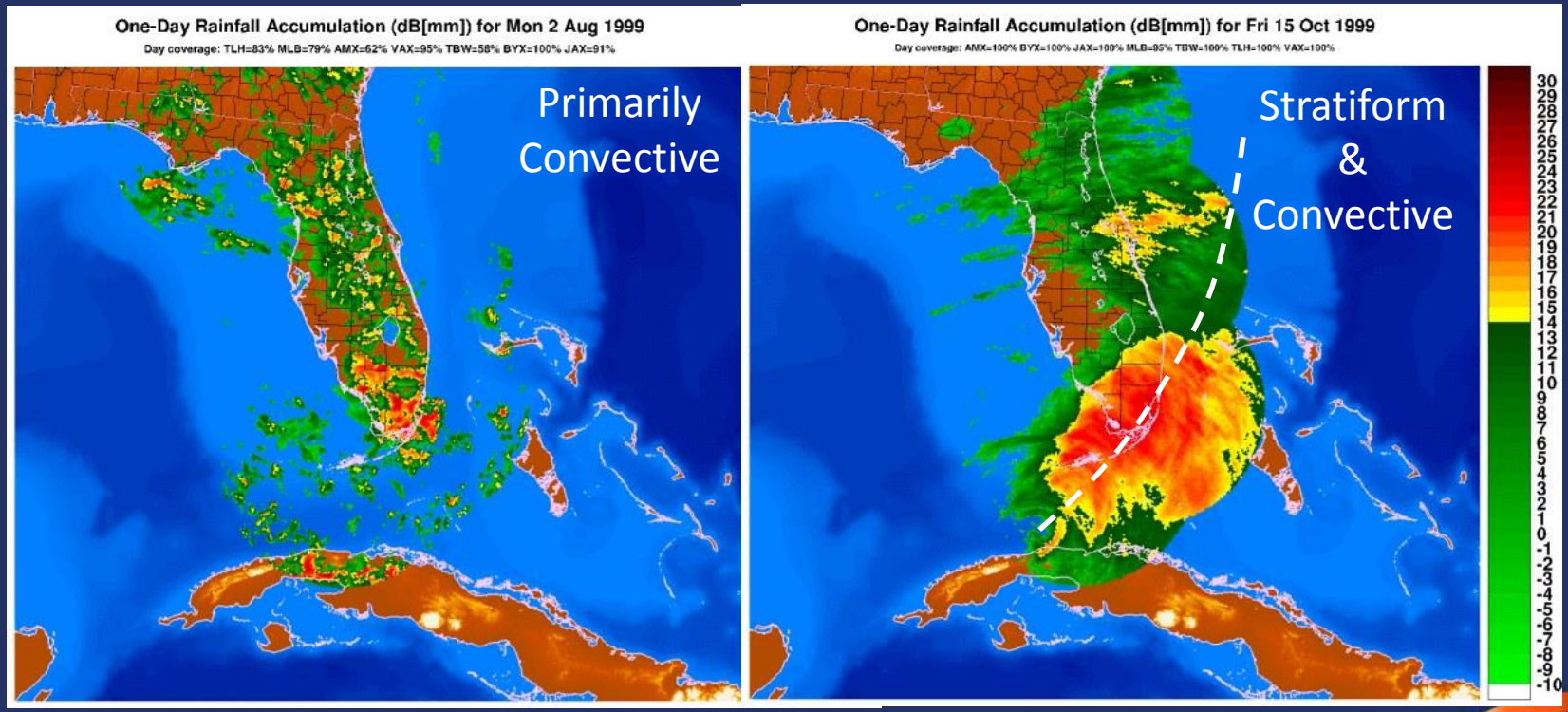
Stratiform and Convective Mechanisms

Stratiform Rain ~50% of Total Rain from TC

NOAA/HRD - Daily Radar Rainfall Estimate Study

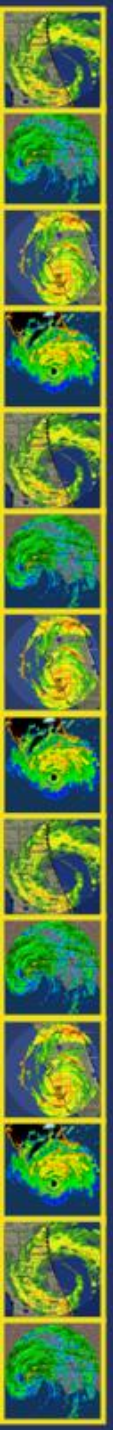
Typical warm season 1-day total

Hurricane Irene 1-day total



Hurricane Irene (15 October 1999)

Frank Marks (HRD)



Factors Influencing Tropical Cyclone Rainfall

What Factors Influence Rainfall from Tropical Cyclones?

- Movement – slow forward motion can produce more rain
- Storm size – the larger the storm, the greater the area typically receiving rain
- Storm track – factor in the location of the rain
- Diurnal cycle – heaviest rainfall generally near the storm center overnight, outer band rainfall during the day
- Topography – enhances rainfall in upslope areas, but decreases rainfall past the spine of the mountains
- Moisture – Entrainment of dry air can redistribute and/or reduce the amount of precipitation; increased moisture can increase rainfall
- Interaction with other meteorological features (troughs, fronts, jets) and extratropical transition can greatly modify rainfall distribution

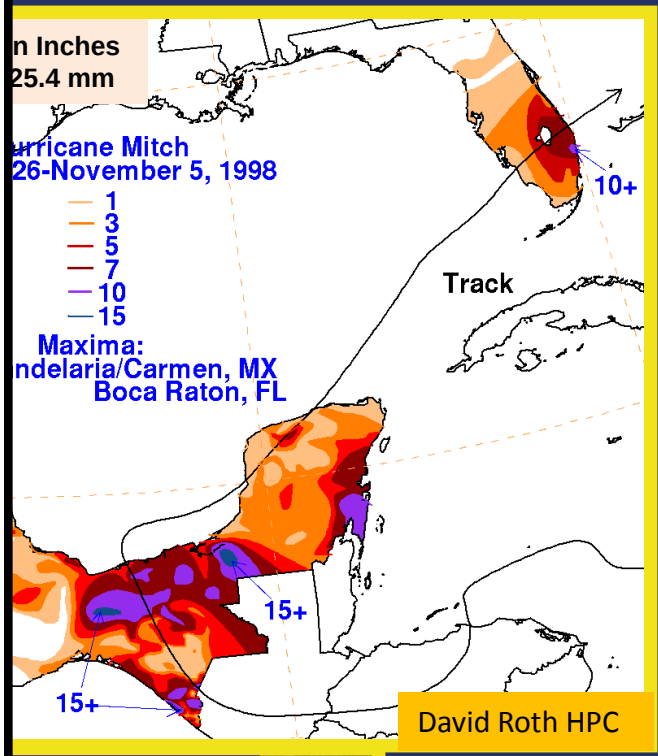
NATIONAL HURRICANE CENTER MIAMI FL

C Rainfall

Deadliest Atlantic hurricanes

Rank	Hurricane	Season	Fatalities
1	"Great Hurricane"	1780	22,000+
2	**Mitch**	1998	19,325+
3	"Galveston"	1900	8,000 – 12,000
4	Fifi	1974	8,000 – 10,000
5	"Dominican Republic"	1930	2,000 – 8,000
6	Flora	1963	7,186 – 8,000
7	"Pointe-à-Pitre"	1776	6,000+
8	"Newfoundland"	1775	4,000 – 4,163
9	"Okeechobee"	1928	4,075+
10	"Monterrey"	1909	4,000

See also: List of deadliest Atlantic hurricanes



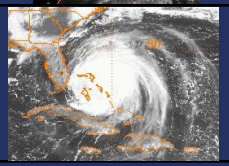
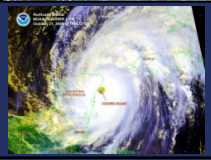
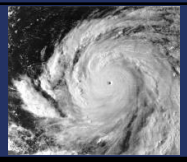
David Roth HPC

r flooding

Factors Influencing TC Rainfall

Storm Size

Determined by distance from center to outermost closed isobar

<2 degrees	“Very small/ midget”	Charley 
2-3 degrees	“Small”	Allison 
3-6 degrees	“Average”	Frances 
6-8 degrees	“Large”	Wilma 
>8 degrees	“Very large”	Gilbert 

Joint Typhoon Warning Center

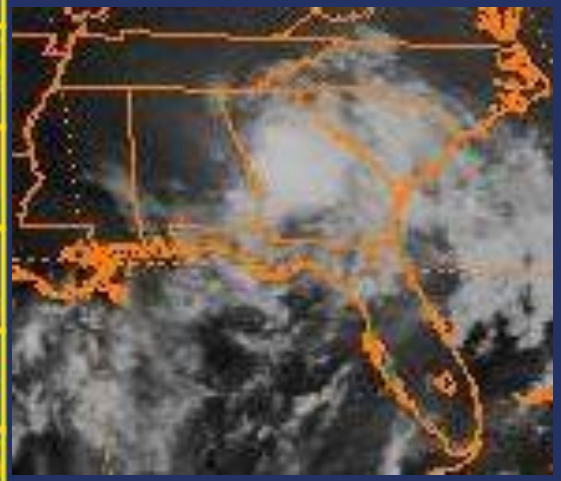
Factors Influencing TC Rainfall

Time of Day

Alberto, July 4-5, 1994

04/18z

00z



05/06z

12z

18z

NATIONAL HURRICANE CENTER
Miami, FL

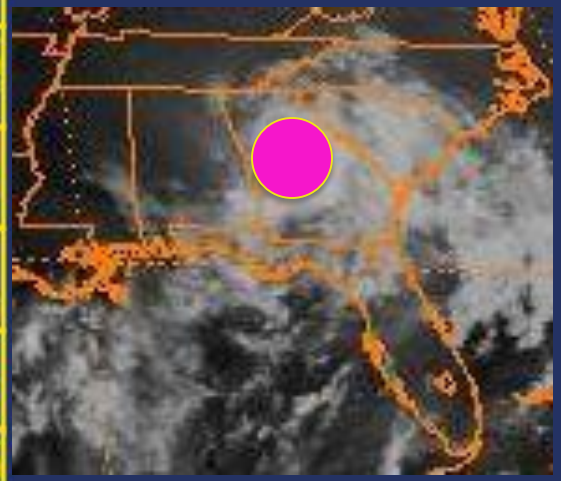
Factors Influencing TC Rainfall

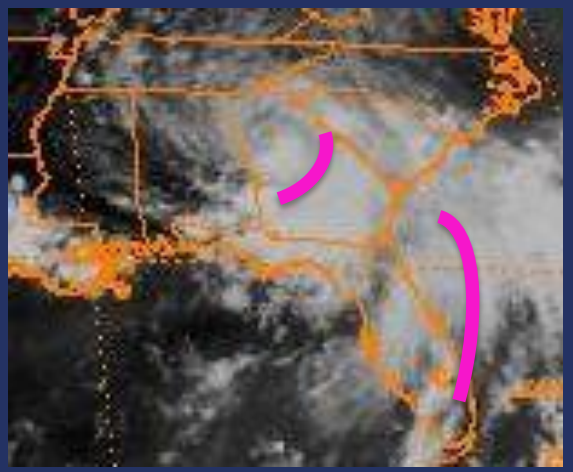
Time of Day

Alberto, July 4-5, 1994

04/18z

00z





05/06z

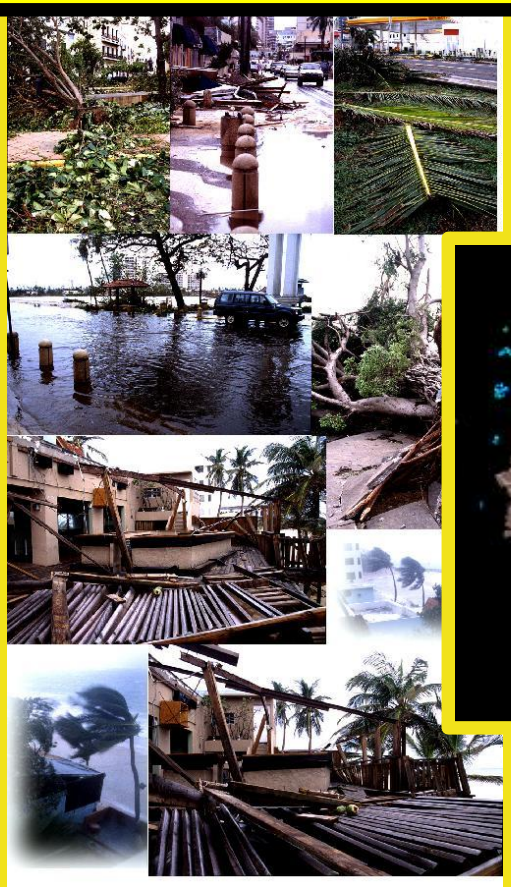
12z

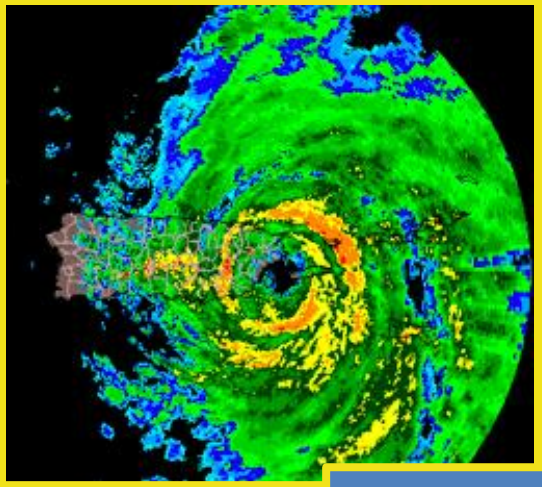
18z

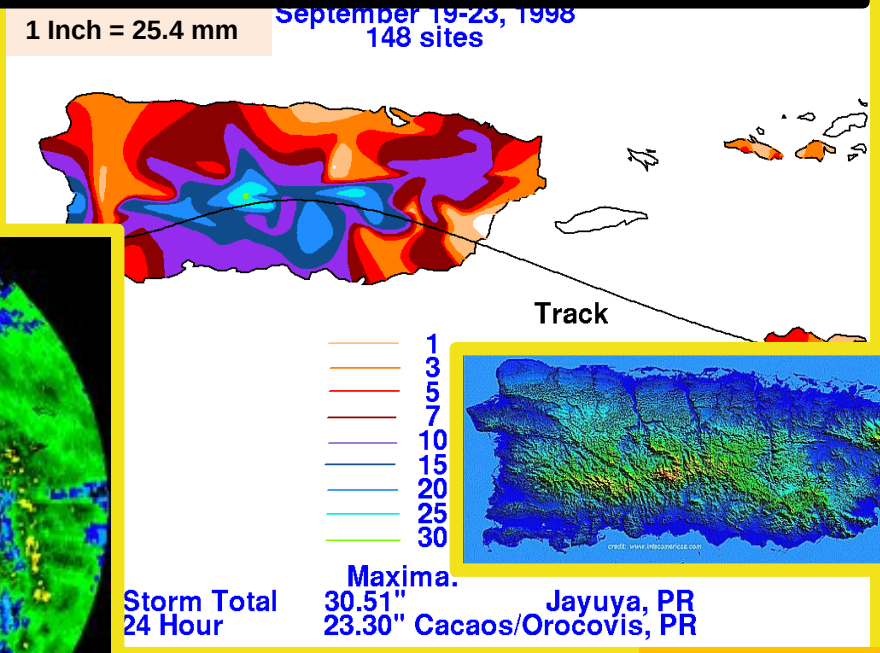
NATIONAL HURRICANE CENTER
Miami, FL

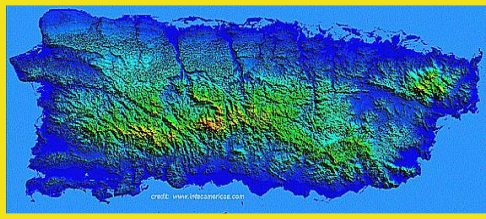
Mountainous Regions

The presence of mountains/hills across much of Mexico, Puerto Rico, Haiti, the Dominican Republic, Central America, Madagascar, China, and Japan acts to magnify rainfall potential due to forced upslope flow into the mountains.









David Roth HPC

Hurricane Georges in Puerto Rico
$1.75 billion in damage
28,005 homes destroyed

Factors Influencing TC Rainfall

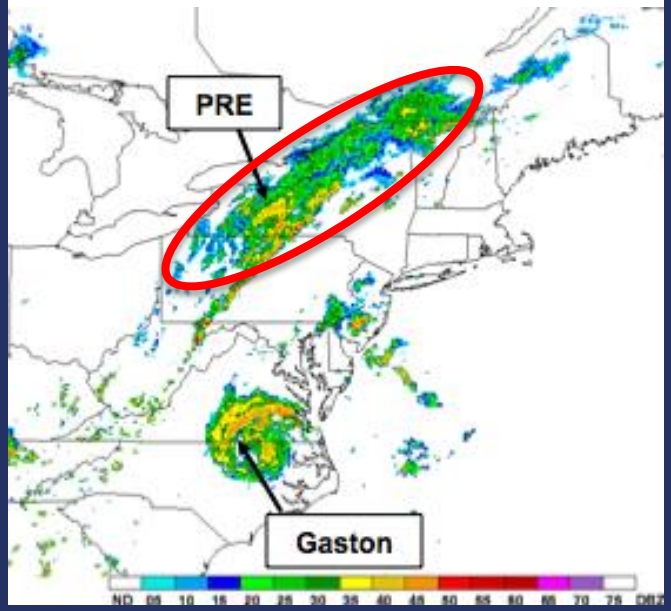
Environmental Steering in Northern Hemisphere

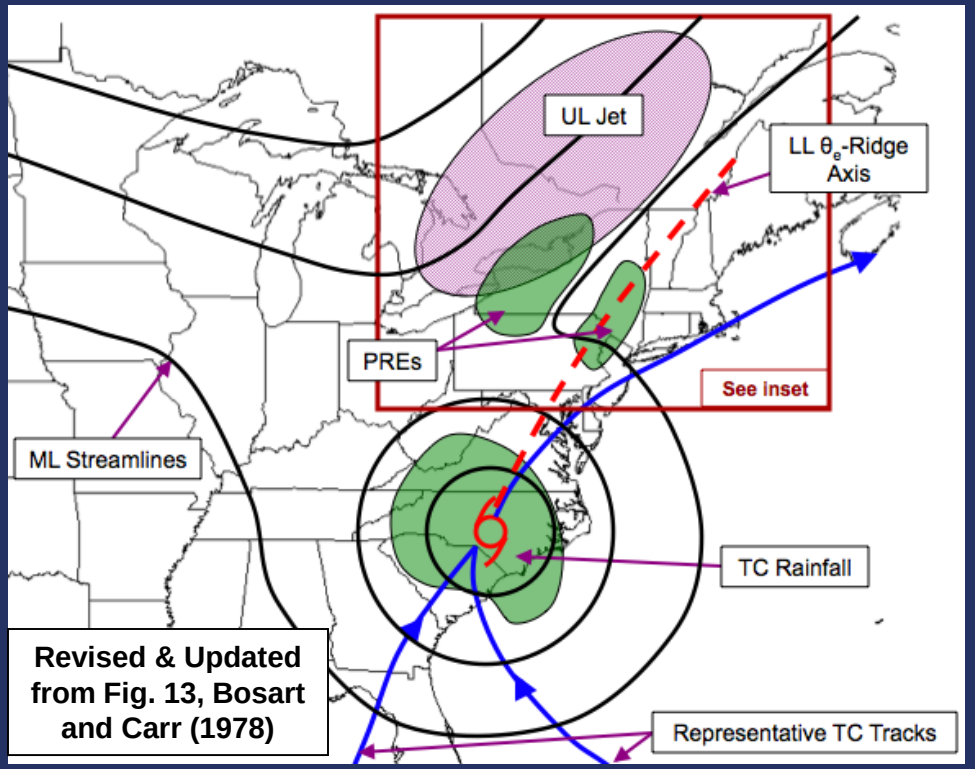
- TCs that move into a break in the subtropical ridge often produce most of the rain *right* of their track
- TCs that recurve due to significant upper troughs in the westerlies often produce most of their rain *left* of their track
  - Rainfall may spread well in advance of the TC due to interaction with the upper jet on the leading edge of the trough
- Very slow moving TCs and symmetrical TCs produce the most rainfall *near the center*
  - Usually cyclical with maximum rainfall at night

Factors Influencing TC Rainfall

Predecessor Rainfall Events

Predecessor Rainfall Event (PRE)
Image from Matt Cote and Lance Bosart – SUNY Albany



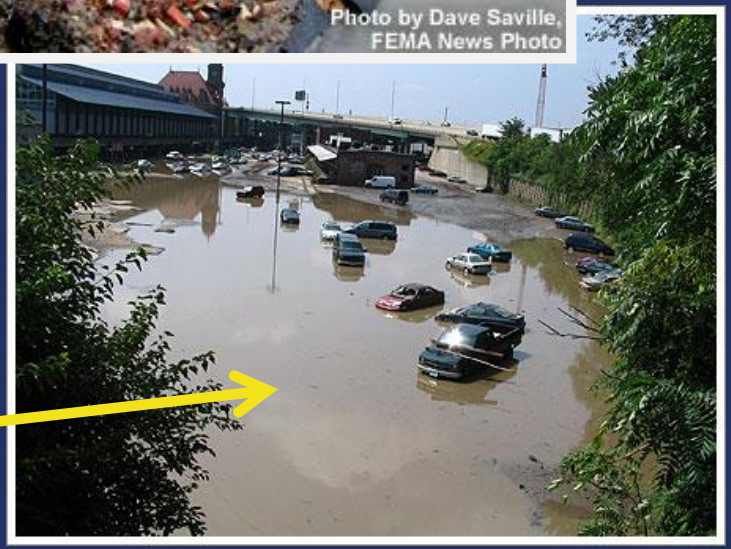


- Moisture transport well ahead of TC itself
- Coherent area of rain displaced north of the TC (near a front or over terrain)
- Maximum rainfall rates can exceed 200 mm in 24 hr
- Occurs for approximately 1 of 3 landfalling TCs in U.S.

Where is Flooding from Tropical Cyclones Likely to Occur?

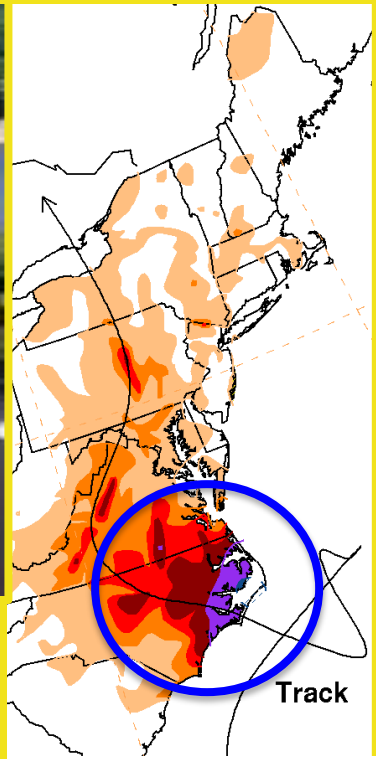
- Areas Where the Ground is Already Saturated (Low Flash Flood Values)
- Valleys/Watersheds
- Areas of Terrain Enhancement
- Areas with Poor Drainage or Prone to Runoff
- Areas with Directed Drainage that can be Overwhelmed

Floyd 1999 - Tar River, NC
NC: 35 deaths

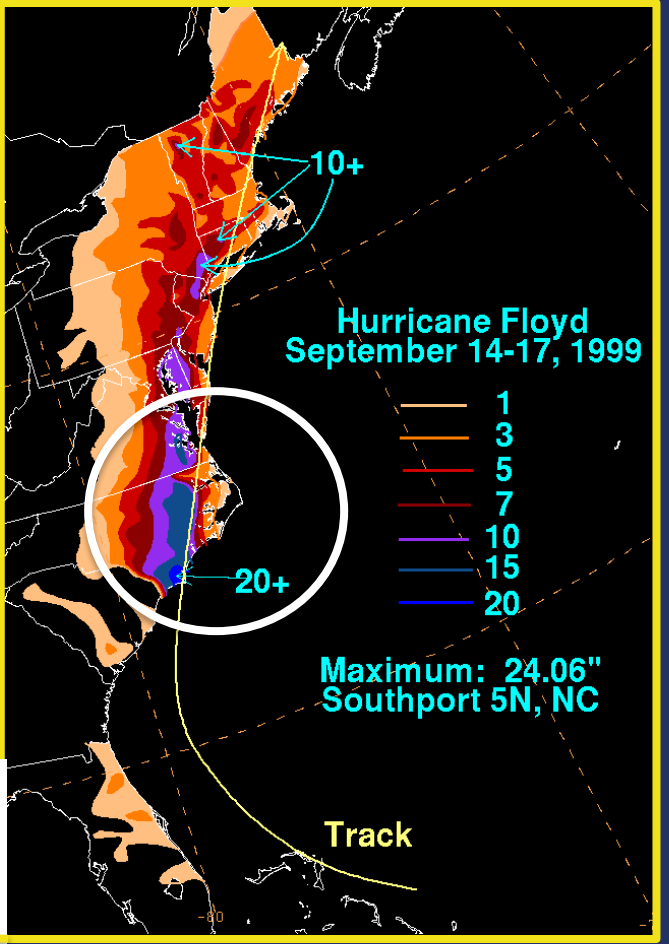


Gaston 2002 - Shockoe Bottom
City of Richmond: $7.9 mil

Warning Signs for Heavy Rainfall Associated with TCs



T.S. Dennis
Aug 28-Sep 8
Ocracoke 19.91”

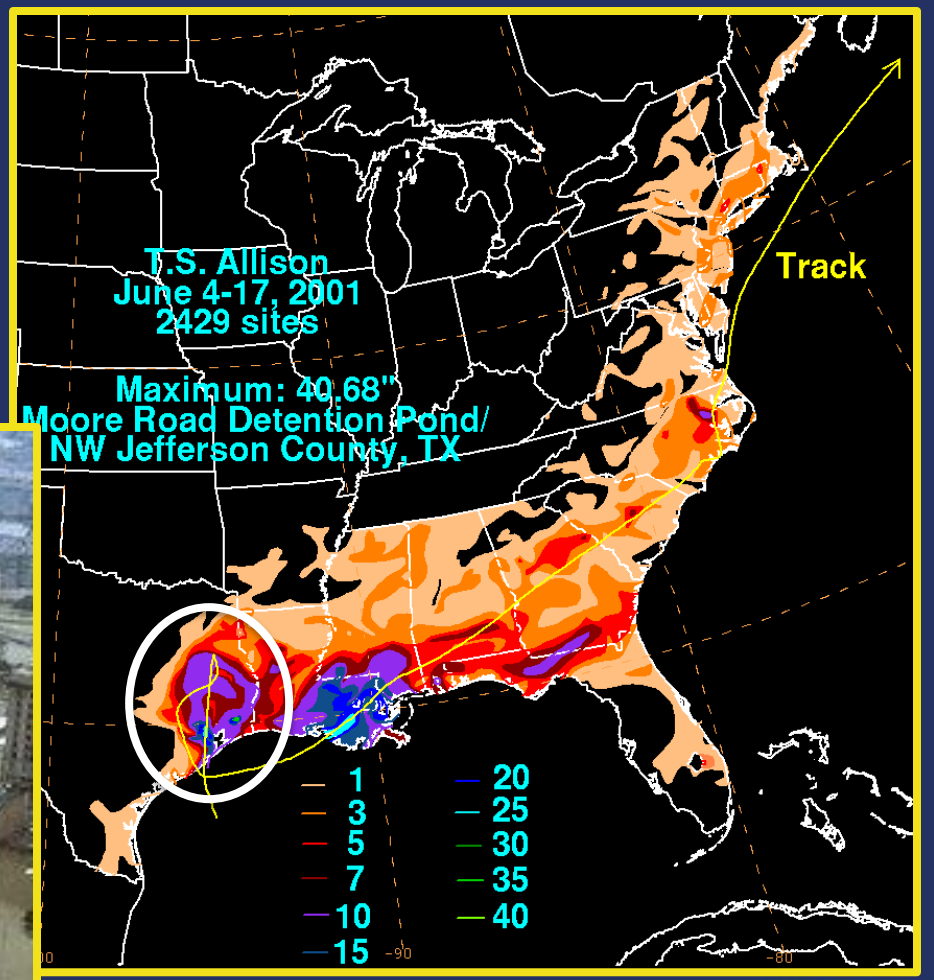


Saturated Soil

Warning Signs for Heavy Rainfall Associated with TCs

- Slow moving TCs
- TCs with a turning or looping track

T.S. Allison $4.8 billion in damage in Houston alone



Tropical Storm Allison - 2001

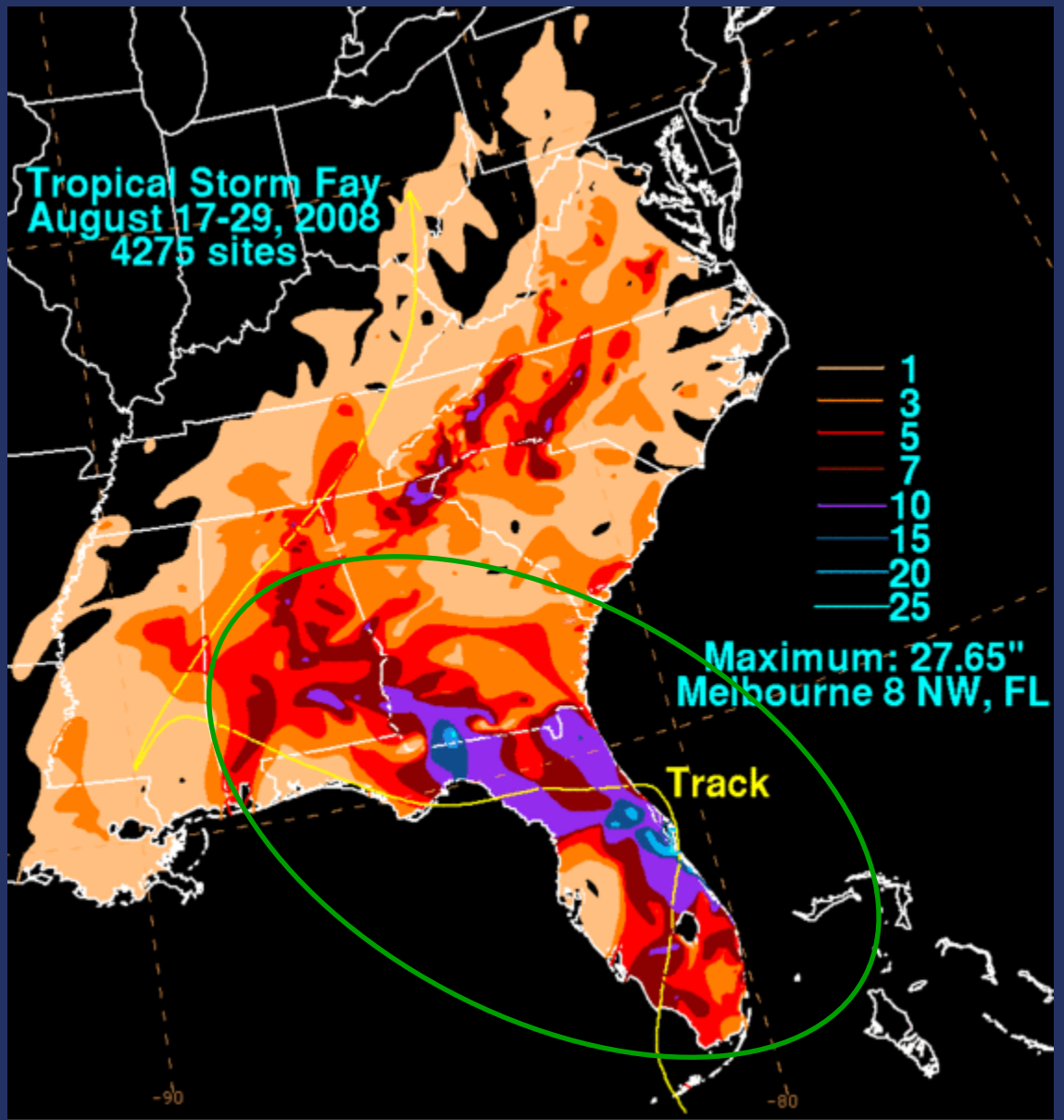
$5.5 Billion, 41 Fatalities

Tropical Storm Fay (2012)
Slow Forward Motion

Tropical Storm Fay

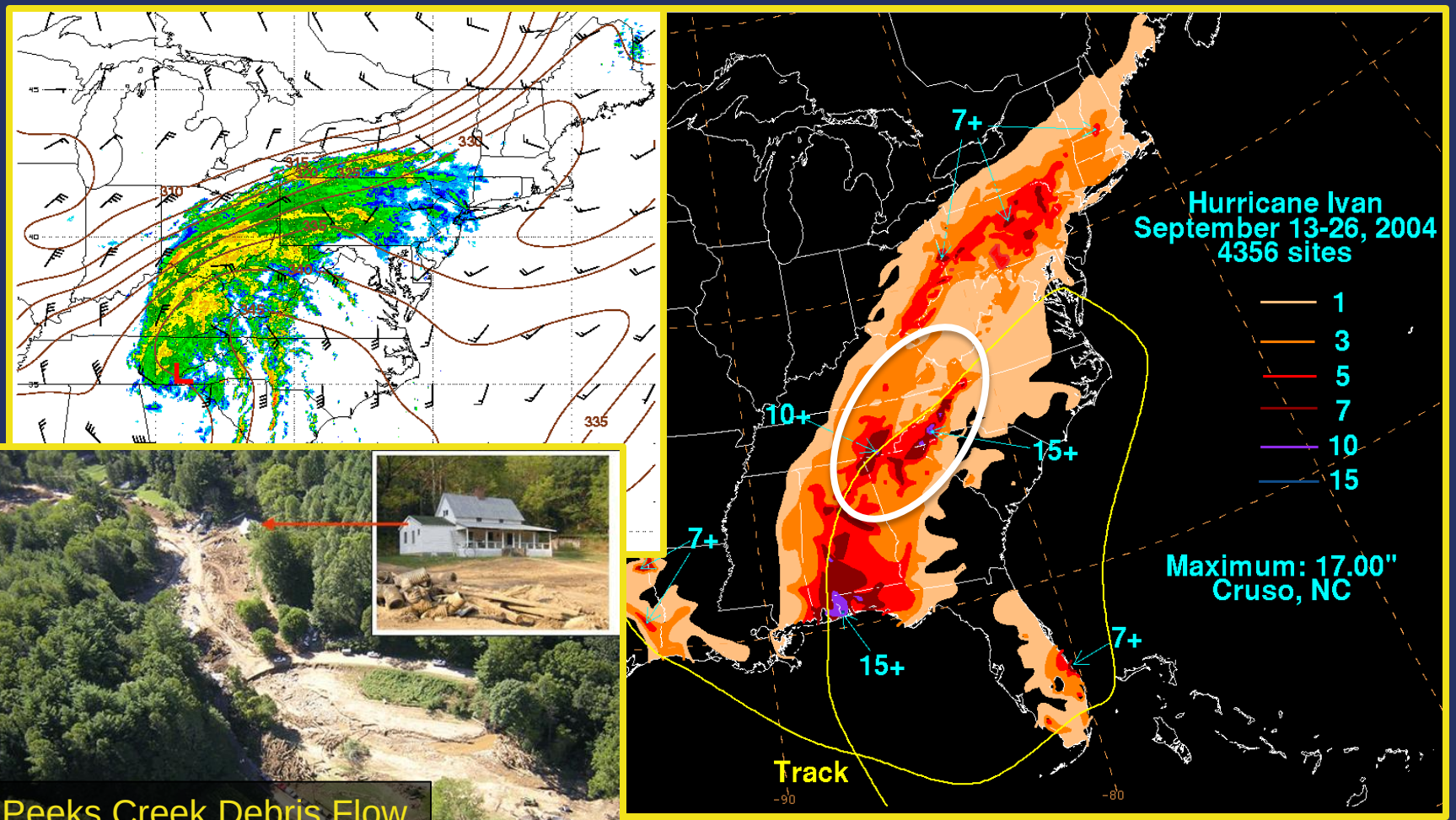
- **Made initial landfall in the Florida Keys.**
- **Came ashore again in the Naples area.**
- **Fay then crossed the state and exited near New Smyrna Beach.**
- **Fay came onshore again near St. Augustine and Jacksonville.**
- **Crossed the Panhandle and finally leaving the Pensacola area into Alabama, early on August 24.**
- **Fay continued to dump heavy rains around Pensacola, Tallahassee, and Panama City, Florida during August 25.**

Tropical Storm Fay (2012)
Slow Forward Motion



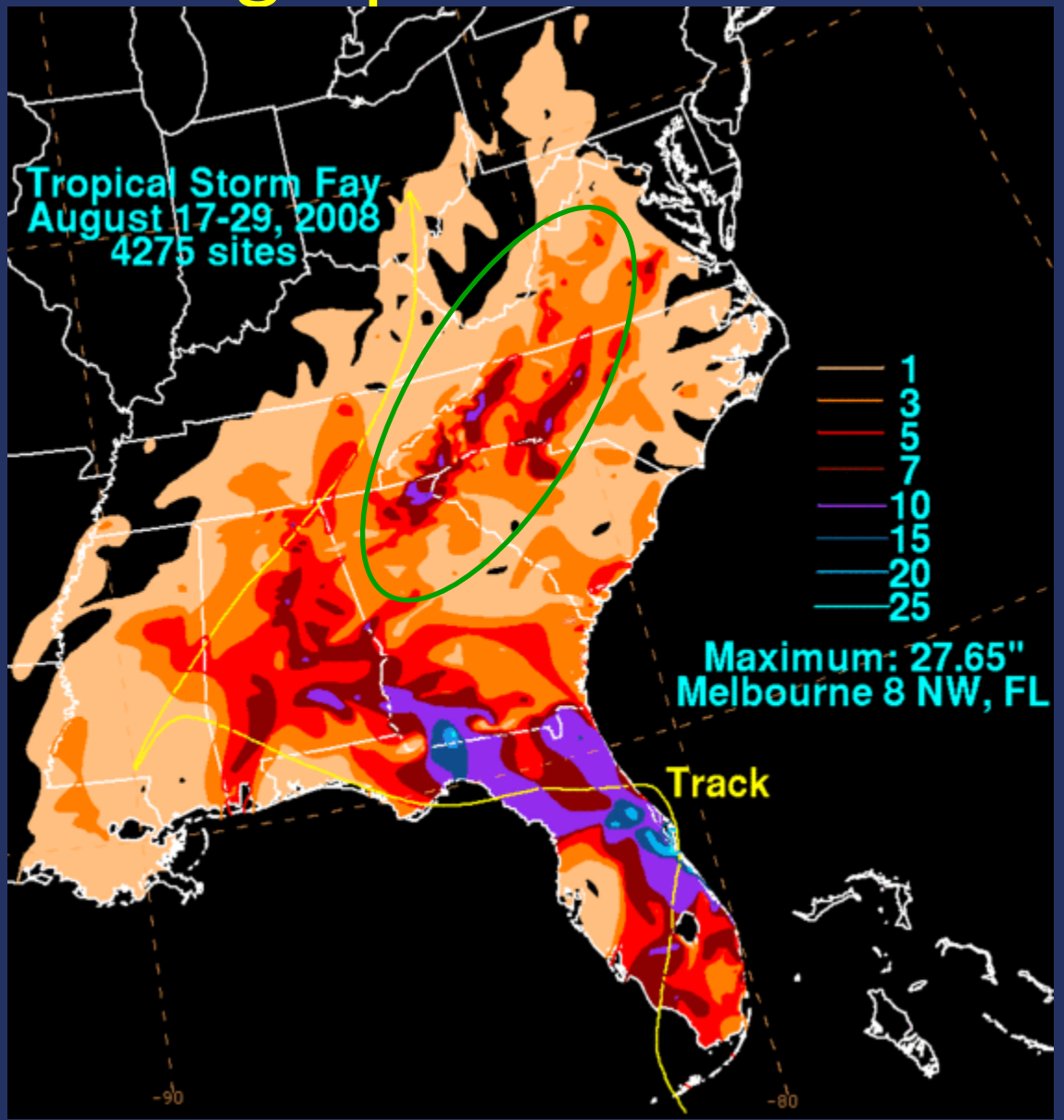
Tropical Storm Fay (2008)
Slow Forward Motion

Warning Signs for Heavy Rainfall Associated with TCs



Terrain Impacts

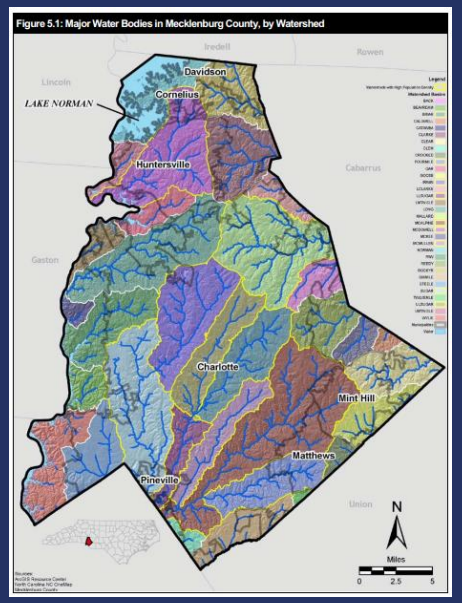
Tropical Storm Fay (2008)
Orographic Interaction



Tropical Storm Fay (2008) Orographic Interaction

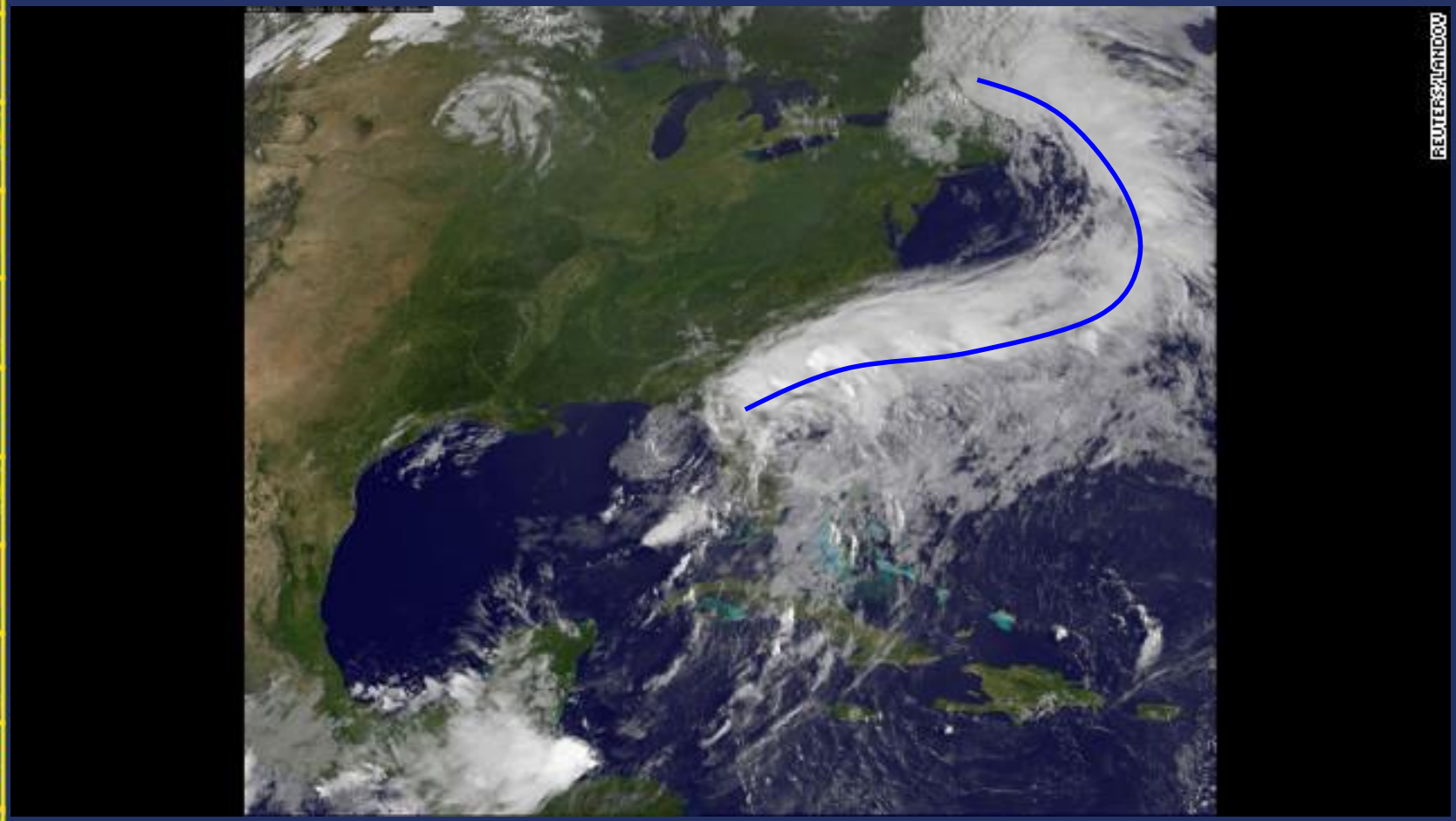
Cavalier Apartments during Fay flood

A tow truck driver wades through waist-deep water to assist motorists as Stewart Creek overtops Morehead Street. *(Photograph from The Charlotte Observer/Kent D. Johnson)*

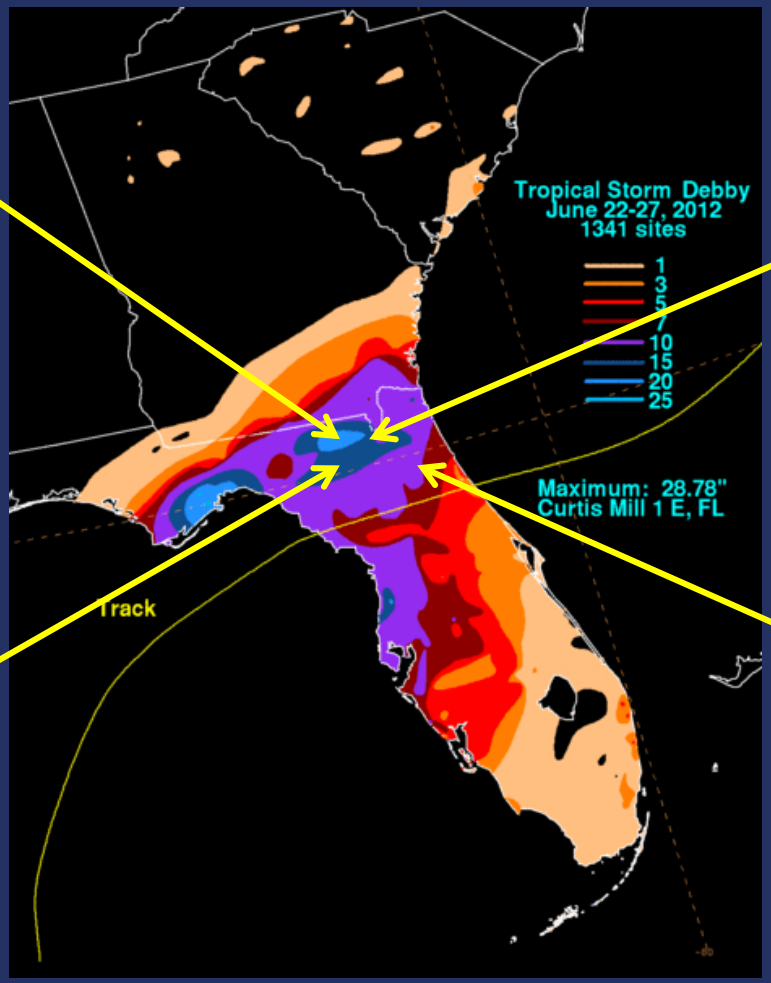


Tropical Storm Debby (2012)

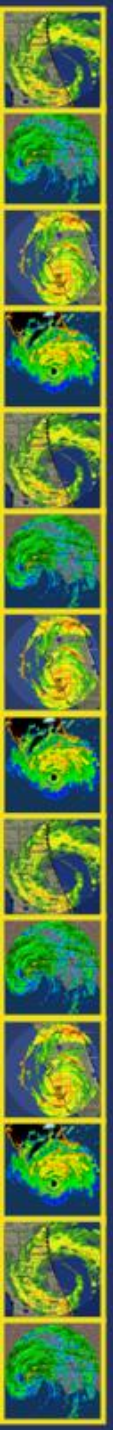
Interaction With A Pre-existing Boundary



Tropical Storm Debby (2012)
Interaction With A Pre-existing Boundary



Tropical Storm Debby



TC Rainfall Forecasting Tools

Kraft Rule

We've come a long way!

Developed in the 1950s by a Hurricane Forecaster R. H. Kraft

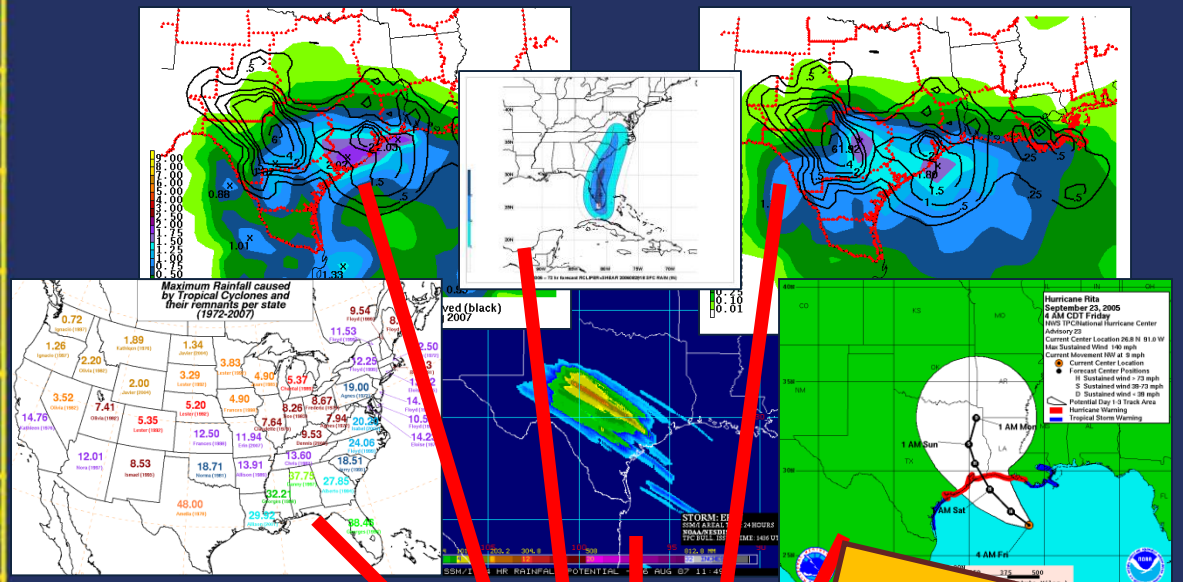
T.C. Rainfall = 100/Forward Motion in Knots

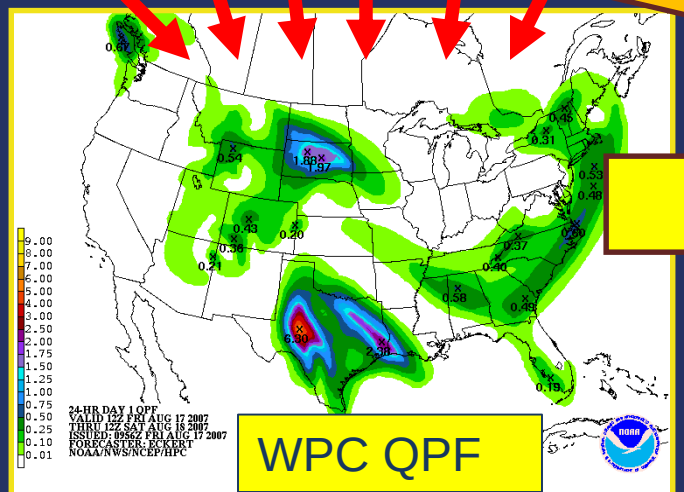
Storm Moving at 25 knots = 4 inches

Storm Moving at 10 knots = 10 inches

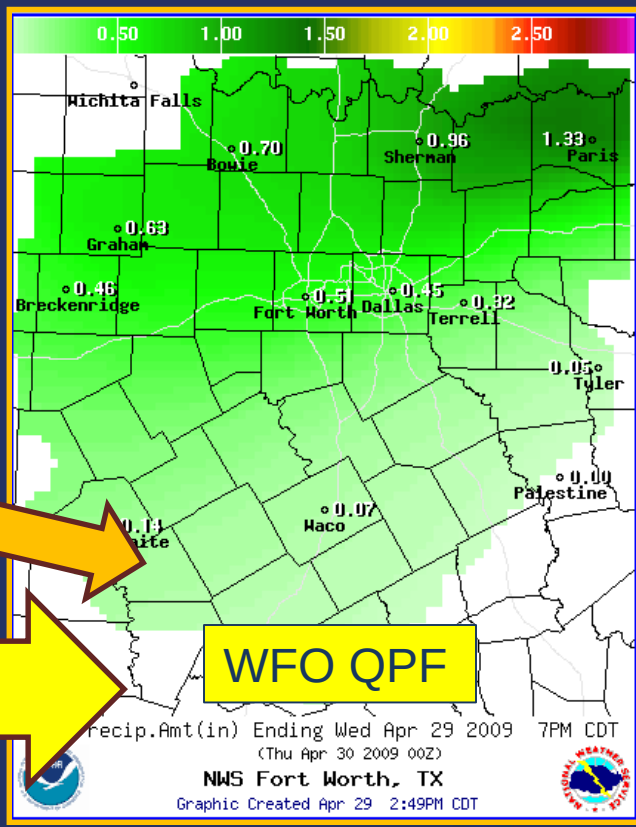
Storm Moving at 05 knots = 20 inches

NWS Tropical Cyclone Quantitative Precipitation Forecasts (QPF)





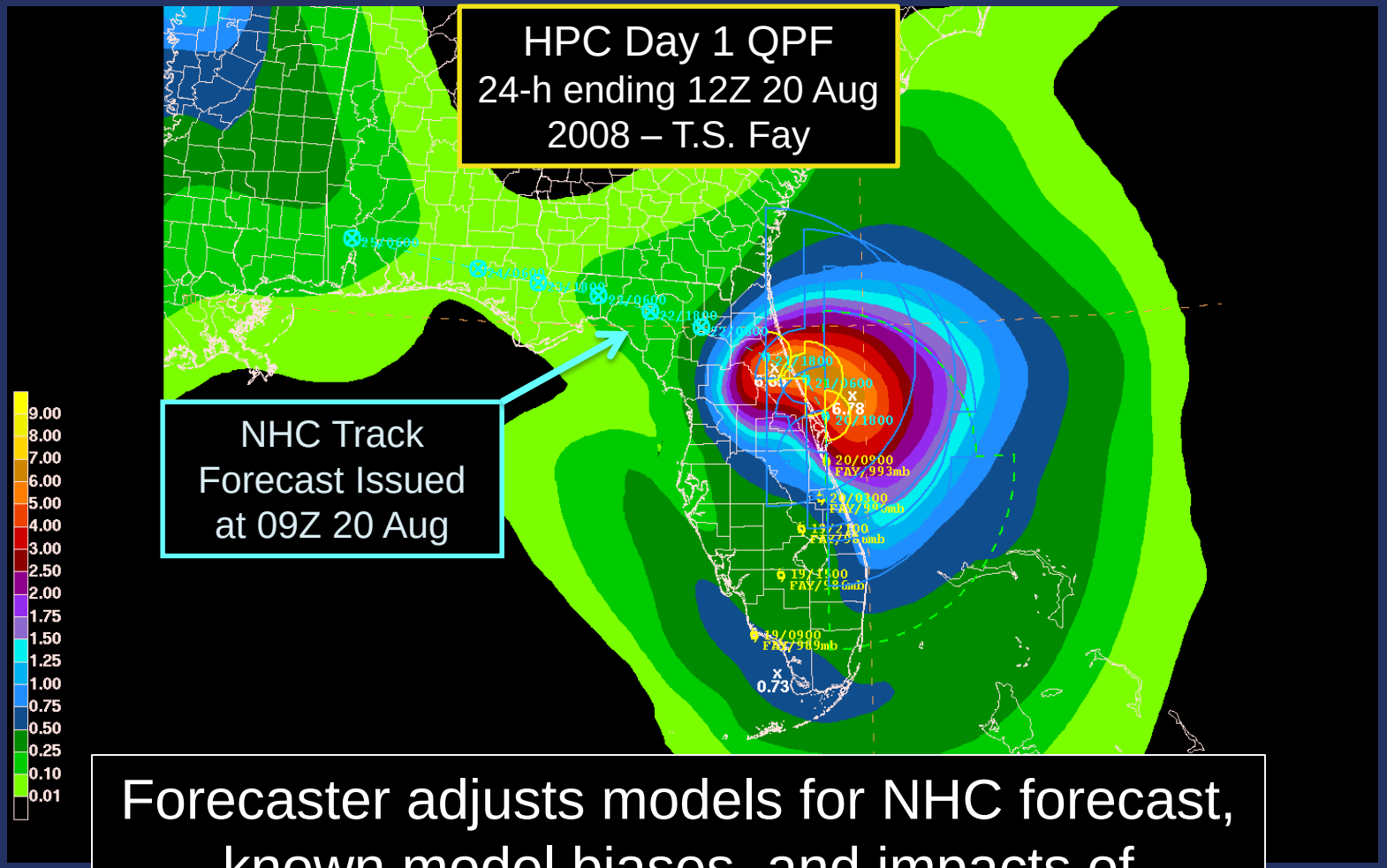
WPC QPF



WFO QPF

NATIONAL HURRICANE CENTER
Miami, FL

Forecaster Improvements over the Models

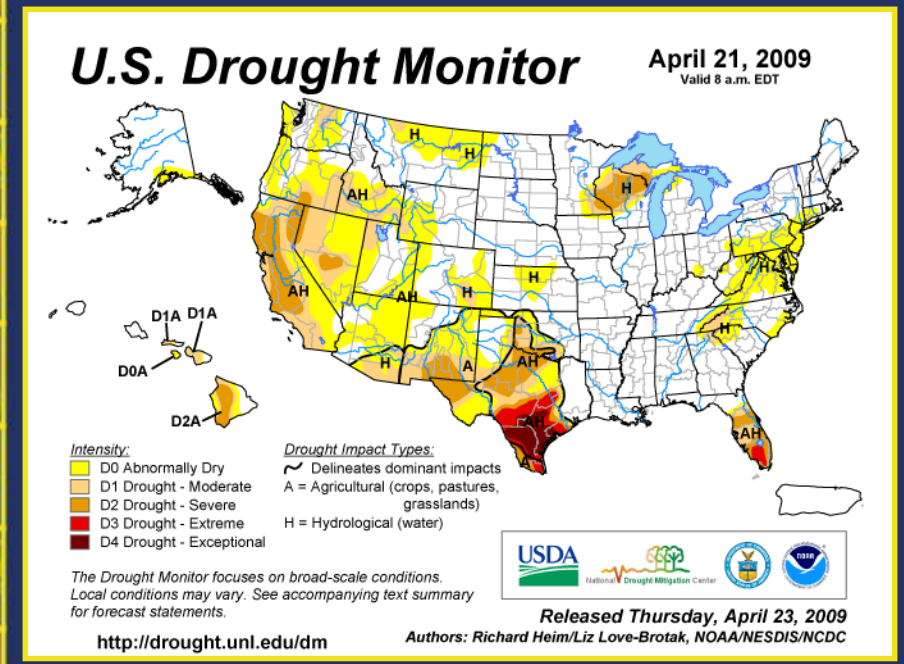


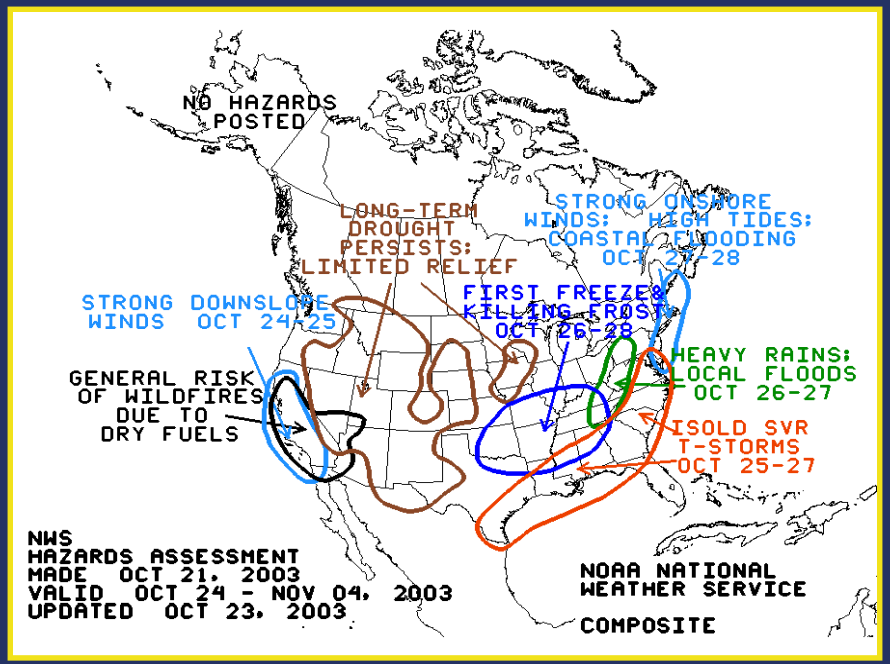
Forecaster adjusts models for NHC forecast, known model biases, and impacts of surrounding meteorological features

Scenario

- Tropical Cyclone (TC) “X” is a week or more away from approaching your area
- What information is available?
- How do I assess the risk of fresh water flooding in my area?

1 Week Before TC Rain Begins
Assess Likelihood of Ground Saturation





- Drought monitor:
  http://drought.unl.edu/DM/MONITOR.html
- Hazards Assessment:
  http://www.cpc.noaa.gov/products/expert_assessment/

4-5 Days Before TC Rains Begin

5 Day Quantitative Precipitation Forecast

Quantitative Precipitation Forecasts

Day 1	Days 1-2	5- and 7-day Totals
Day 2	Days 1-3	
Day 3	Days 4-5 and Days 6-7	

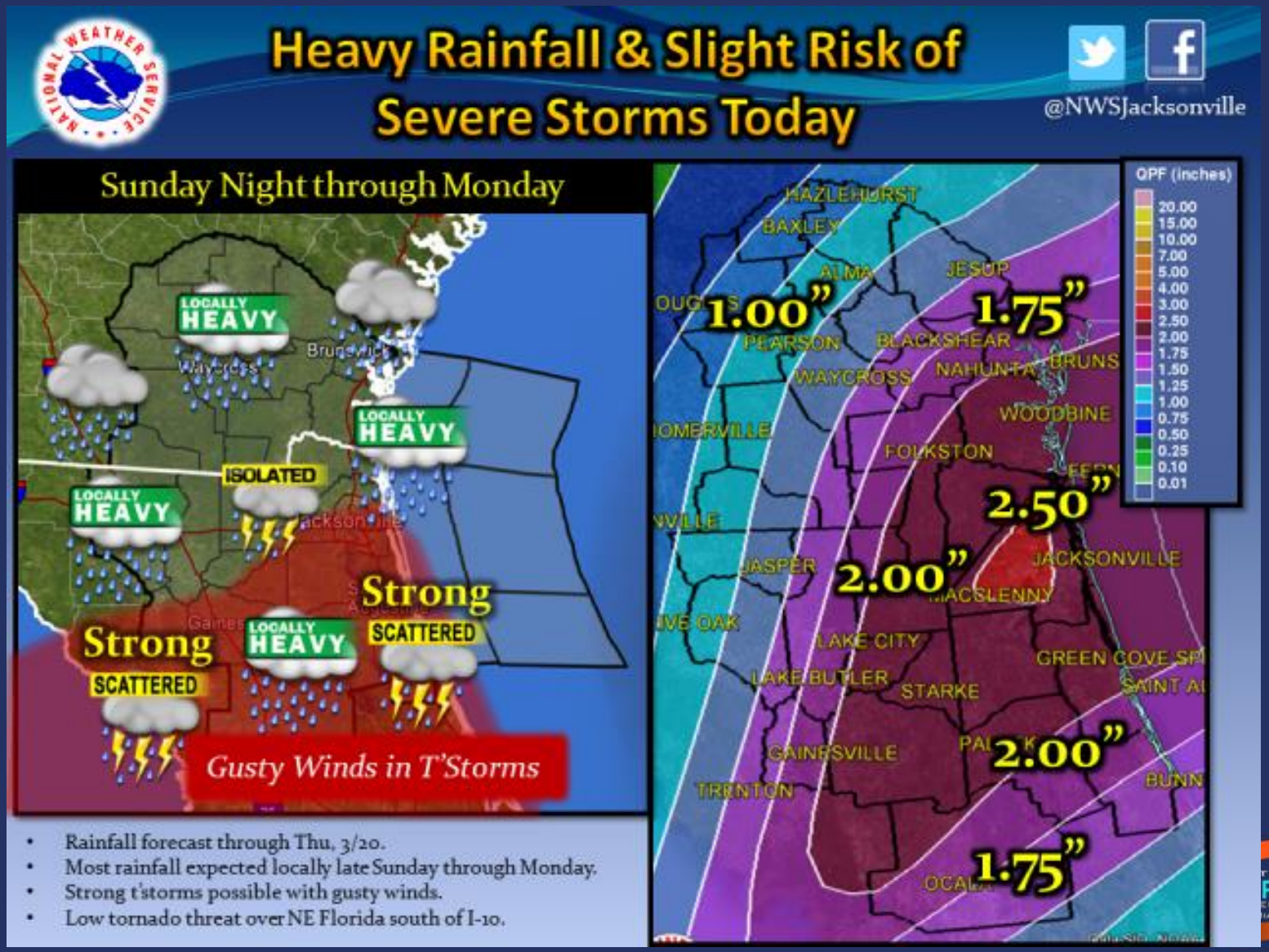
Loop of All 6-hourly or 24-hourly Forecasts for Days 1-3

View 12-Hour QPFs for Days 1-3

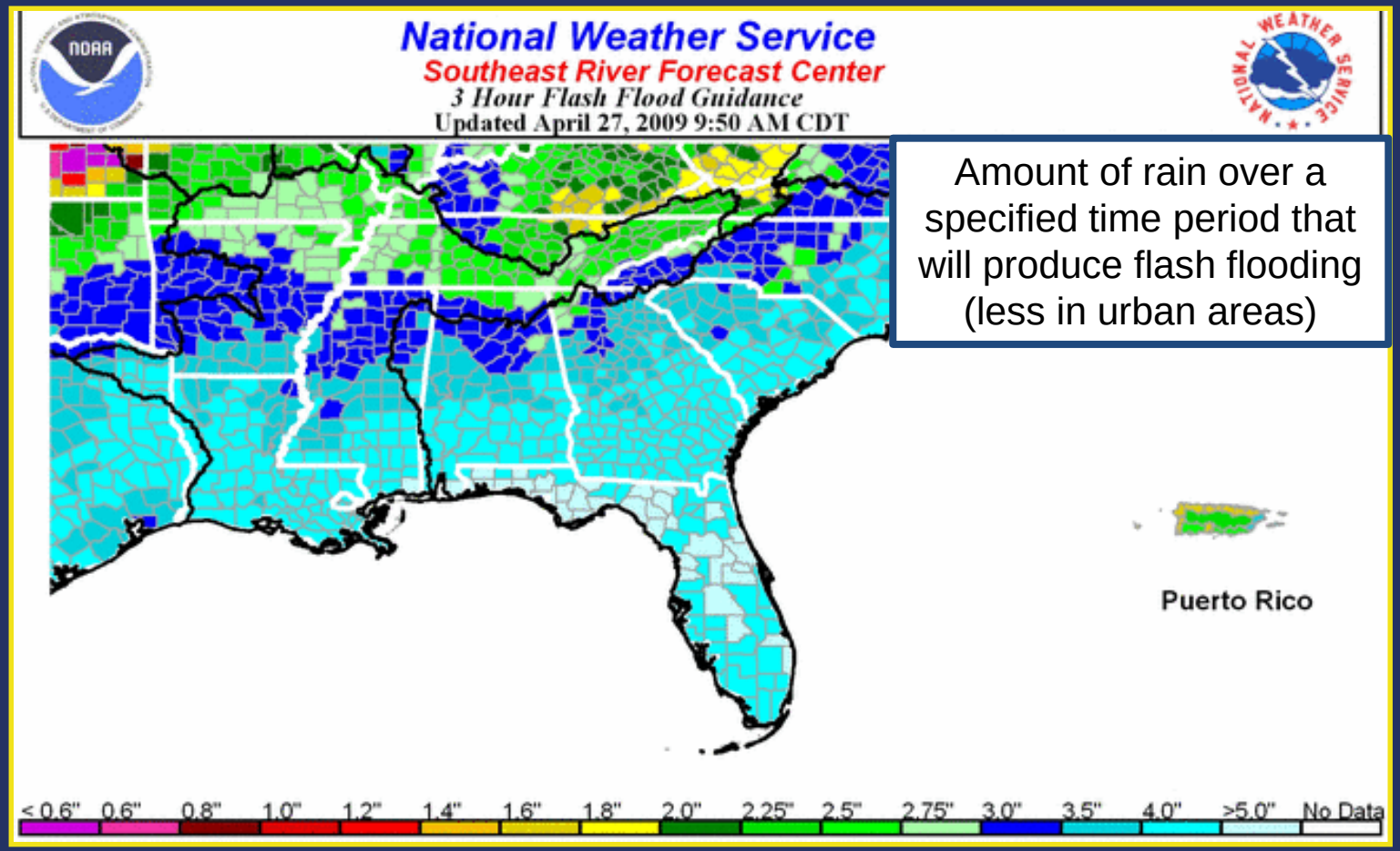
Weather Prediction Center (WPC) 5 Day QPF

http://www.wpc.ncep.noaa.gov/qpf/day4-7.shtml

Can Utilize Google Earth



Flash Flood Guidance



http://www.srh.noaa.gov/rfcshare/ffg.php

1-3 Days Before TC Rains Begin

Weather Prediction Center

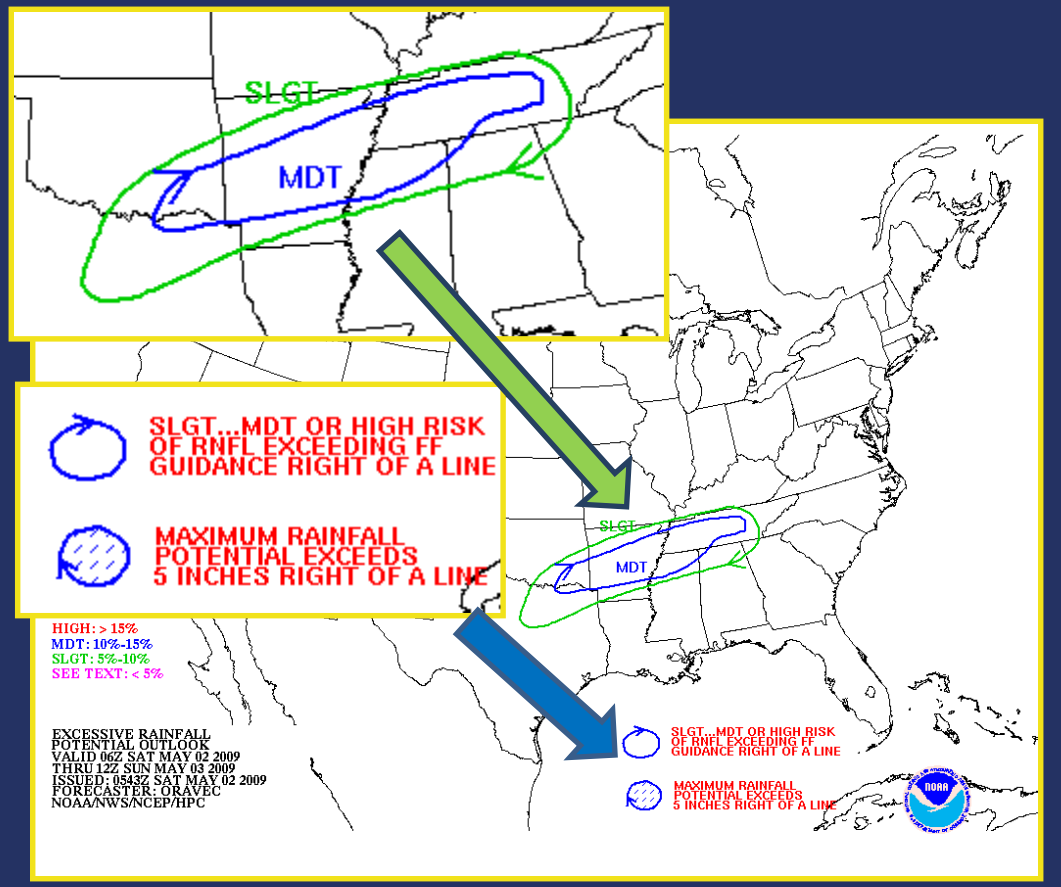
Excessive Rainfall Graphics

Risk of Exceeding Flash Flood Guidance:

- Slight (SLGT) 5-10%
- Moderate (MDT) 10-15%
- High (HIGH) >15%

Done for Days 1, 2, & 3
(24 hr forecast periods)

Area where Maximum Rainfall may Exceed 5 Inches Highlighted for Day 1 Only

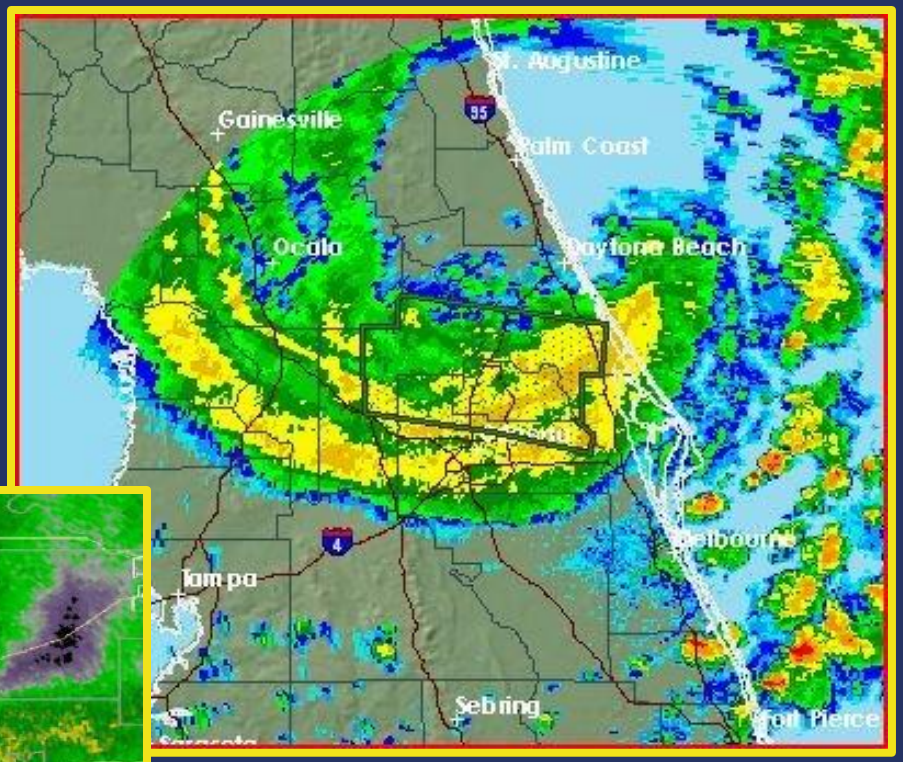


http://www.wpc.ncep.noaa.gov/qpf/excess_rain.shtml

NATIONAL HURRICANE CENTER MIAMI FL

During TC Event
Local Weather Forecast Office

- Near term QPF
- Local Watches/Warnings/ Advisories
- Local Statements and Nowcasts
- Graphicast

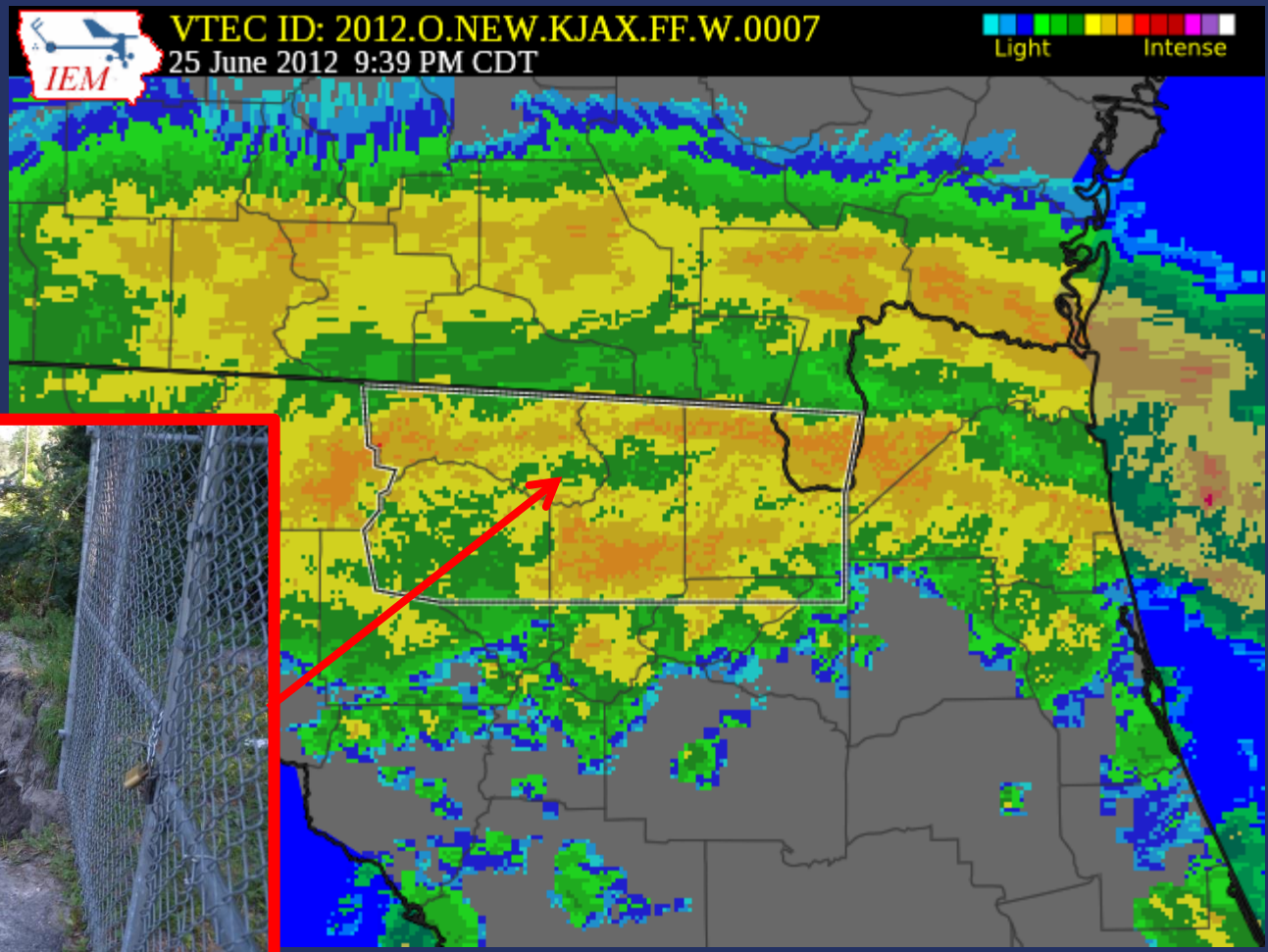


http://weather.gov

Click on map for local office

During TC Event
Local Weather Forecast Office

- Flash Flood Warnings!

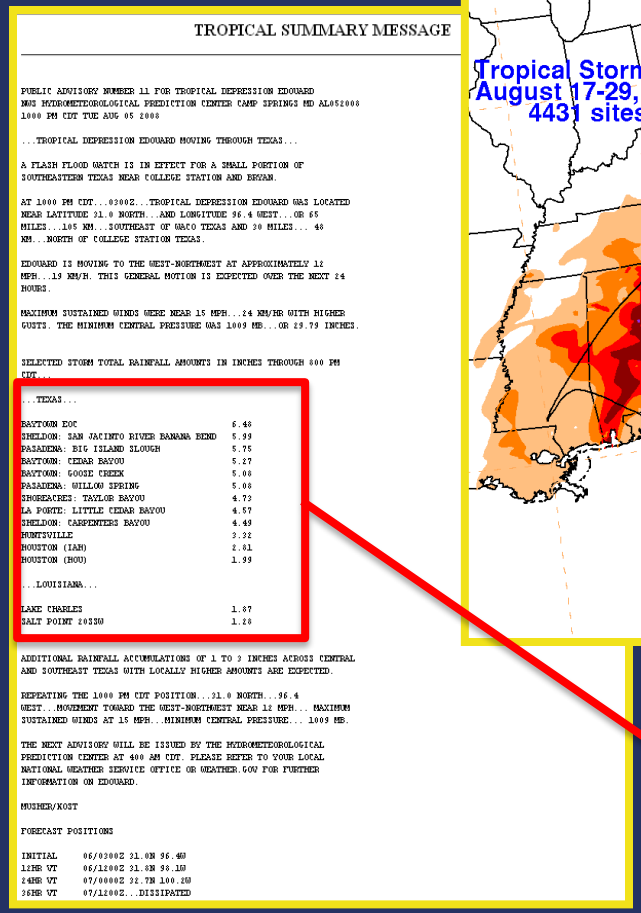


http://weather.gov

Click on map for local office

How Much Rain Fell?
Weather Prediction Center

- HPC Tropical Cyclone Public Advisories
  (available at same issuance times as NHC Public Advisories)
- Storm specific rainfall accumulation graphics
  (available several weeks later)



TROPICAL SUMMARY MESSAGE

PUBLIC ADVISORY NUMBER 11 FOR TROPICAL DEPRESSION EDOUARD
NWS HYDROMETEOROLOGICAL PREDICTION CENTER CAMP SPRINGS MD AL052008
1000 PM CDT TUE AUG 05 2008

...TROPICAL DEPRESSION EDOUARD MOVING THROUGH TEXAS...

A FLASH FLOOD WATCH IS IN EFFECT FOR A SMALL PORTION OF
SOUTHEASTERN TEXAS NEAR COLLEGE STATION AND BRYAN.

AT 1000 PM CDT...0300Z...TROPICAL DEPRESSION EDOUARD WAS LOCATED
NEAR LATITUDE 31.0 NORTH...AND LONGITUDE 96.4 WEST...OR 65
MILES...105 KM...SOUTHEAST OF WACO TEXAS AND 30 MILES... 48
KM...NORTH OF COLLEGE STATION TEXAS.

EDOUARD IS MOVING TO THE WEST-NORTHWEST AT APPROXIMATELY 12
MPH...19 KM/H. THIS GENERAL MOTION IS EXPECTED OVER THE NEXT 24
HOURS.

MAXIMUM SUSTAINED WINDS WERE NEAR 15 MPH...24 KM/HR WITH HIGHER
GUSTS. THE MINIMUM CENTRAL PRESSURE WAS 1009 MB...OR 29.79 INCHES.

SELECTED STORM TOTAL RAINFALL AMOUNTS IN INCHES THROUGH 800 PM
CDT...

...TEXAS...

BAYTOWN EOC	6.48
SHELDON: SAN JACINTO RIVER BANANA BEND	5.99
PASADENA: BIG ISLAND SLOUGH	5.75
BAYTOWN: CEDAR BAYOU	5.27
BAYTOWN: GOOSE CREEK	5.08
PASADENA: WILLOW SPRING	5.08
TROSPACRES: TAYLOR BAYOU	4.72
LA PORTE: LITTLE CEDAR BAYOU	4.57
SHELDON: CARPENTERS BAYOU	4.49
HUNTSVILLE	3.32
HOUSTON (IAH)	2.81
HOUSTON (HOU)	1.99

...LOUISIANA...

LAKE CHARLES	1.87
SALT POINT 2@3SW	1.28

ADDITIONAL RAINFALL ACCUMULATIONS OF 1 TO 3 INCHES ACROSS CENTRAL
AND SOUTHEAST TEXAS WITH LOCALLY HIGHER AMOUNTS ARE EXPECTED.

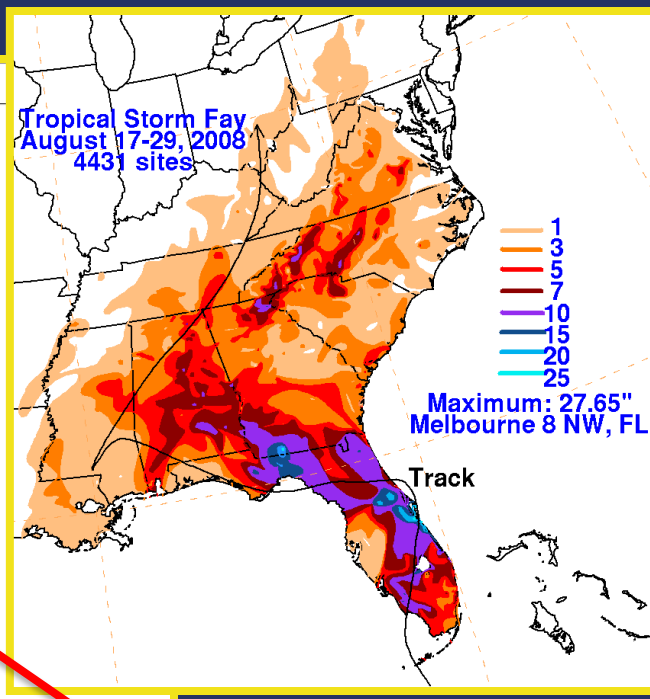
REPEATING THE 1000 PM CDT POSITION...31.0 NORTH...96.4
WEST...MOVEMENT TOWARD THE WEST-NORTHWEST NEAR 12 MPH... MAXIMUM
SUSTAINED WINDS AT 15 MPH...MINIMUM CENTRAL PRESSURE... 1009 MB.

THE NEXT ADVISORY WILL BE ISSUED BY THE HYDROMETEOROLOGICAL
PREDICTION CENTER AT 400 AM CDT. PLEASE REFER TO YOUR LOCAL
NATIONAL WEATHER SERVICE OFFICE OR WEATHER.GOV FOR FURTHER
INFORMATION ON EDOUARD.

MUSHER/KOST

FORECAST POSITIONS

INITIAL	05/0300Z 31.0N 96.4W
12HR VT	05/1200Z 31.8N 98.1W
24HR VT	07/0000Z 32.7N 100.2W
36HR VT	07/1200Z...DISSIPATED



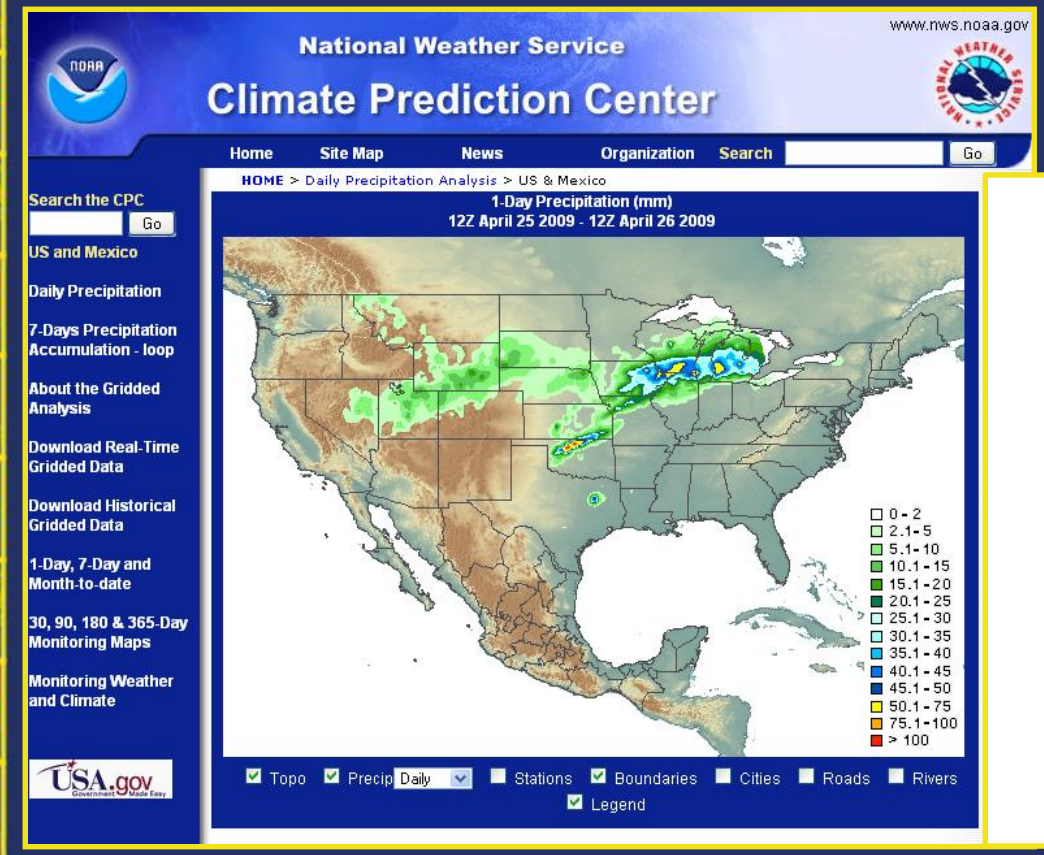
Rainfall Reports

http://www.wpc.ncep.noaa.gov/tropical/tropstorms.shtml

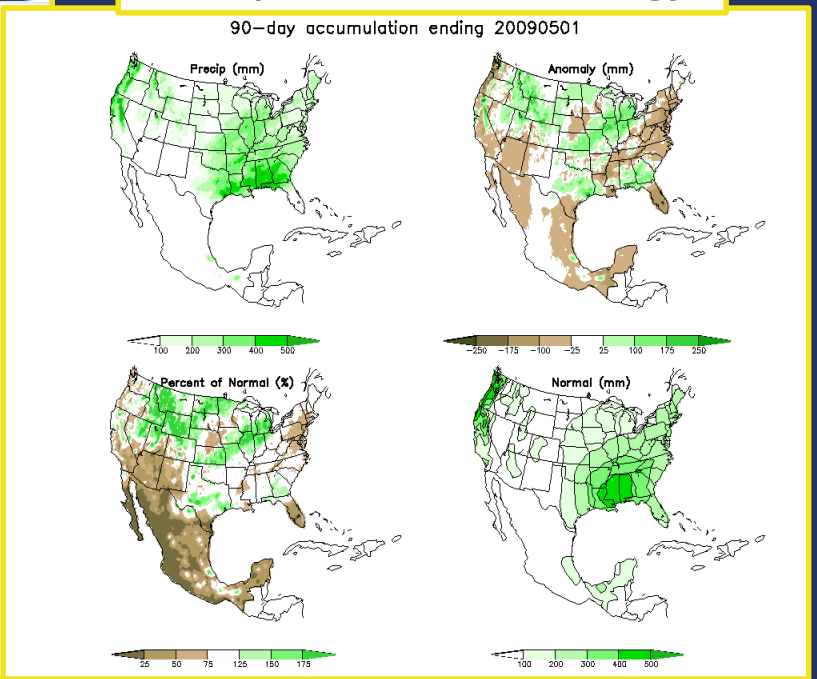
How Much Rain Fell?

http://www.srh.noaa.gov/ridge2/RFC_Precip/

How Much Rain Fell?
Climate Prediction Center



Observed Amount Compared to Climatology



Climate Prediction Center – Accumulated Precipitation from Day 1 to 1 Year

http://www.cpc.ncep.noaa.gov/products/Global_Monsoons/American_Monsoons/NAMS_precip_monitoring.shtml

How do you stay informed

- hurricanes.gov
- Mobile.weather.gov
- e-mail *Scott.Cordero@noaa.gov*
- Facebook *US National Weather Service Jacksonville*
- Twitter *@NWSJacksonville*
- GotoMeeting
- High Impact Youtube Briefing
- Phone 361-289-0959

In Conclusion

- Remember the factors that influence TC rainfall (size of storm, time of day, speed etc.)
- Evaluate the quality of the model data available to you compared to the current conditions
- Assess the amount of shear in the environment How will it influence rainfall?
- Are there past TCs that resemble the rainfall distribution and forecast of the TC?
- Use all of the tools available (products from NHC, NWP models, Local Offices, etc.)
- Remember, heavy rain can also occur well away from the TC itself (PRE, secondary disturbances, etc.)

Questions

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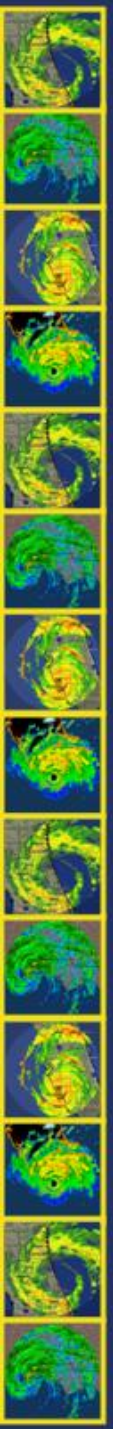
Working Together to Save Lives



Thank You

Questions?