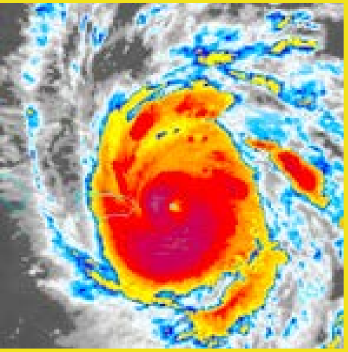
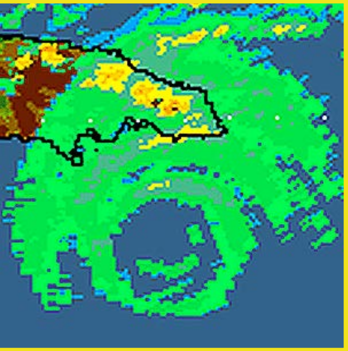




Tropical Rainfall

Marc Chenard
Jose Galvez
Weather Prediction Center

NATIONAL
HURRICANE
CENTER
MIAMI FL

Weather Prediction Center

MISSION: Provide national weather situational awareness and precipitation expertise to enable readiness for hazardous weather events

College Park, MD

National Weather Situational Awareness

- Heavy Rainfall
- Winter Weather
- Upcoming Hazards

10 Different Desks!

- Surface Analysis
- Basic Weather (Days 1-3 fronts)
- Alaska
- Medium Range CONUS (days 3.5-7)
- Hazards (days 3-7)

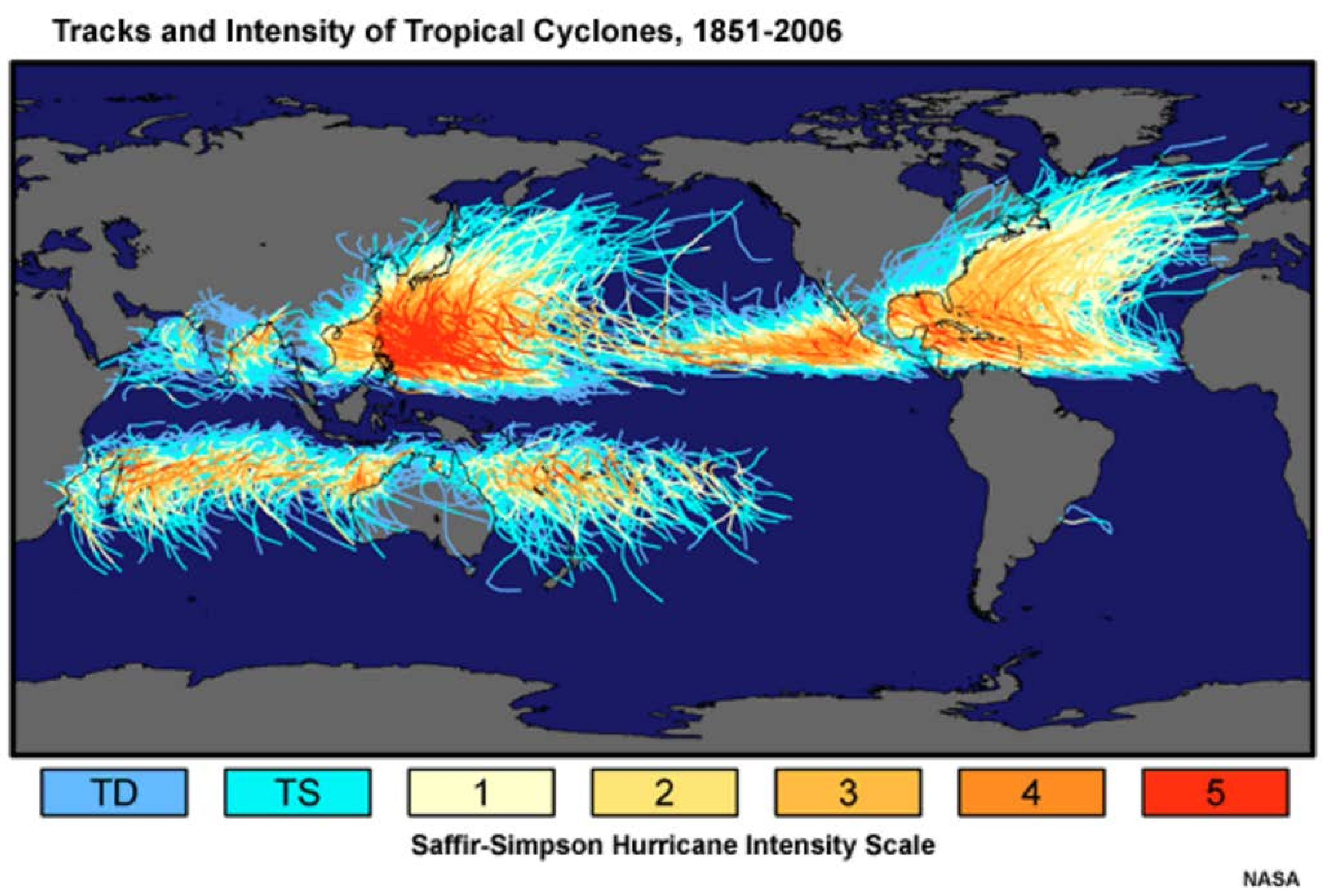
- QPF (days 1-3)
- Excessive Rainfall
- Metwatch
- Winter Weather
- International

Outline

- Tropical Cyclone (TC) rainfall climatology
- Factors influencing TC rainfall
- TC rainfall forecasting tools
- TC rainfall forecasting process
- Weather Prediction Center (WPC) role in TC rainfall forecasting

Tropical Cyclone Rainfall Climatology

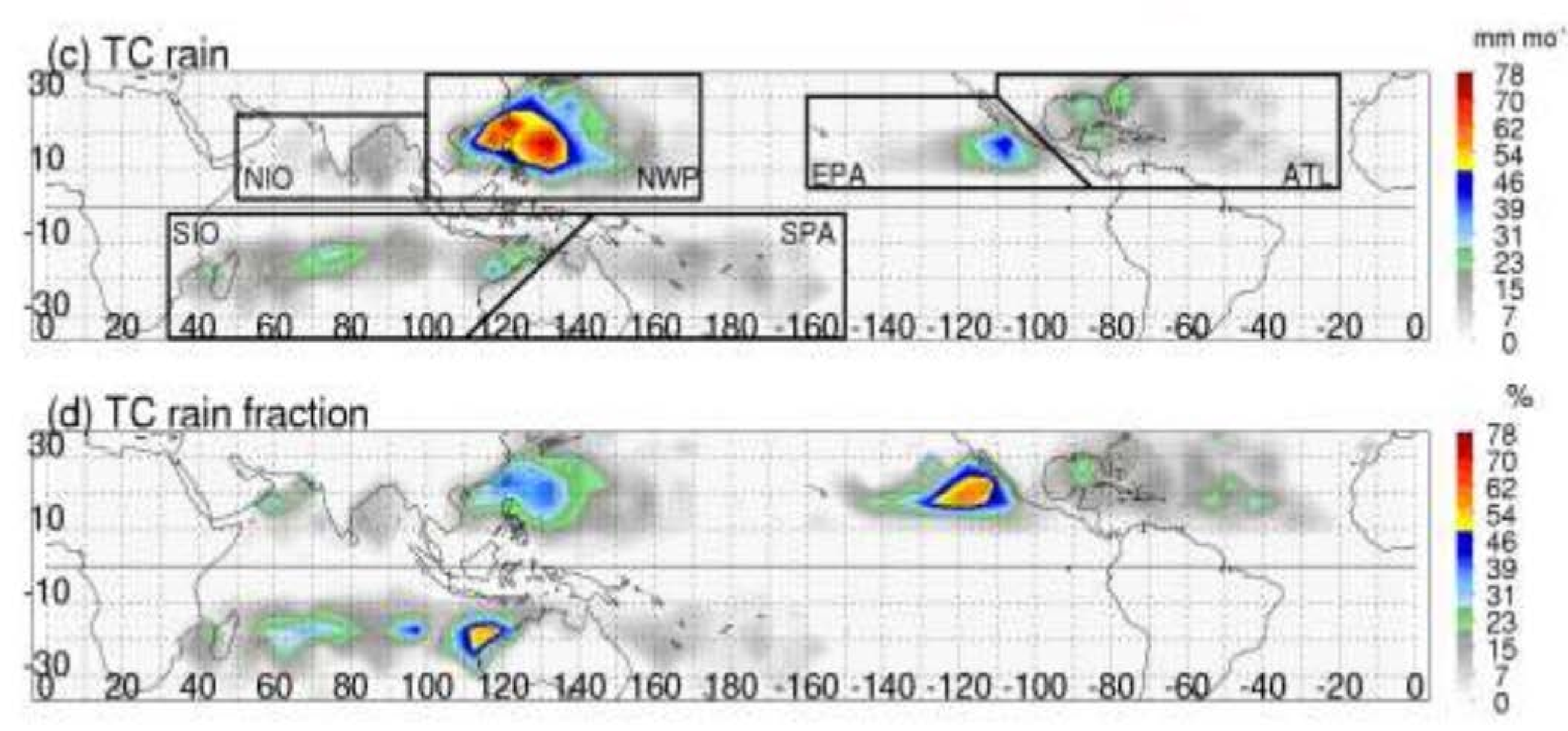
Tropical Cyclone Tracks



COMET (2011)

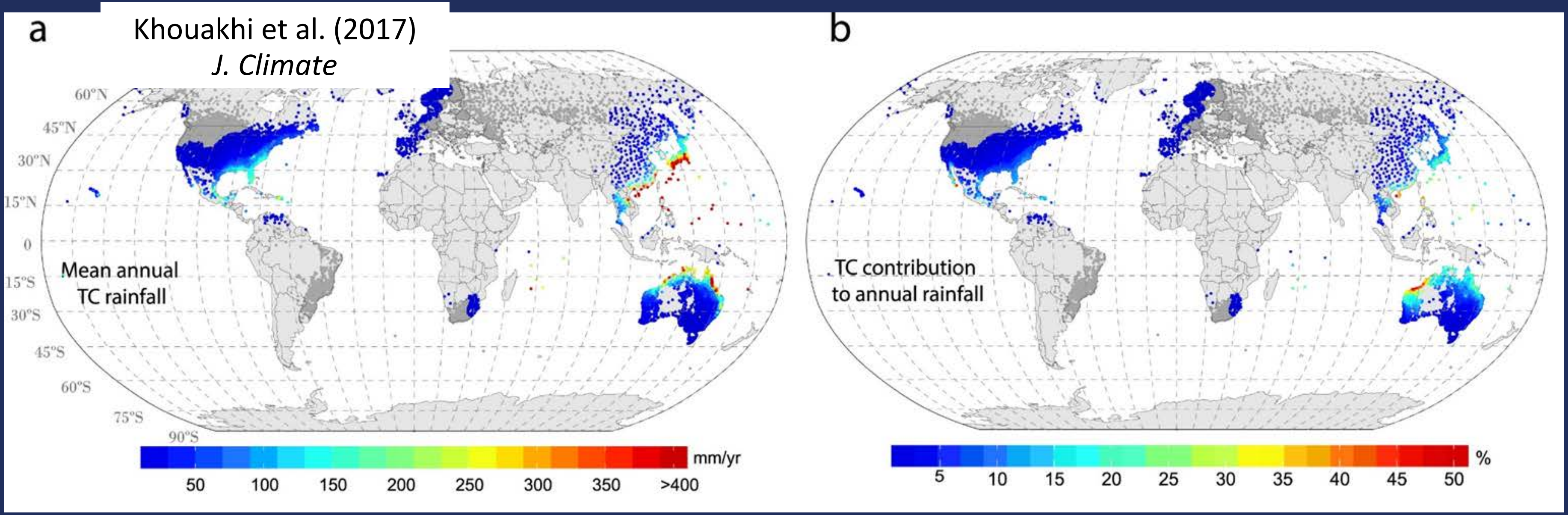
Global Mean Monthly TC Rainfall During the TC Season and Percent of Total Annual Rainfall

Data from TRMM 2A25 Precipitation Radar from 1998-2006



Jiang and Zipser (2010)

Contribution to Global Rainfall from TCs (1970-2014 rain gauge study)

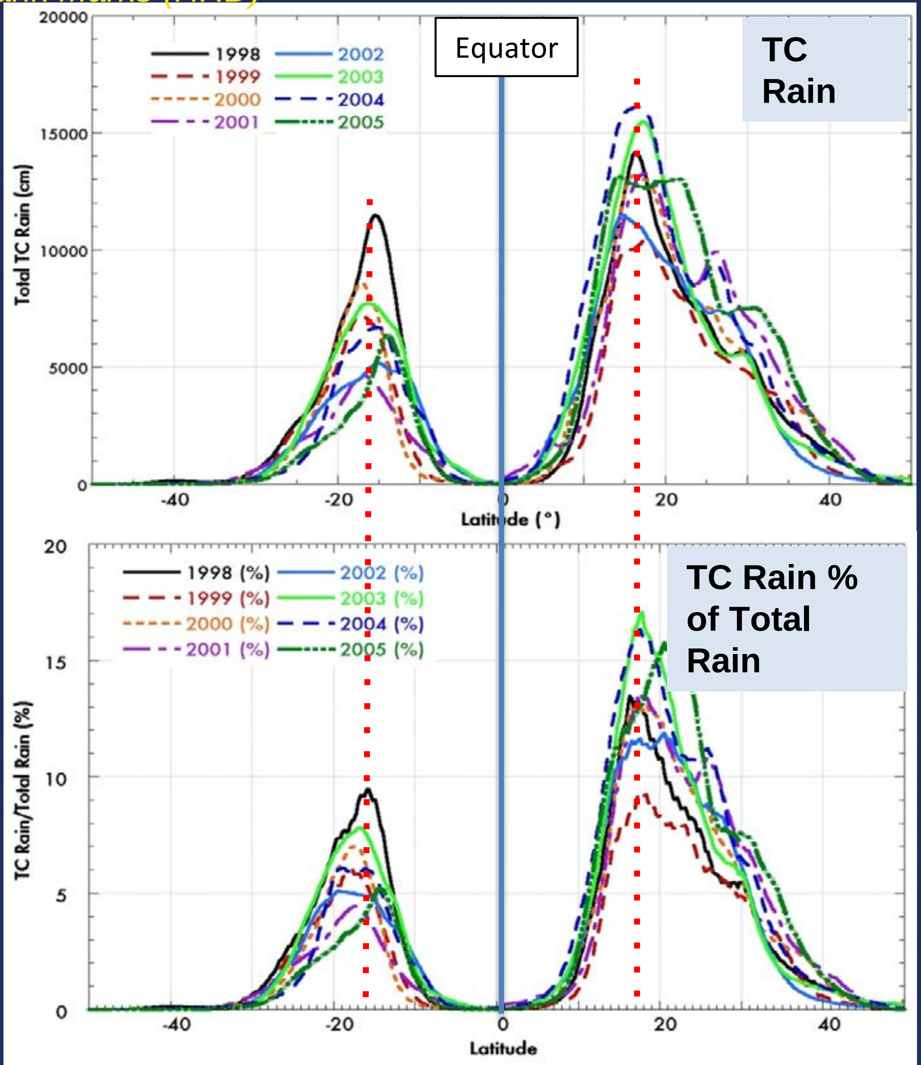


Khouakhi et al. (2017)
J. Climate

- Globally, highest TC rainfall totals are in eastern Asia, northwestern Australia, and the southeastern United States
- Percentage of annual rainfall contributed by TCs:
  - 35-50%: NW Australia, SE China, northern Philippines, Baja California, Western coast of Australia, south Indian Ocean islands, East Asia

Annual TC Rainfall

Frank Marks (HRD)



- TC rainfall makes up a larger percentage of total rainfall during years when global rainfall is low
- Asymmetric - generally more TC rainfall in the Northern Hemisphere
  - TCs produce 10-17% of global rain from 15-25°N
  - TCs produce 5-10% of global rain from 15-25°S

Biggest TC Rain Producers By Country/Island

Belize	829.8 mm	32.67”	Keith (2000)
Bermuda	186.7 mm	7.35”	October 1939 Hurricane
Canada	302.0 mm	11.89”	Harvey (1999)
Cayman Islands	764.8 mm	31.29”	Sanibel Island Hurricane (1944)
Costa Rica	920.0 mm	36.22”	Cesar (1996)
Cuba	2550.0 mm	100.39”	Flora (1963)
Dominica	825 mm	32”	Erica (2015)
Dominican Rep.	1001.5 mm	39.43”	Flora (1963)
El Salvador	1513 mm	59.57”	Twelve E (2011)
Guadeloupe	582.0 mm	22.91”	Luis (1995)
Guatemala	600.0 mm	23.62”	Mitch (1998)
Haiti	1447.8 mm	57.00”	Flora (1963)
Honduras	912.0 mm	35.89”	Mitch (1998)
Jamaica	3429.0 mm	135.00”	November 1909 Hurricane
Martinique	680.7 mm	26.80”	Dorothy (1970)
Mexico	1576.0 mm	62.05”	Wilma (2005)
Nicaragua	1597.0 mm	62.87”	Mitch (1998)
Panama	695.0 mm	27.36”	Mitch (1998)
Puerto Rico	1058.7 mm	41.68”	T.D. #15 (1970)
St. Lucia	668.0 mm	26.30”	Tomas (2010)
St. Martin/Maarten	866.6 mm	34.12”	Lenny (1999)
Venezuela	339.0 mm	13.30”	Brett (1993)

Original Source: David Roth WPC (2006)

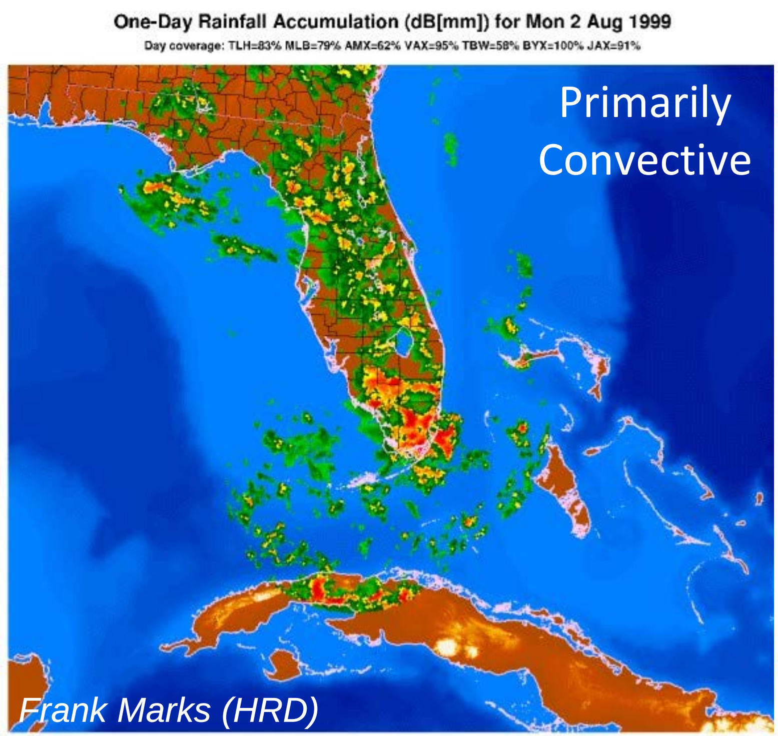
Characteristics of TC Precipitation

Stratiform and Convective Mechanisms

Stratiform Rain ~50% of Total Rain from TC

NOAA/HRD - Daily Radar Rainfall Estimate Study

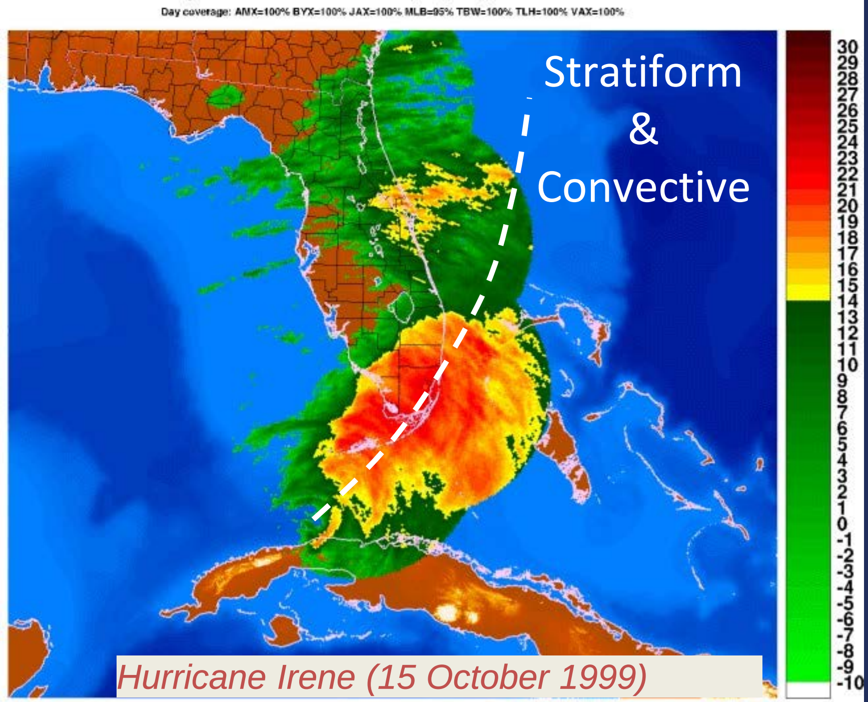
Typical warm season 1-day total



Primarily Convective

Frank Marks (HRD)

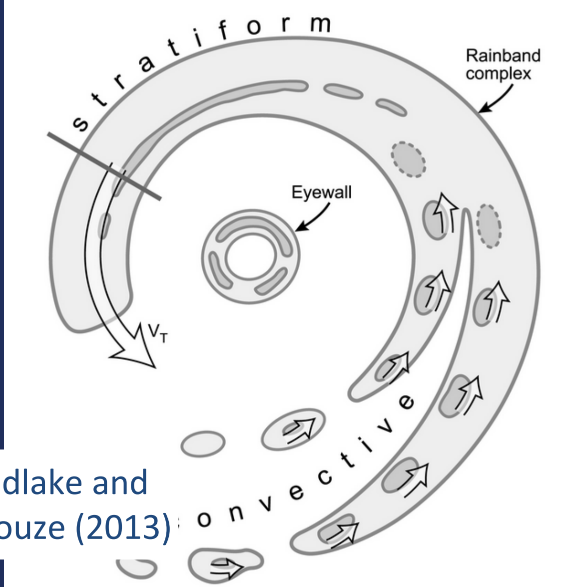
Hurricane Irene (1999) 1-day total



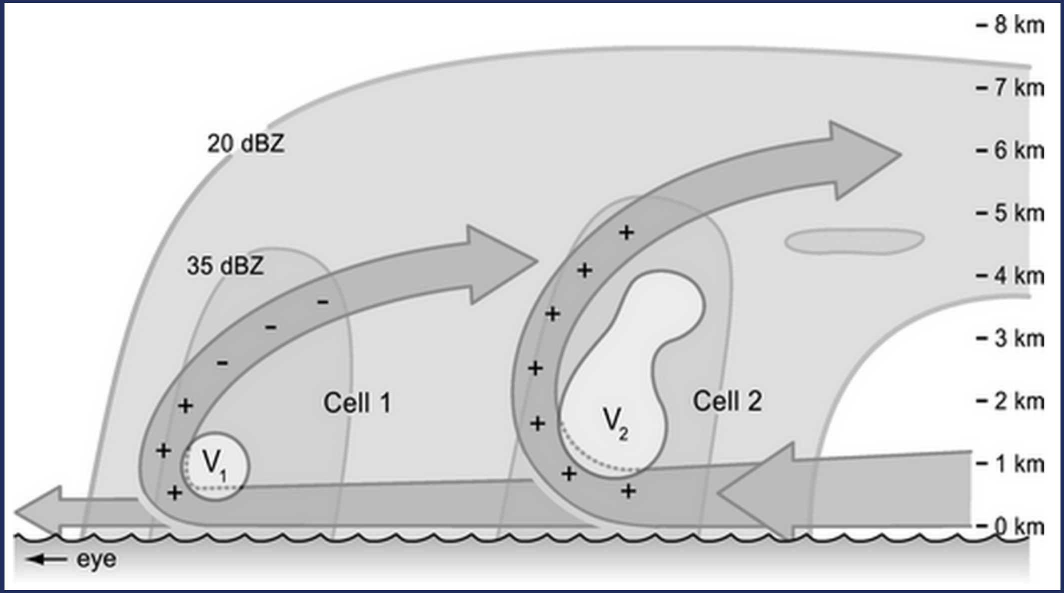
Stratiform & Convective

Hurricane Irene (15 October 1999)

TC Rainband Complexes



Didlake and Houze (2013)



Convective Cells

Cell 1 (inner rainband)

- Weaker, shallower reflectivity core
- Weaker updraft

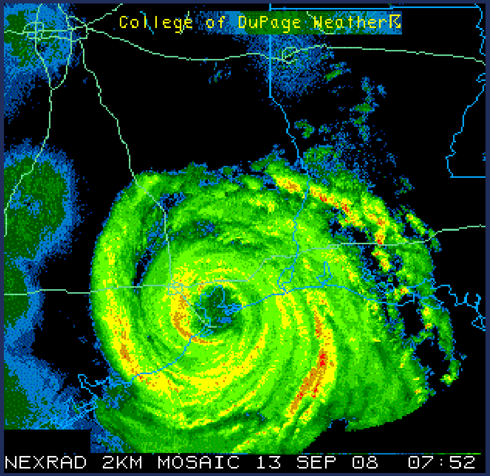
Cell 2 (outer rainband)

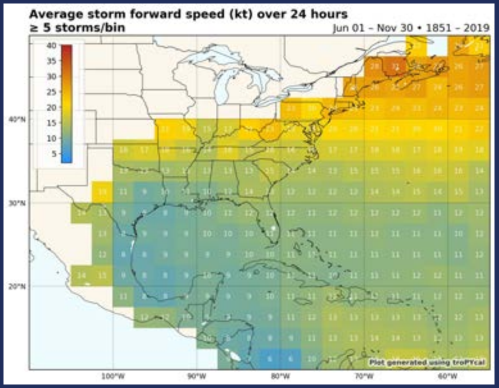
- More intense reflectivity, heavier rain
- Increased CAPE, more buoyant updraft

Stratiform

- Convection travels downwind and becomes increasingly stratiform in nature
- Primarily focuses in left-of-shear half of the storm

Heavy rainfall with a tropical cyclone





- Stratiform rain encompasses ~50% of TC rainfall (Marks 2002), which can be more in a CDO of a TC that undergoes rapid intensification (Tao et. al. 2017)
- Eyewall size (roughly 50 km) and forward motion (usually 7+ knots) tend to prevent excessively heavy rainfall from the convective eyewall alone
- Instability/CAPE in the core lower than at the storm's periphery
- Tropical cyclone banding is more convective due to greater instability near the system's fringe
- Large amounts accumulate over time so long as the bands remain stationary and within the instability pool

Factors Influencing Tropical Cyclone Rainfall

“An almost absurdly simple concept”

The heaviest rain falls where it rains hardest for the longest time.

(Paraphrase of Doswell, 1996)

Rainfall rate, or intensity

Related to the magnitude of…

- Forcing
- Moisture
- Instability
- Rainfall efficiency

Rainfall duration

Related to the…

- Persistence of forcing
- Areal extent of rainfall
- Storm motions
- Backbuilding potential

The *duration aspect* makes this a tough forecasting challenge!

With most severe weather (tornadoes, hail, wind) the event is instantaneous. However with heavy rain, not only do we have to forecast the potential for instantaneous heavy rates, but also how long they will last. There’s a big difference between 3” per hour rates lasting fifteen minutes (0.75” total) or two hours (6” total)!

Tropical Cyclones and Heavy Rainfall

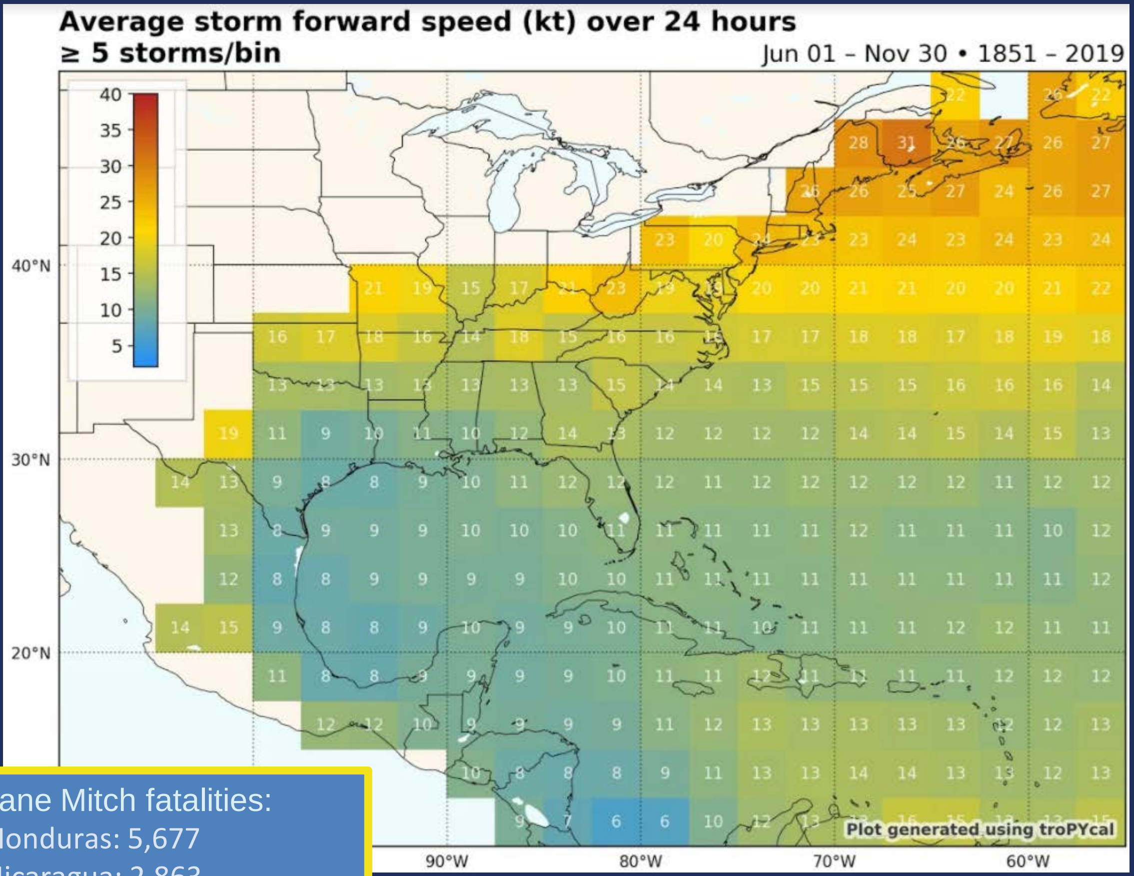
Factors Influencing Rainfall from tropical Cyclones

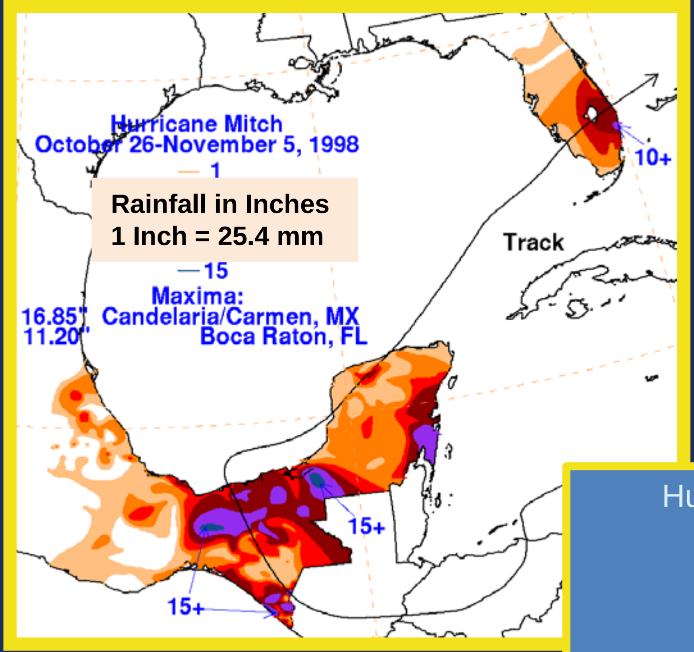
- **Movement** – slow forward motion can produce more rain
- **Storm size** – the larger the storm, the greater the area typically receiving rain
- **Storm track** – determines the location of the rain
- **Diurnal cycle** – heaviest rainfall generally near the storm center overnight, outer band rainfall 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

Factors Influencing TC Rainfall

Storm Motion

- Slow vs. fast moving TCs
- TCs with a turning or looping track vs. straight mover





Hurricane Mitch fatalities:
Honduras: 5,677
Nicaragua: 2,863
Guatemala: 258
El Salvador: 239

Factors Influencing TC Rainfall

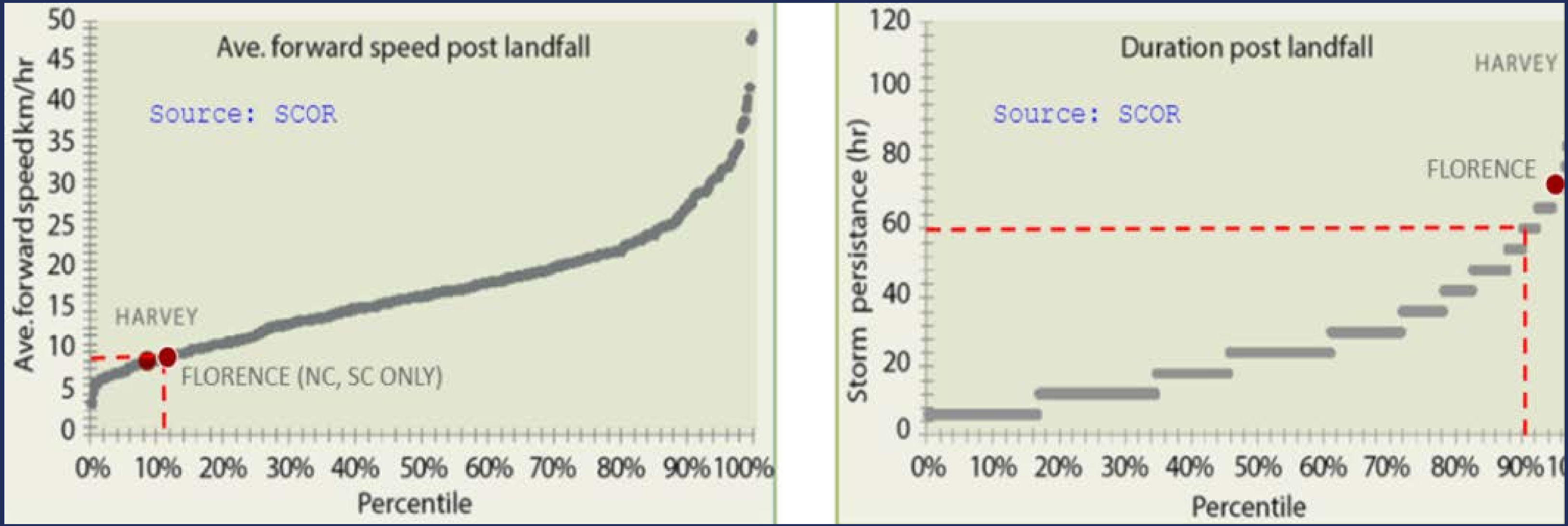
Situations that Favor the "Big Ones"

Slow-Moving Storms that Create Multi-Day Opportunity for **Repetitive, High-Intensity Rainfall**

Storm speed being equal: larger, higher-intensity storms that approach areas with terrain or urban development are factors

Few with widespread, catastrophic rain

People want us to get these right
Need to minimize false alarms

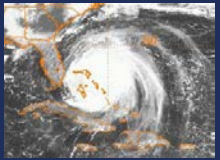


When storms are unusually slow-moving (~5 knots or less) and also unusually persistent in their tropical characteristics post-landfall, watch out for extreme rainfall and potentially catastrophic flooding.

Factors Influencing TC Rainfall

Storm Size

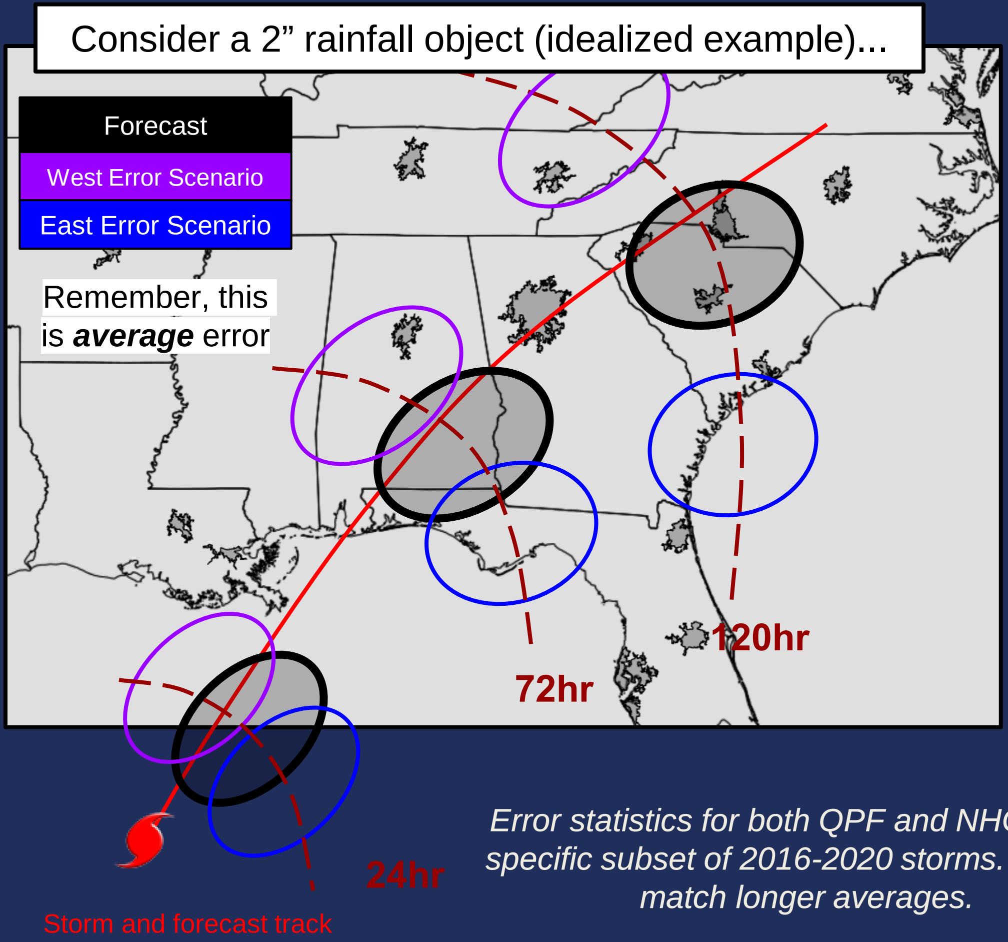
Determined by distance from center to outermost closed isobar

<2 degrees	"Very small"	Marco (2008) 
2-3 degrees	"Small"	Ida (2009) 
3-6 degrees	"Average"	Frances (2008) 
6-8 degrees	"Large"	Wilma (2008) 
>8 degrees	"Very large"	Sandy (2012) 

Original Source: Joint Typhoon Warning Center

Factors Influencing TC Rainfall

Storm Track


Consider a 2” rainfall object (idealized example)...

Remember, this is ***average*** error

Storm and forecast track

How far off are we with placement of higher amounts?

Fcst Hour	Avg QPF Error	NHC Track Error
24	56 mi.	42 mi.
48	65 mi.	58 mi.
72	86 mi.	90 mi.
96	126 mi.	121 mi.
120	157 mi.	178 mi.

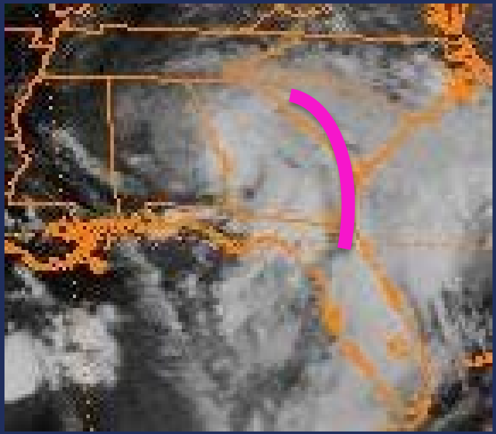
Error statistics for both QPF and NHC from a specific subset of 2016-2020 storms. May not match longer averages.

Factors Influencing TC Rainfall

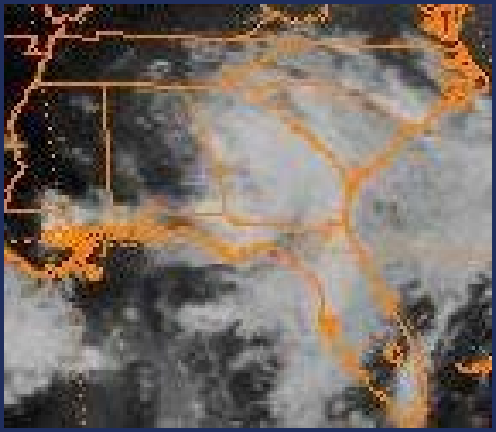
Time of Day

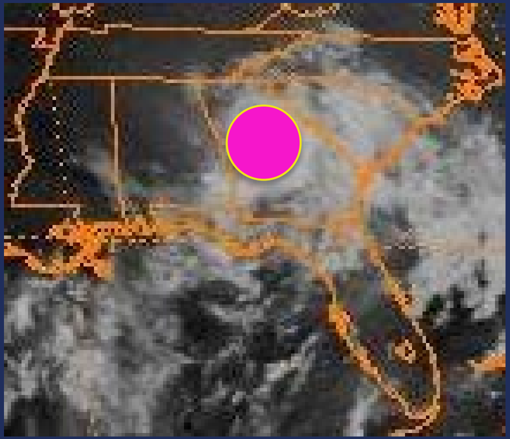
Alberto, July 4-5, 1994

04/18z

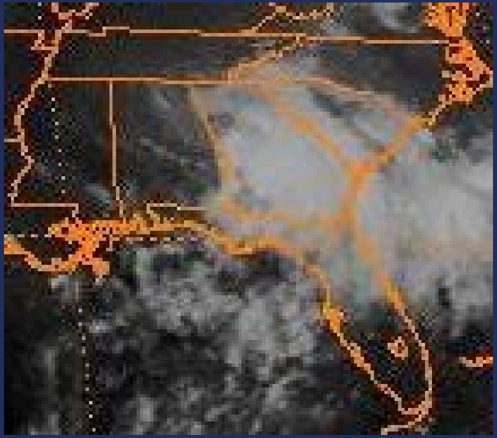


00z

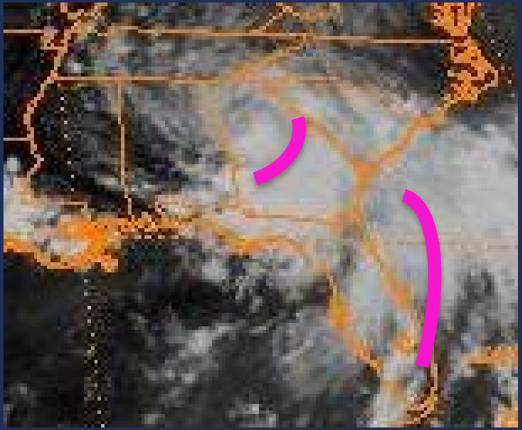




05/06z



12z

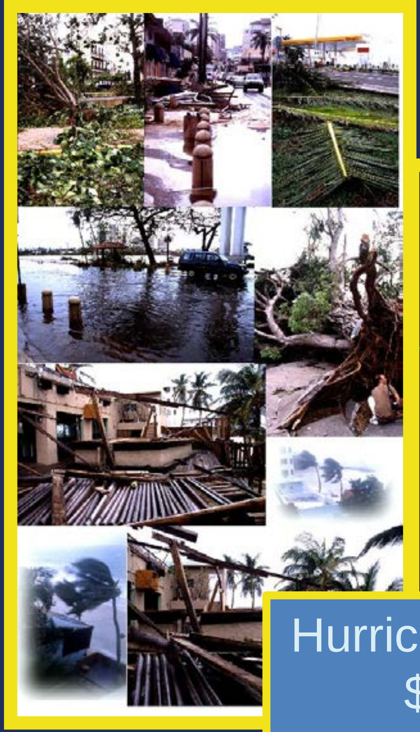


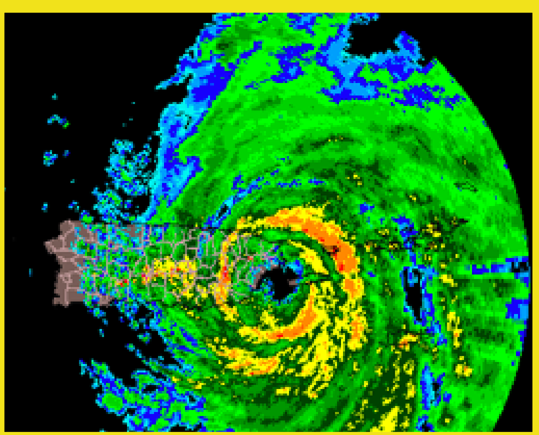
18z

Factors Influencing TC Rainfall

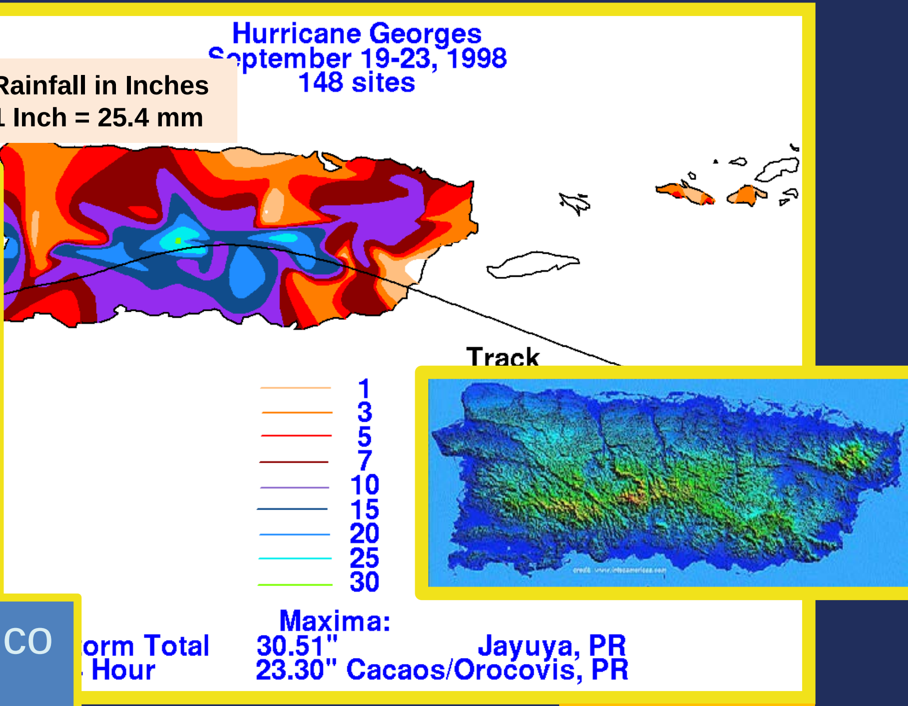
Terrain Impacts

Heaviest rainfall favors mountains perpendicular to the wind





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

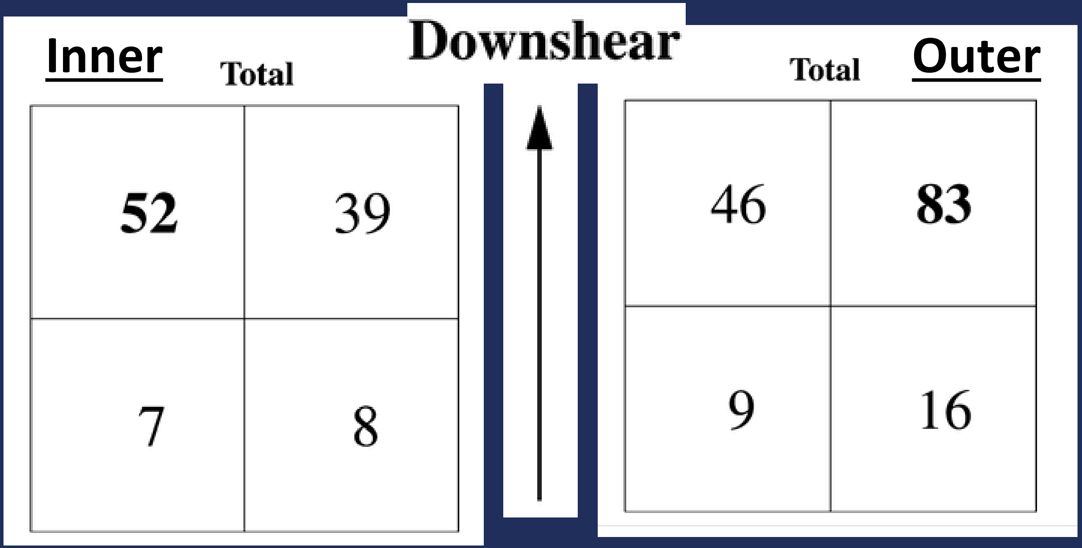


Rainfall in Inches
1 Inch = 25.4 mm

David Roth WPC

Factors Influencing TC Rainfall

Vertical Wind Shear – Northern Hemisphere



Downshear

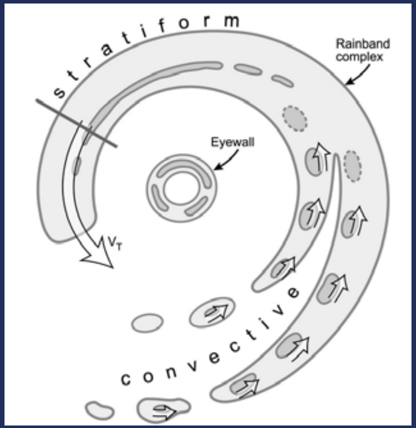
Inner Total

52	39
7	8

Total **Outer**

46	**83**
9	16

Corbosiero, Molinari 2002



More than 90% of lightning flashes occurred downshear

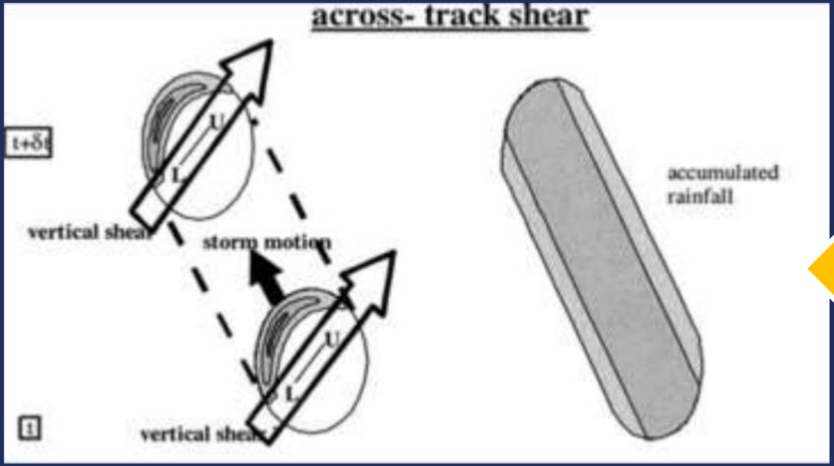
Downshear left slightly favored within inner rainbands

Downshear right favored within outer rainbands

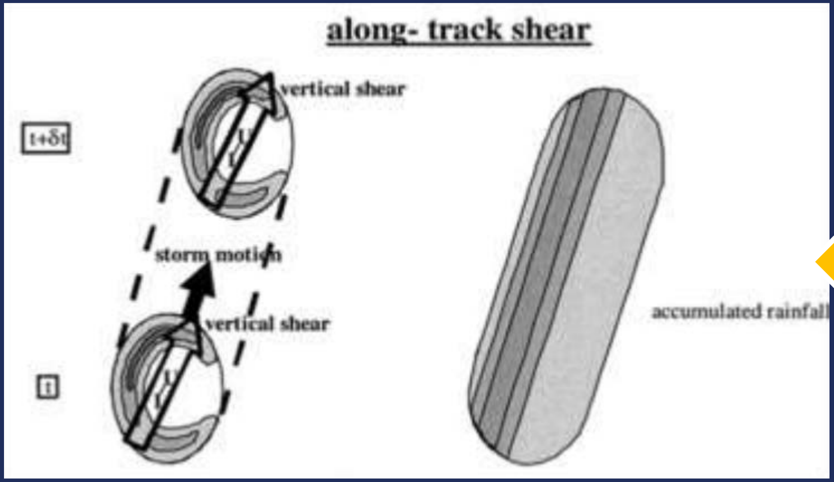
Factors Influencing TC Rainfall

Vertical Wind Shear – Northern Hemisphere

Rogers et al, 2003



Shear directed across the storm track leads to more uniform distribution of the rainfall



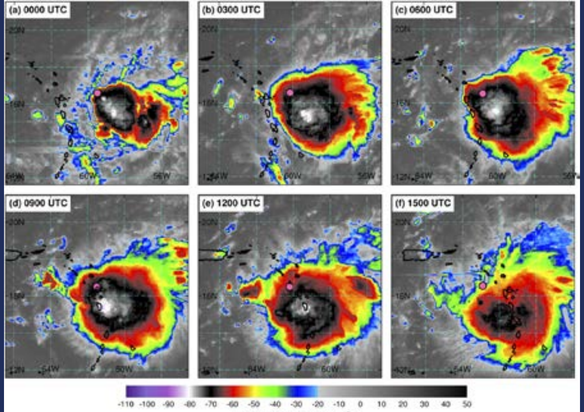
Shear directed parallel to the storm track leads to a distribution of the rainfall asymmetry on the left side of the track

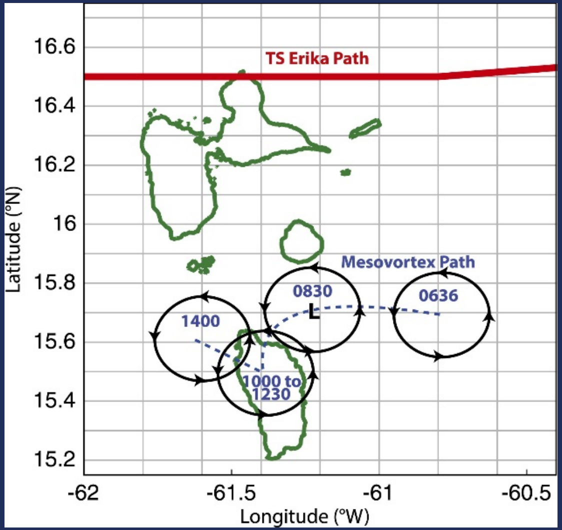
Factors Influencing TC Rainfall

Shear, Mesovortices, and Topography

- Downshear region of strong convection associated with Erika (2015) passed directly over Dominica, producing over 500 mm of rainfall
    - Driven by 500-850 mb shear rather than deep layer shear

- Mesovortex on the scale of ~ 100 km developed within Erika's circulation and persisted over Dominica for 3 hours, likely due to topographic effects, enhancing heavy rainfall



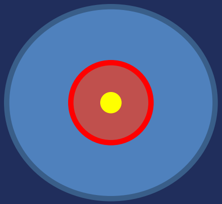


Nugent and Rios-Berrios (2018, MWR)

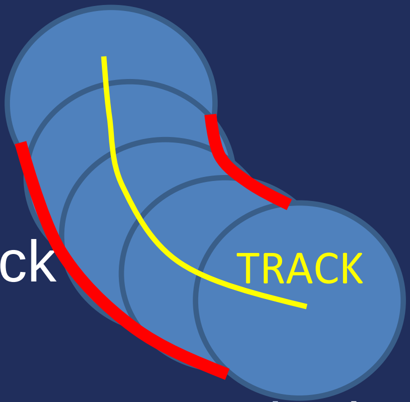
Factors Influencing TC Rainfall

Environmental Steering in Northern Hemisphere

- Very slow moving TCs and symmetrical TCs produce the most rainfall *near the center*
  - Maximum rainfall at night (especially when over land)
  - Weak steering flow



- TCs that move into a break in the subtropical ridge often produce most of the rain *right* of their track



Even rainfall distribution = Rain over smaller area on right side = Higher totals

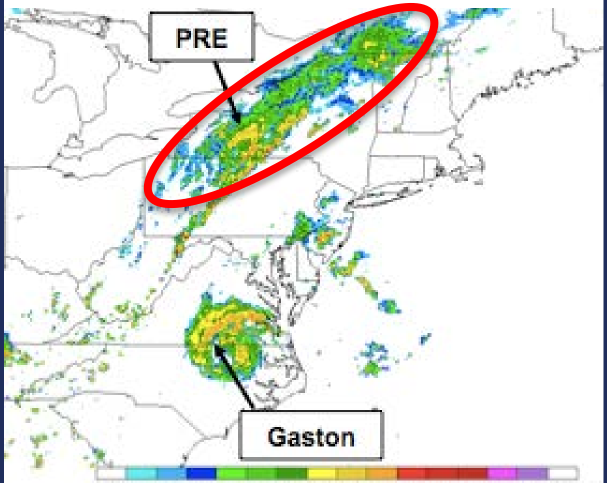
- TCs that recurve due to significant upper troughs in the westerlies often produce most of their rain *left* of their track
  - Rainfall may spread well in advance of the TC due to interaction with the upper jet on the leading edge of the trough

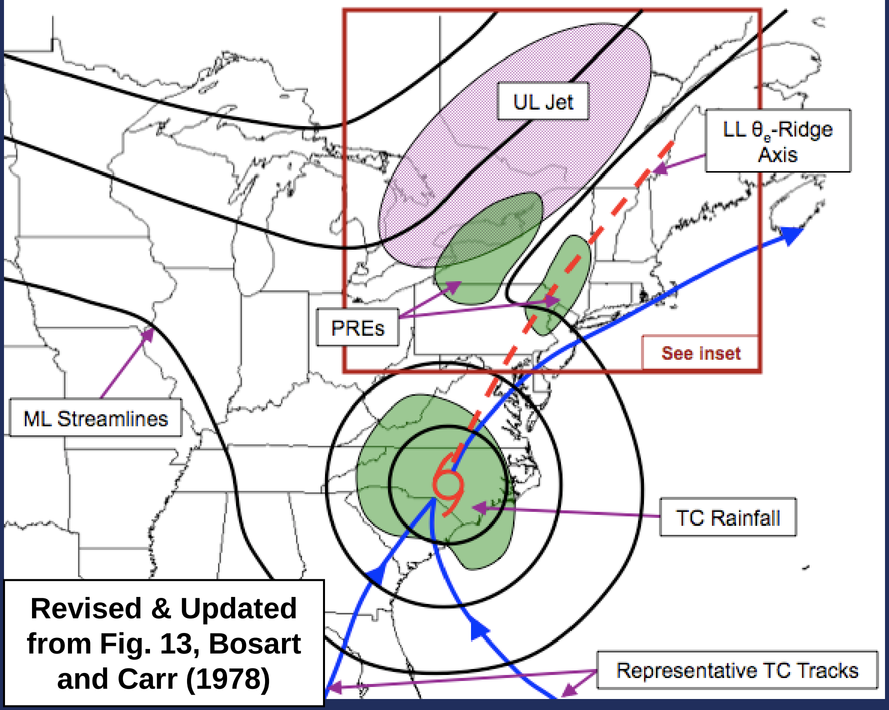
Factors Influencing TC Rainfall

Predecessor Rainfall Events

Predecessor Rainfall Event (PRE)

Image from Matt Cote and Lance Bosart – SUNY Albany



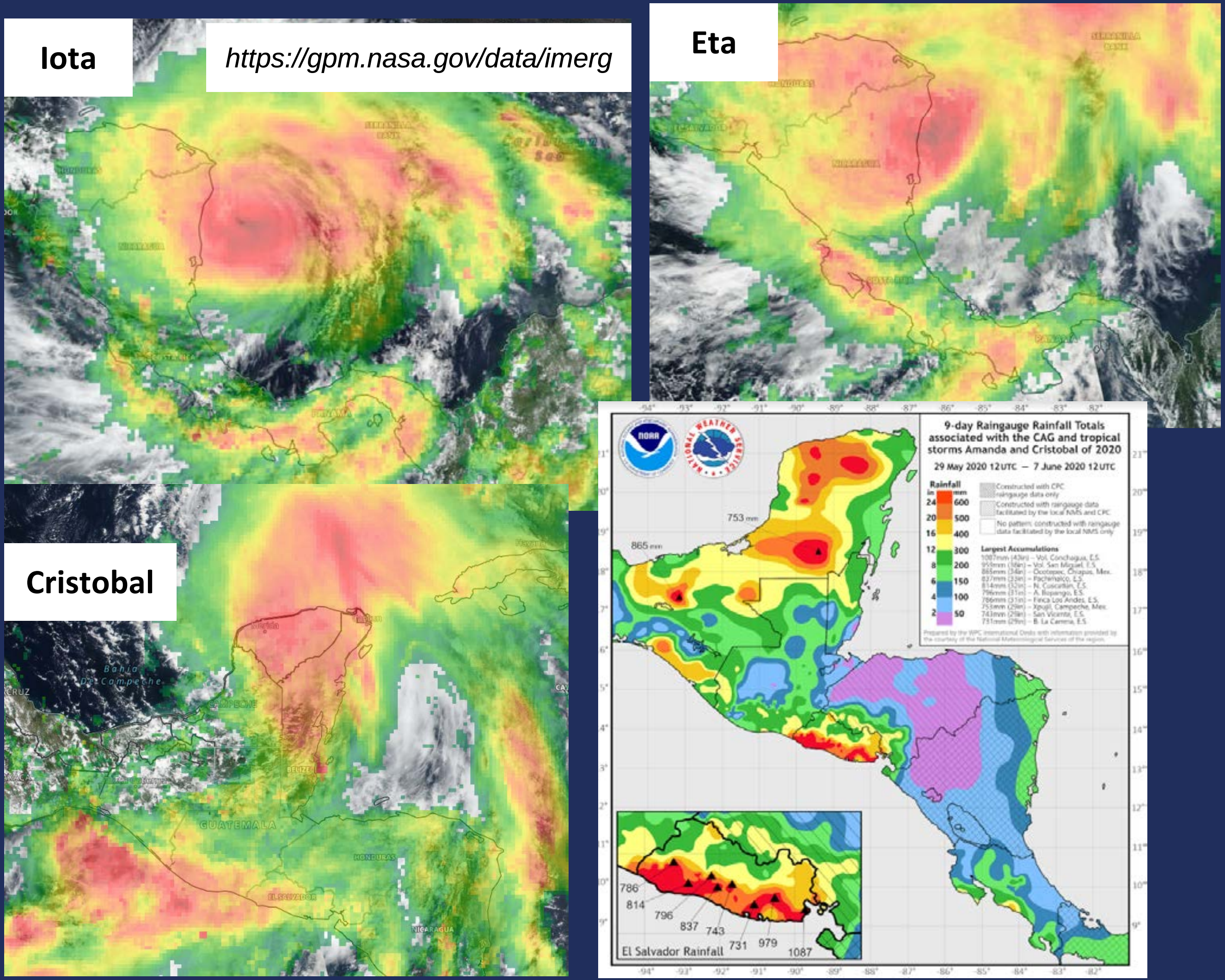


Revised & Updated from Fig. 13, Bosart and Carr (1978)

- **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.**

Factors Influencing TC Rainfall

Other Secondary Features and/or CAGs



Secondary features and CAGs (Central American Gyre) can result in heavy rainfall well away from the center of the TC. Especially when orographic enhancement comes into play

CAGs are most common early and late in the hurricane season

Where is Flooding from Tropical Cyclones More Likely to Occur?

- Areas where the ground is already saturated (low flash flood guidance values)
- Valleys/watersheds
- Areas of orographic enhancement
- Areas with poor drainage or prone to runoff
- Areas with directed drainage that can be overwhelmed

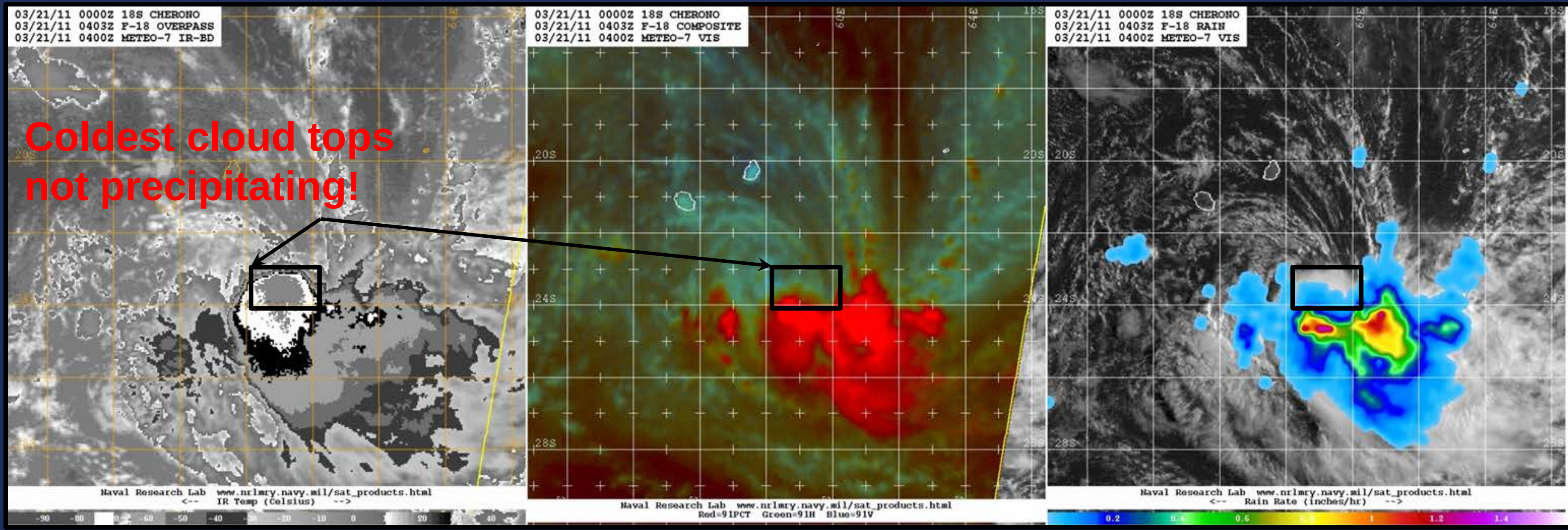
Costa Rica stream flooding

Clear Cut Areas in Haiti

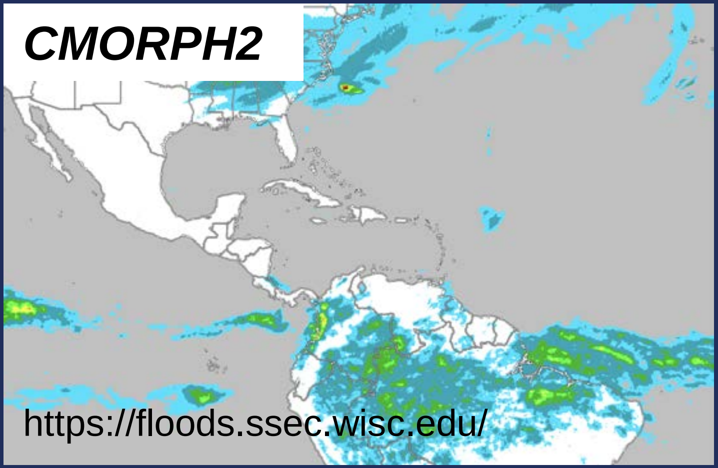
TC Rainfall Forecasting Tools

Advantages of Microwave Products

- Geostationary IR data provides excellent spatiotemporal resolution, but is not optimal for rain estimation
- Microwave provides improved rainfall accuracy but at low temporal resolution
- Quantitative precipitation estimate (QPE) products leverage each method's strength…

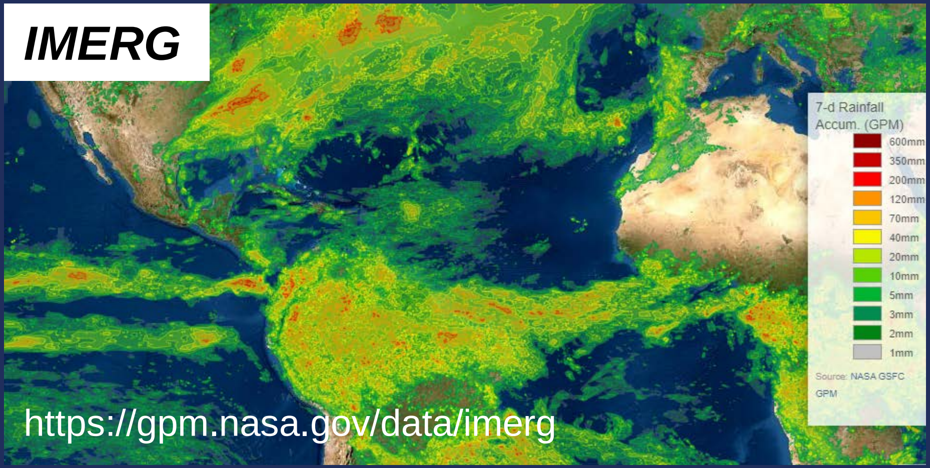

Coldest cloud tops not precipitating!

Satellite Rainfall Estimates



CMORPH2

https://floods.ssec.wisc.edu/



IMERG

https://gpm.nasa.gov/data/imerg

JAX

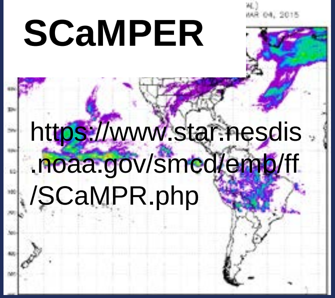
https://sharaku.eorc.jaxa.jp/GSMaP_NOW/index.htm

<u>**CMORPH2, IMERG and JAX**</u>: Most sophisticated of the estimates. All use a combination of microwave and geostationary satellite data to derive estimated rainfall.

<u>**NESDIS Blended Rain Rate:**</u> Blended microwave rainfall estimates

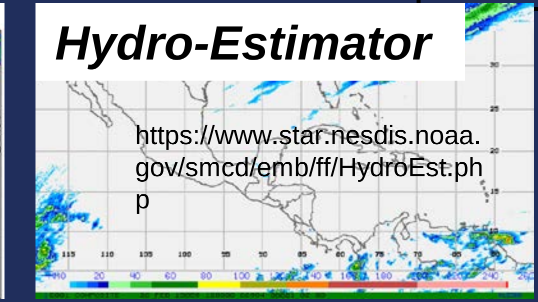
<u>**Hydro-Estimator:**</u> Only uses GOES IR imagery

<u>**SCaMPER:**</u> IR imagery calibrated with Microwave data



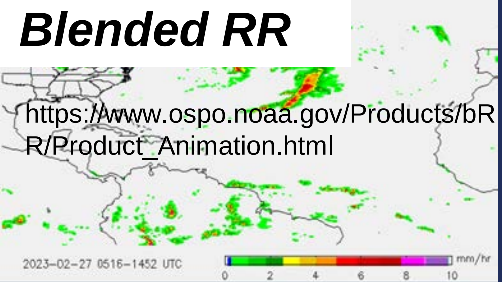
SCaMPER

https://www.star.nesdis.noaa.gov/smcd/emb/ff/SCaMPR.php



Hydro-Estimator

https://www.star.nesdis.noaa.gov/smcd/emb/ff/HydroEst.php

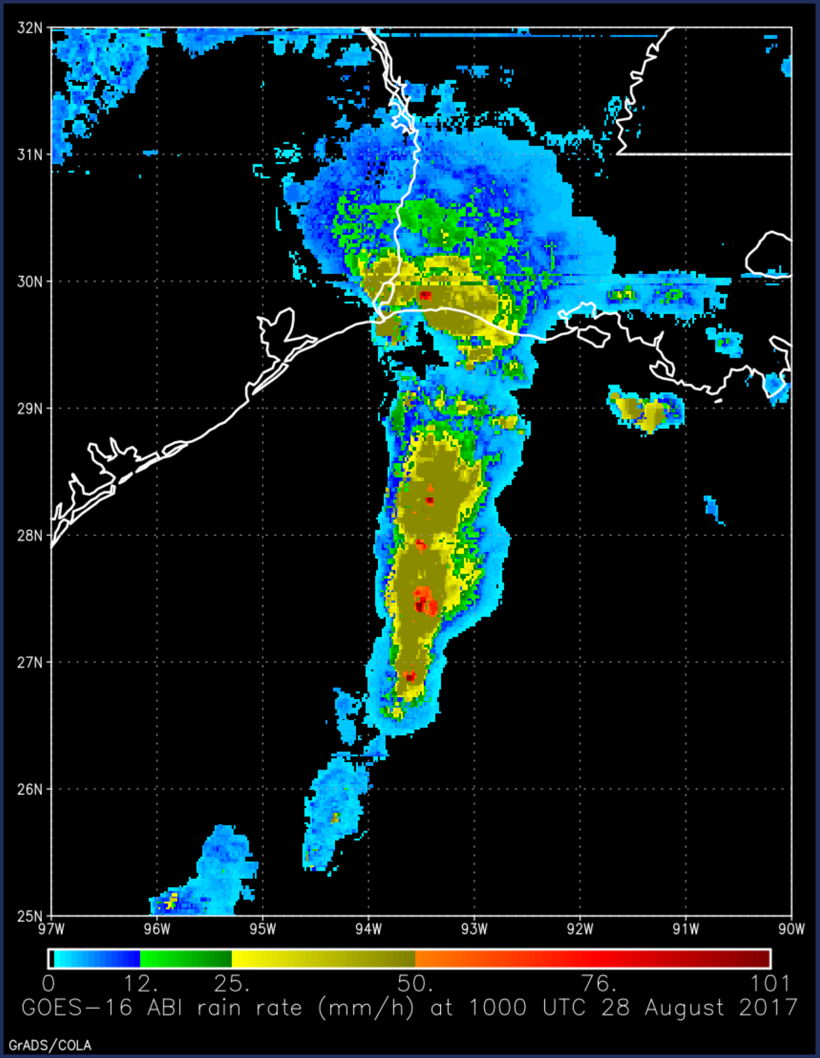


Blended RR

https://www.ospo.noaa.gov/Products/bRR/Product_Animation.html

GOES-16/18 Products

Rainfall Rate



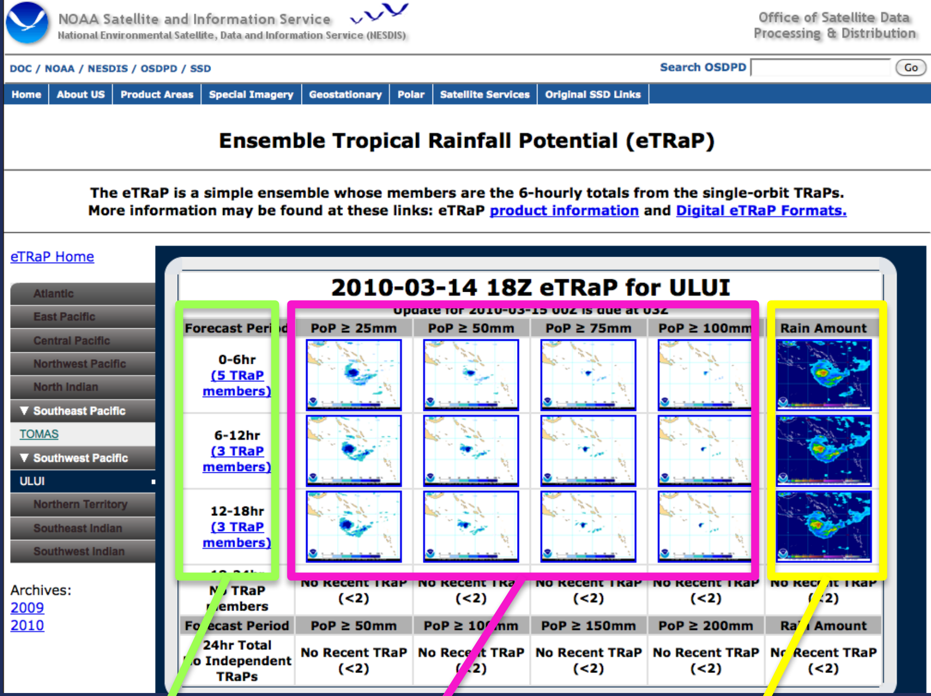
- Algorithm generates estimates of instantaneous rainfall rate at each IR pixel
- Uses IR brightness temperatures and calibrated in real time against microwave-derived rain rates to enhance accuracy
- The higher spatial and temporal resolution available from GOES-16 will be able to automatically resolve rainfall rates on a finer scale

Ensemble Tropical Rainfall Potential Product (eTRaP)

- 6-hourly Day 1 forecasts: Extrapolates polar orbiting satellite rain rate along TC forecast tracks

  (AMSU, SSMI, AMSRE, TRMM)

- A satellite “member” is included when its path passes over the TC
- “Members” are weighted according to age of pass and past performance of sensor
- Official forecast of TC track & at least 2 members needed to create a forecast
- Updated daily at 0315, 0915, 1515, and 2115 UTC



Ensemble Tropical Rainfall Potential (eTRaP)

The eTRaP is a simple ensemble whose members are the 6-hourly totals from the single-orbit TRaPs. More information may be found at these links: eTRaP product information and Digital eTRaP Formats.

2010-03-14 18Z eTRaP for ULUI

Update for 2010-03-15 00Z is due at 03Z

Forecast Peri d	PoP ≥ 25mm	PoP ≥ 50mm	PoP ≥ 75mm	PoP ≥ 100mm	Rain Amount
0-6hr (5 TRaP members)					
6-12hr (3 TRaP members)					
12-18hr (3 TRaP members)					
N TRaP embers	No Recent TRaP (<2)	No Recent TRa (<2)	No Recent TRaP (<2)	No Recent TRaP (<2)	No Rec nt TRaP (2)
Fo ecast Period	PoP ≥ 50mm	PoP ≥ 10 mm	PoP ≥ 150mm	PoP ≥ 200mm	Ra Amount
24hr Total o Independent TRaPs	No Recent TRaP (<2)	No Rece t TRaP (2)	No Recent TRaP (<2)	No Recent TRaP (<2)	N Recent TRaP (<2)

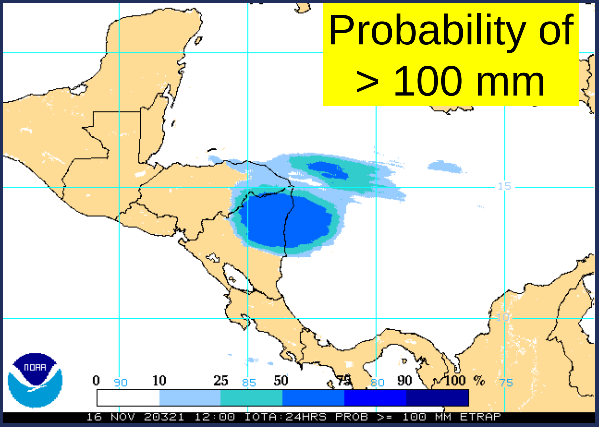
Forecast Period

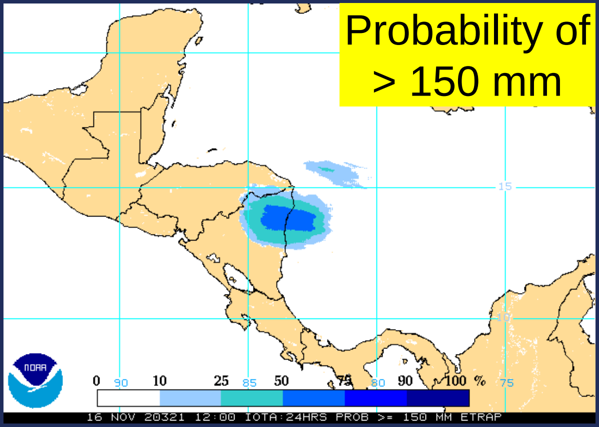
Probability of exceedance

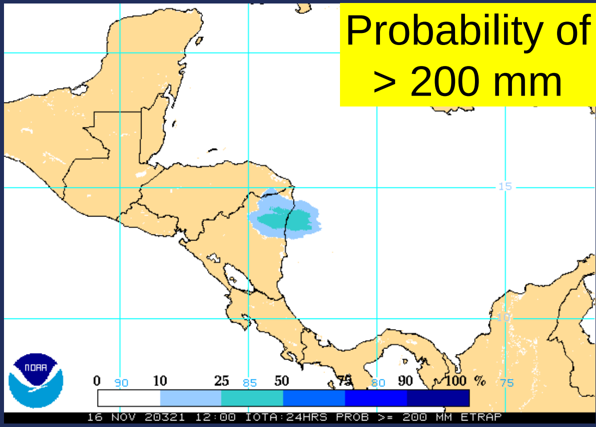
Quantitative Precipitation Forecast

http://www.ssd.noaa.gov/PS/TROP/etrap.html

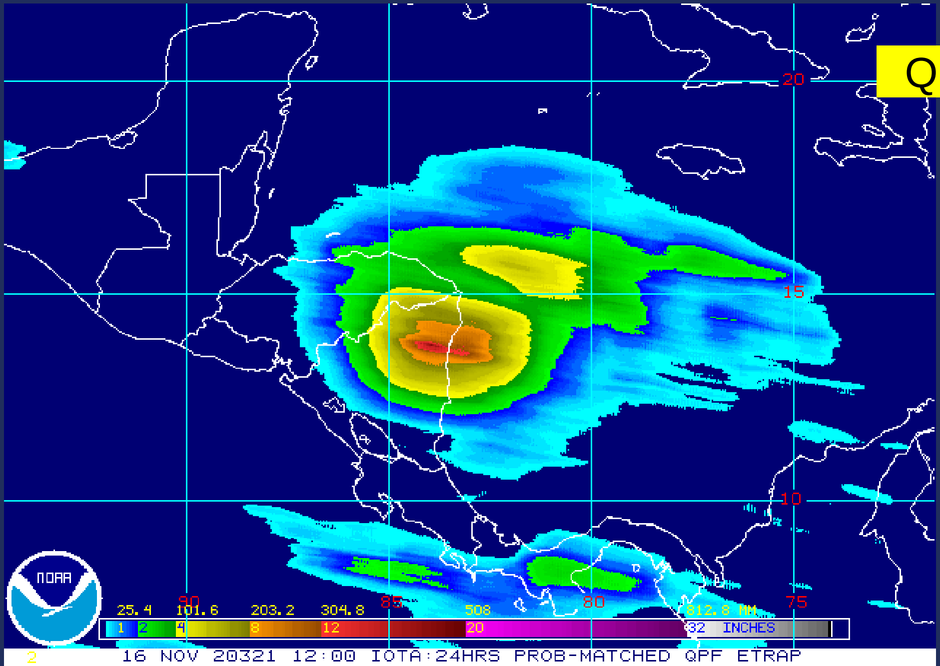
eTRaP: http://www.ssd.noaa.gov/PS/TROP/etrap.html


Probability of > 100 mm


Probability of > 150 mm


Probability of > 200 mm

Hurricane Iota 24 hr eTRaP forecast


QPF

Weather Prediction Center and National Hurricane Center
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

CLIQR: Picking an Analog for a TC Rainfall Event

www.wpc.ncep.noaa.gov/tropical/rain/web/cliqr.html

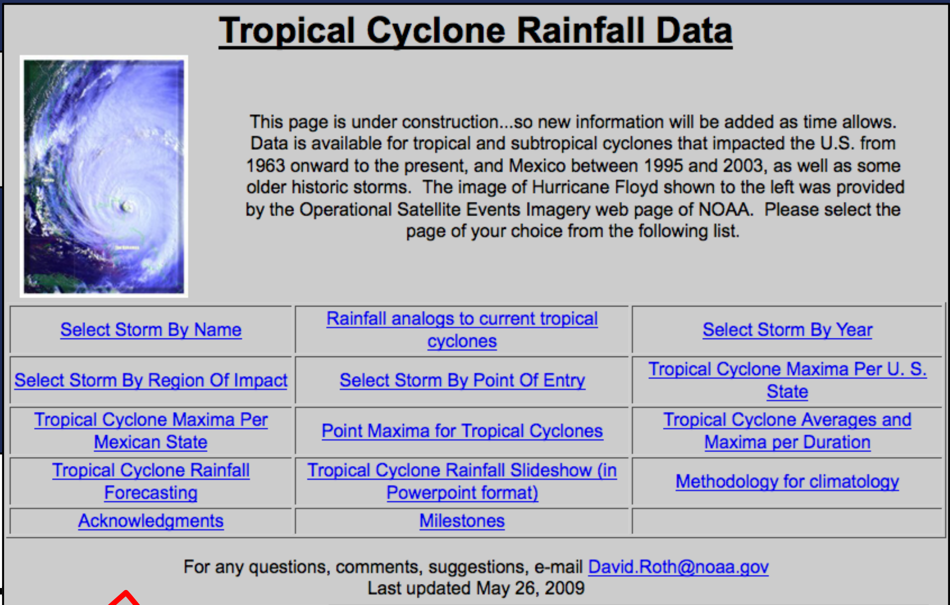
Look at:

- The current rain shield size and compare it to TCs from the past
- How fast is the TC moving?
- Vertical wind shear in current/past events?
- Look for storms with similar or parallel tracks
- Is topography a consideration?
- Look for nearby fronts and examines the depth of nearby upper troughs for current event and possible analogs

Not all TC events will have a useful analog

Tropical Cyclone Rainfall Data

http://www.wpc.ncep.noaa.gov/tropical/rain/tcrainfall.html



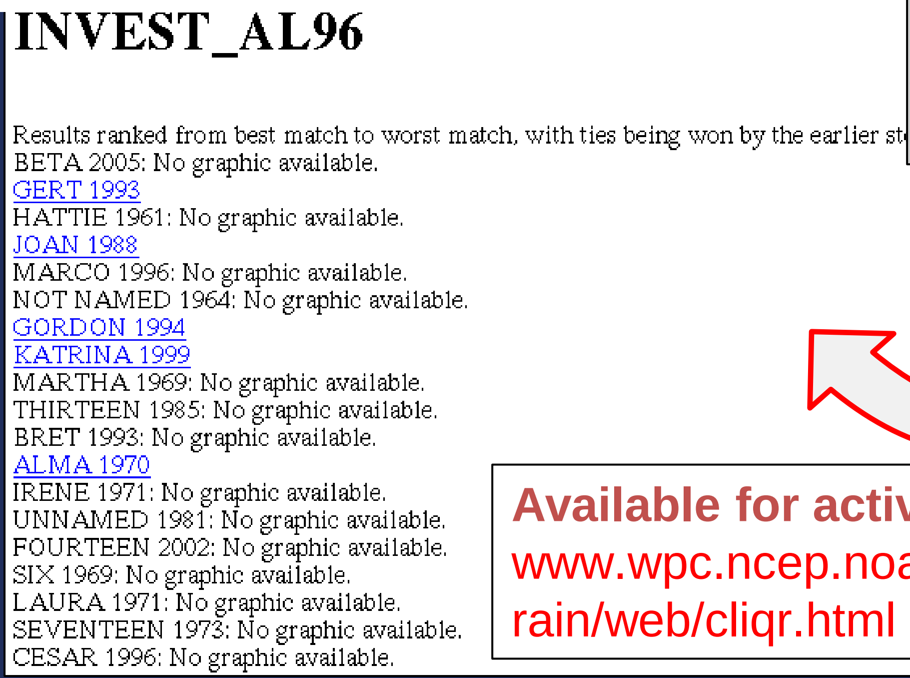
Tropical Cyclone Rainfall Data

This page is under construction...so new information will be added as time allows. Data is available for tropical and subtropical cyclones that impacted the U.S. from 1963 onward to the present, and Mexico between 1995 and 2003, as well as some older historic storms. The image of Hurricane Floyd shown to the left was provided by the Operational Satellite Events Imagery web page of NOAA. Please select the page of your choice from the following list.

Select Storm By Name	Rainfall analogs to current tropical cyclones	Select Storm By Year
Select Storm By Region Of Impact	Select Storm By Point Of Entry	Tropical Cyclone Maxima Per U. S. State
Tropical Cyclone Maxima Per Mexican State	Point Maxima for Tropical Cyclones	Tropical Cyclone Averages and Maxima per Duration
Tropical Cyclone Rainfall Forecasting	Tropical Cyclone Rainfall Slideshow (in Powerpoint format)	Methodology for climatology
Acknowledgments	Milestones	

For any questions, comments, suggestions, e-mail David.Roth@noaa.gov
Last updated May 26, 2009

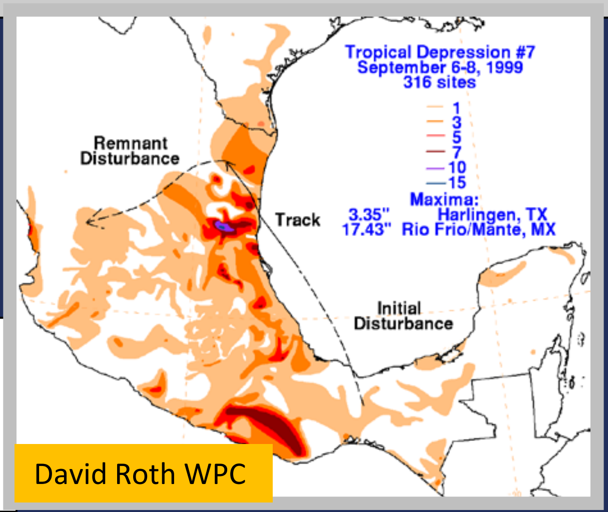
CLIQR Matching TC List (Rainfall Matches Accessible via Hyperlink)



INVEST_AL96

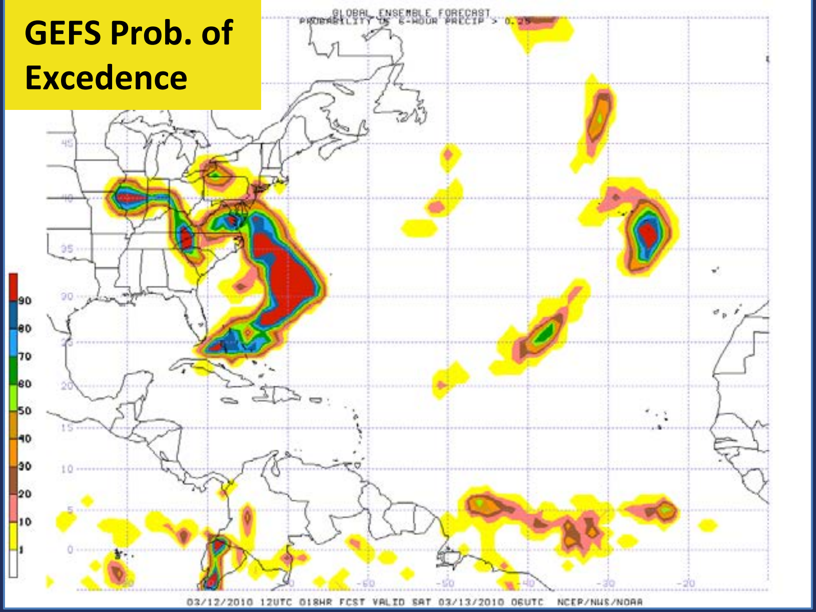
Results ranked from best match to worst match, with ties being won by the earlier st
BETA 2005: No graphic available.
GERT 1993
HATTIE 1961: No graphic available.
JOAN 1988
MARCO 1996: No graphic available.
NOT NAMED 1964: No graphic available.
GORDON 1994
KATRINA 1999
MARTHA 1969: No graphic available.
THIRTEEN 1985: No graphic available.
BRET 1993: No graphic available.
ALMA 1970
IRENE 1971: No graphic available.
UNNAMED 1981: No graphic available.
FOURTEEN 2002: No graphic available.
SIX 1969: No graphic available.
LAURA 1971: No graphic available.
SEVENTEEN 1973: No graphic available.
CESAR 1996: No graphic available.

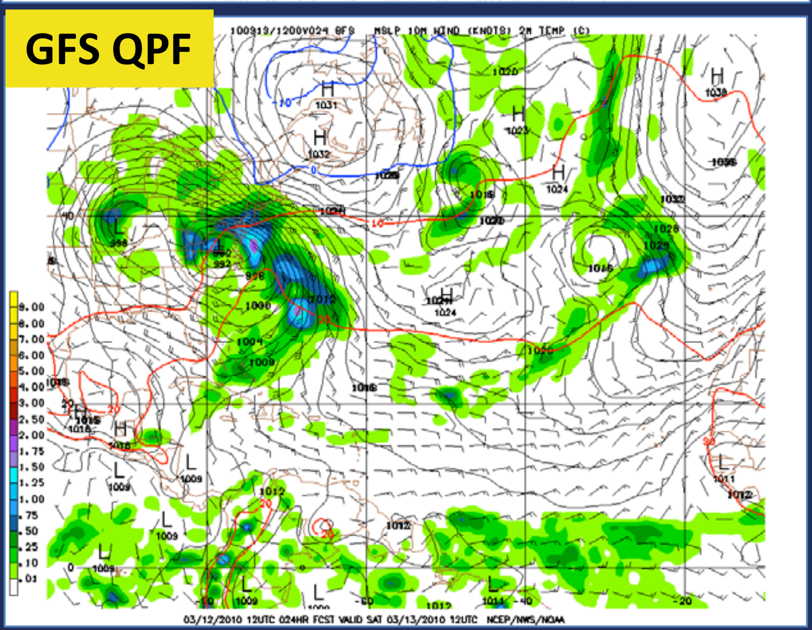
Available for active TCs at:
www.wpc.ncep.noaa.gov/tropical/rain/web/cliqr.html



David Roth WPC

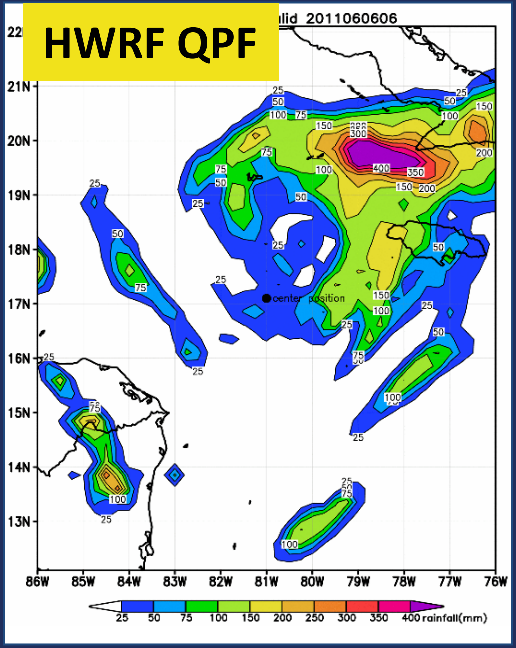
Model Forecasts


GEFS Prob. of Excedence


GFS QPF

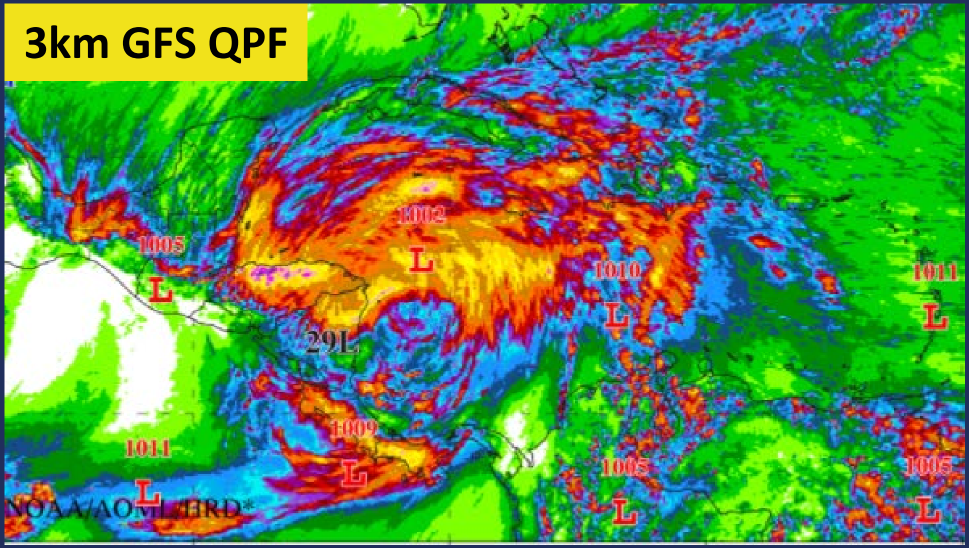
Global deterministic models, global ensemble means and probabilities, hurricane models, high resolution models

- GFS, NAM, GEFS
- ECMWF, ECMWF ensemble
- HWRF/HMON
- UKMET
- GEM

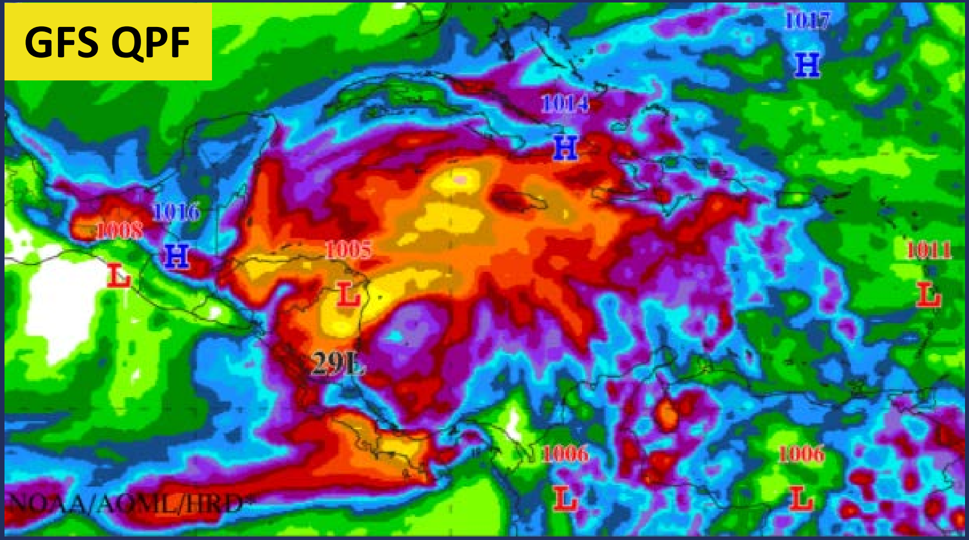

HWRF QPF

Model Forecasts

3km GFS QPF



GFS QPF



High resolution convective allowing models (CAMs) have many advantages:

- Resolve convective rain bands better than global models
- Better depiction of orographic enhancement and rain shadowing
- Better signal of potential upper bound of rainfall magnitudes
- Coverage and availability of CAMs should continue to increase over the coming years

Where to Find Model QPFs

- **NCEP models (GFS, NAM, GEFS, NAEFS) including tropical guidance (HWRF and HMON)**

http://mag.ncep.noaa.gov

- **ECMWF**

https://www.ecmwf.int/en/forecasts/charts

- **Pivotal Weather**

https://www.pivotalweather.com/model.php

- **Tropical Tidbits**

https://www.tropicaltidbits.com/analysis/models/

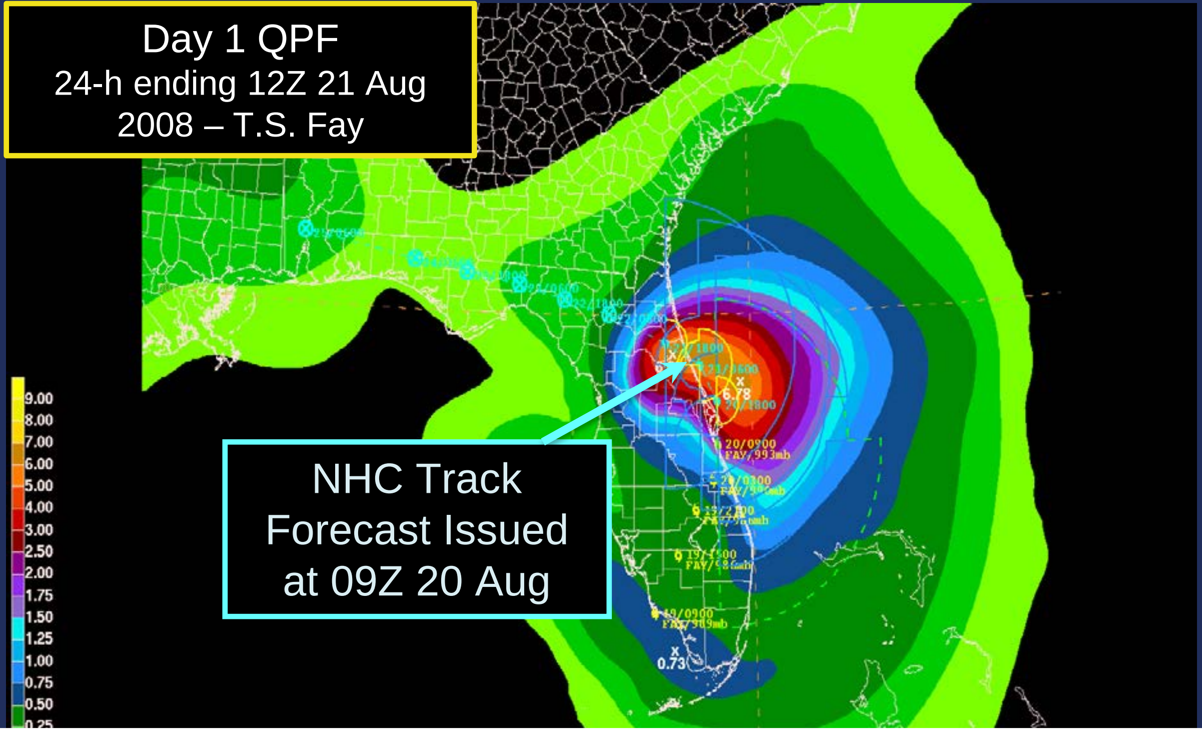
- **HWRF/HMON/ experimental guidance**

https://www.emc.ncep.noaa.gov/gc_wmb/vxt/HWRF/index.php
https://storm.aoml.noaa.gov/viewer/

TC QPF Forecast Process

Production of Tropical Cyclone Quantitative Precipitation Forecasts

A good place to start is the model closest to the NHC track forecast



Day 1 QPF
24-h ending 12Z 21 Aug 2008 – T.S. Fay

NHC Track Forecast Issued at 09Z 20 Aug

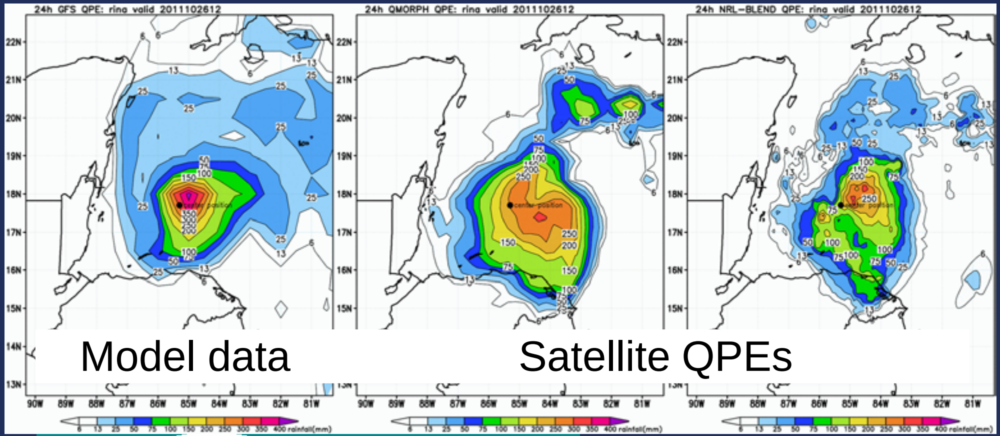
Model trends are important. Look at last several runs of a particular model to see if a persistent trend is seen.

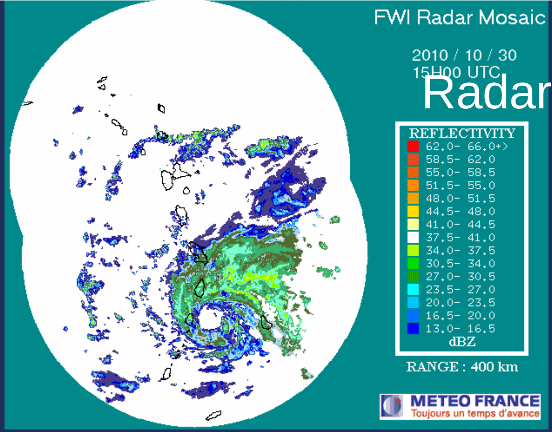
Run to run consistency and model to model consistency can increase confidence

> **“a primary determinant of tropical cyclone QPF errors is track forecast error”**
> **– Marchok et al 2007**

Production of Tropical Cyclone Quantitative Precipitation Forecasts

Use observations and recent model data to determine the current structure/rainfall rates

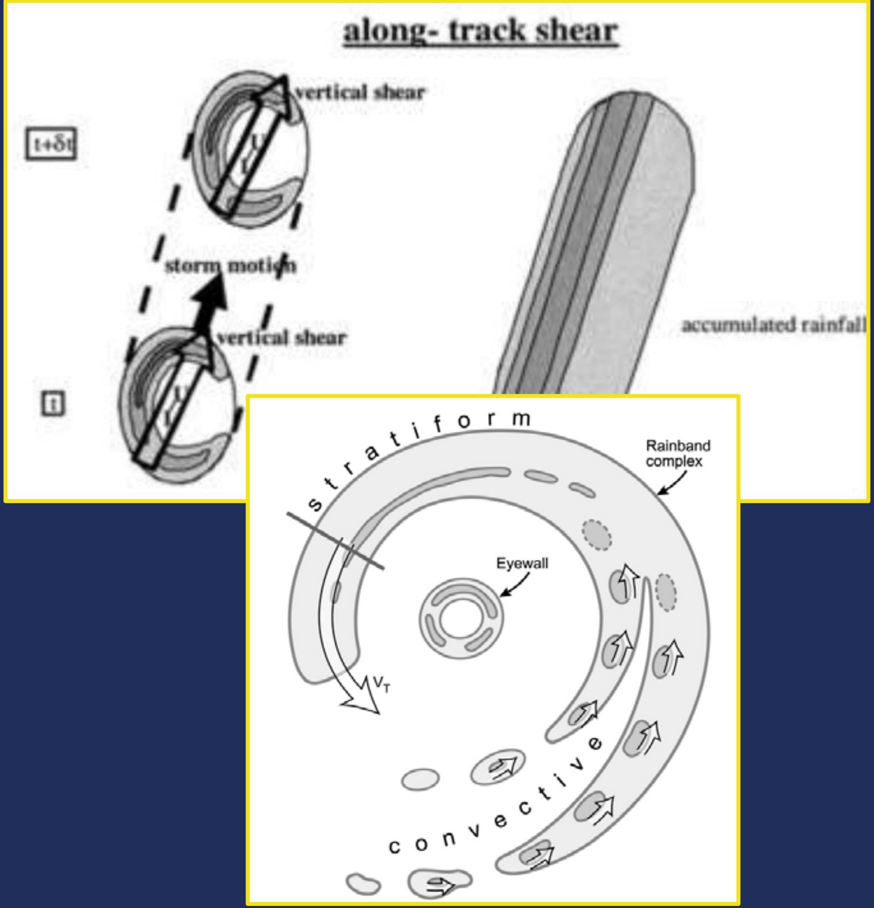




- **Do the models have a good handle on the current storm structure?**
- **If yes, then more trust in model QPF forecasts going forward**
- **If not, adjustments to the models may be needed. Is the structure expected to change?**
- **Models tend to struggle most with structure during the developmental phase of a system and with weaker/disorganized systems**

Production of Tropical Cyclone Quantitative Precipitation Forecasts

Use conceptual models and pattern recognition to further adjust QPF as needed



- **Model QPF forecasts have improved considerably over the last couple decades**

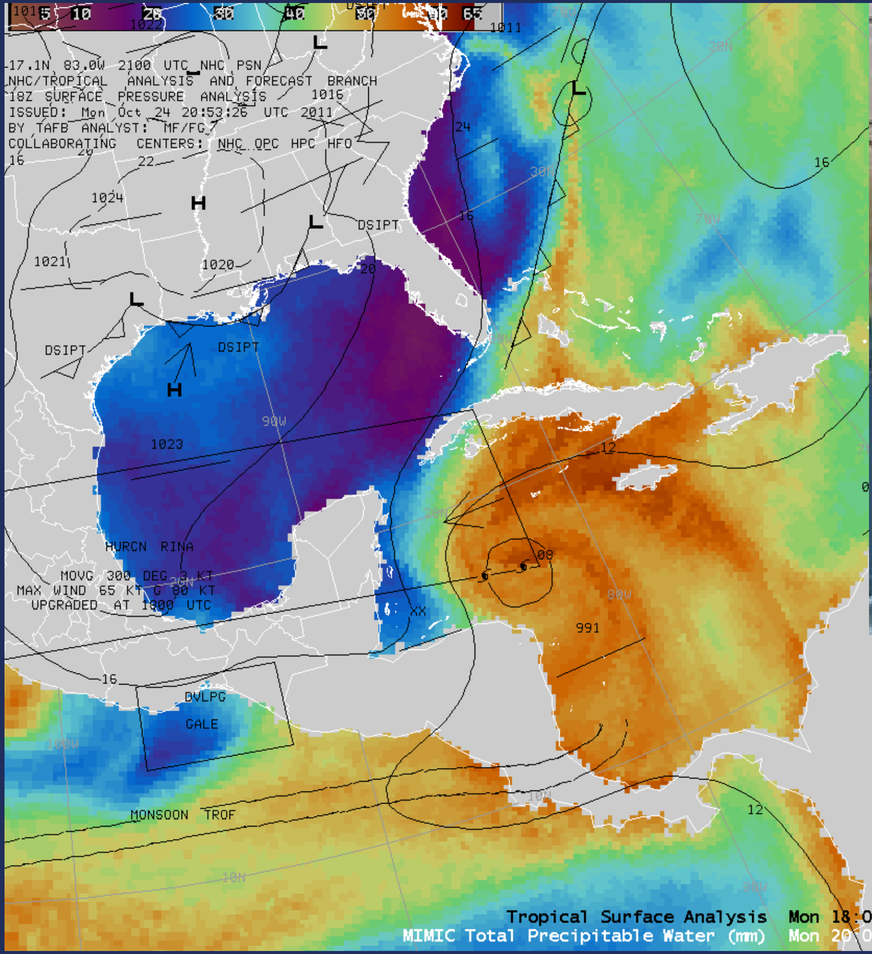
- **Often have a good handle on approximate magnitudes and placement of higher QPF (left or right of track)**

- **However, conceptual models and pattern recognition can become important when models are not properly depicting the initial structure/size/intensity of the storm**

- **Higher res models generally better for resolving convective banding location and amounts**

Production of Tropical Cyclone Quantitative Precipitation Forecasts

Locate relevant synoptic scale and meso-scale boundaries

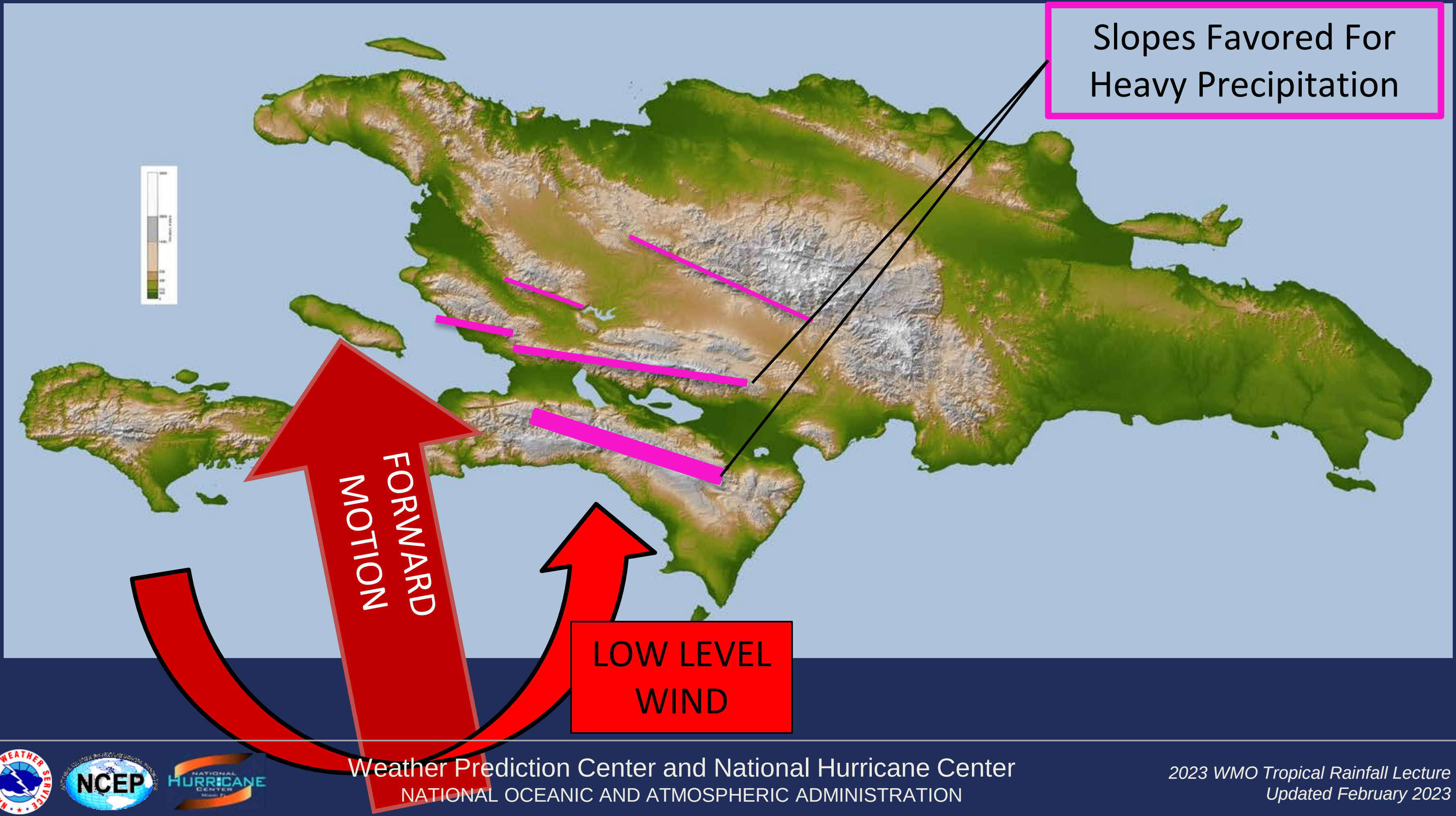


Tropical Surface Analysis Mon 18:00Z 24-Oct-11
MIMIC Total Precipitable Water (mm) Mon 20:00Z 24-Oct-11

Hurricane Rina (2011)

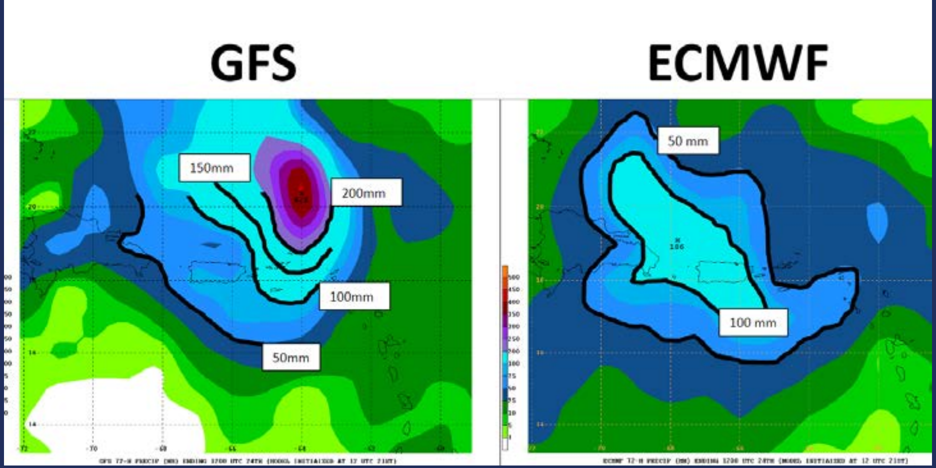
Production of Tropical Cyclone Quantitative Precipitation Forecasts

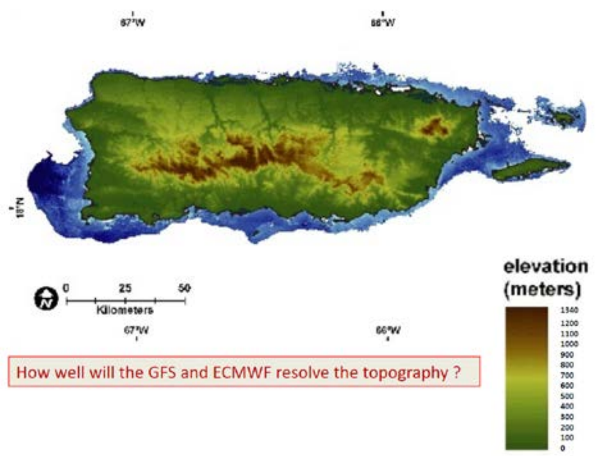
Identify areas of orographic enhancement



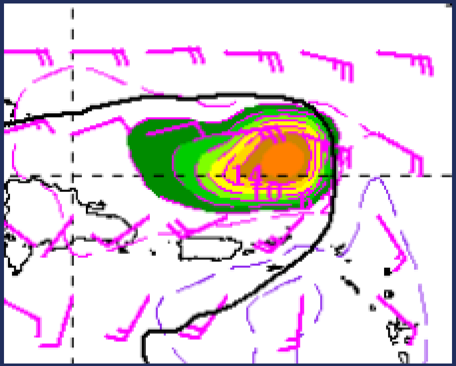
Production of Tropical Cyclone Quantitative Precipitation Forecasts

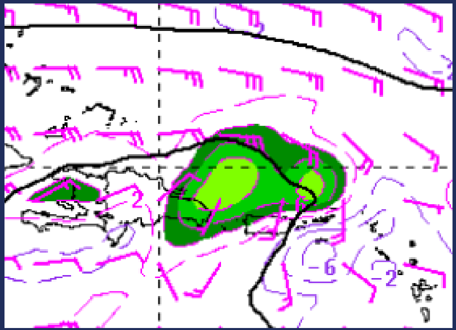
Importance of track and wind direction in areas of terrain

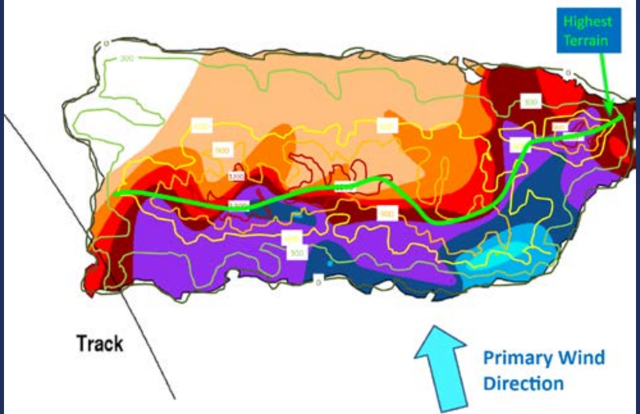




How well will the GFS and ECMWF resolve the topography ?

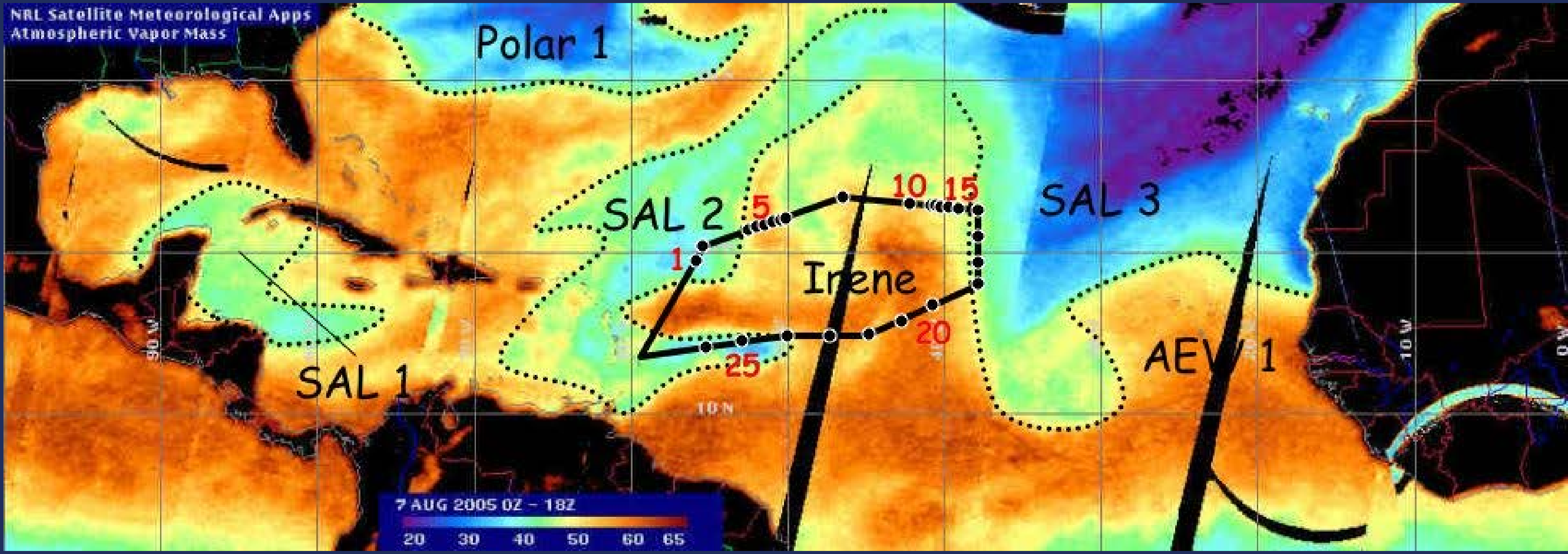




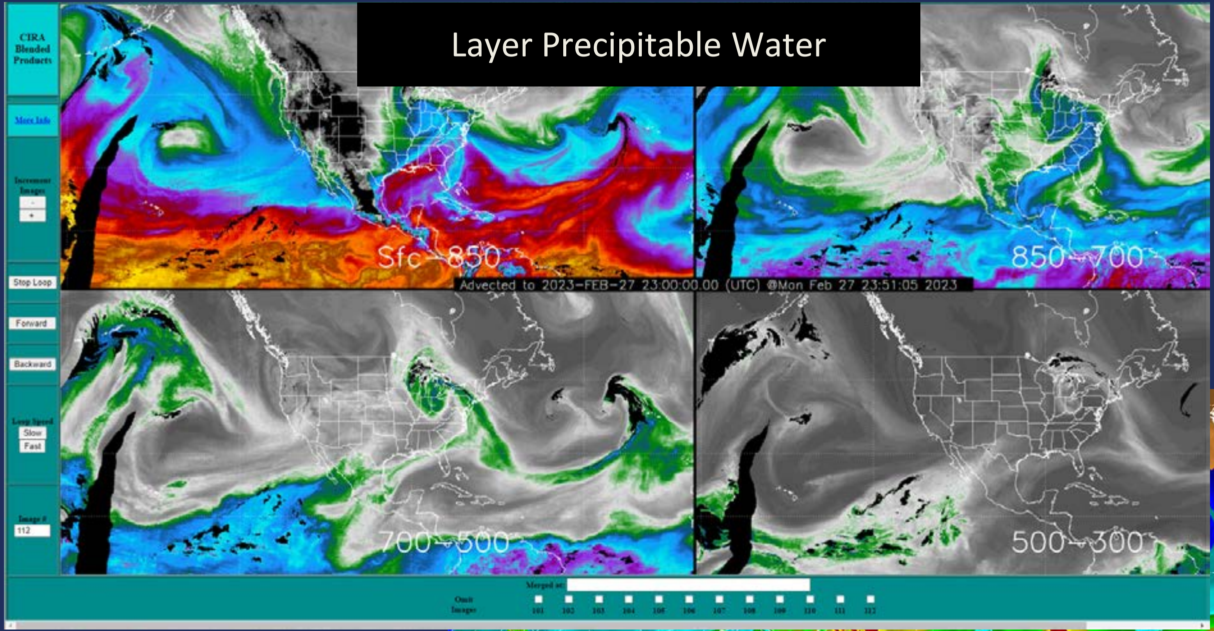


Production of Tropical Cyclone Related QPF

Determine how a change in available moisture could increase, decrease, or redistribute rainfall



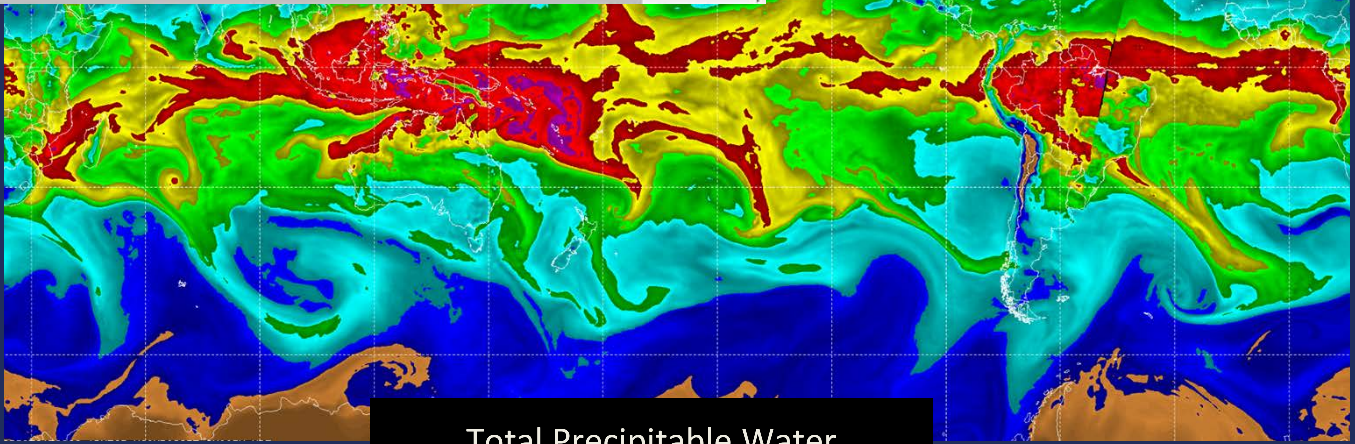
Available Moisture



Layer Precipitable Water

http://cat.cira.colostate.edu/SPoRT/Layered/Advected/ALPW_Hourly.htm

http://cdat.cira.colostate.edu/CAT/aTPW/aTPW.htm



Total Precipitable Water

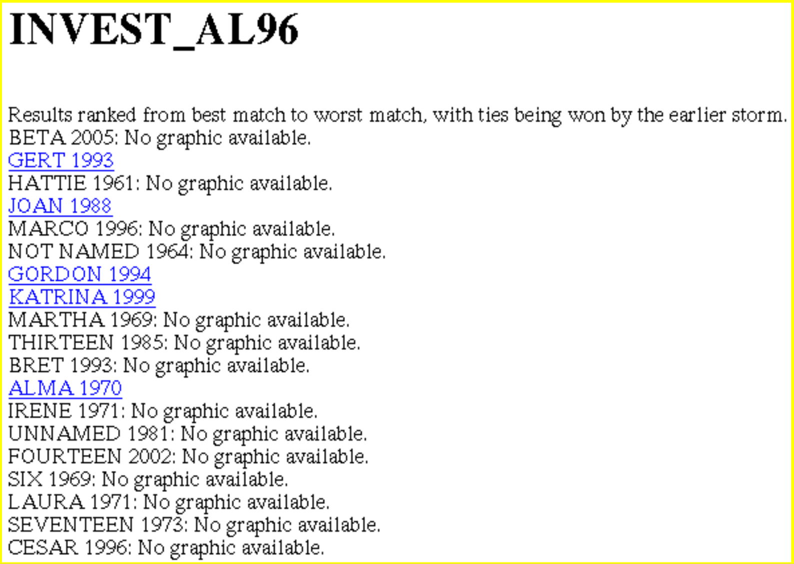
All else equal, higher TPW means more potential for heavier rainfall

High PW in multiple layers supports more efficient rainfall

Production of Tropical Cyclone Related QPF

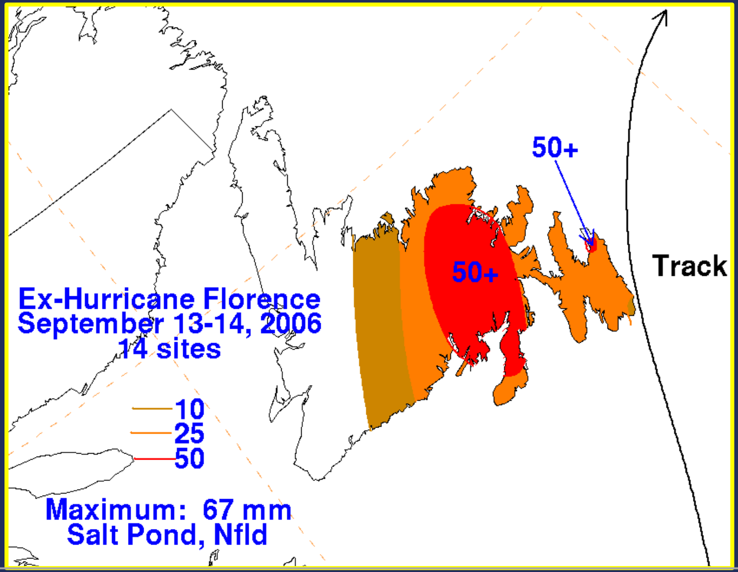
Use climatology (CLIQR, R-CLIPER, TC Rainfall Climatology) and data from past storms to:

- Increase/decrease amounts
- Adjust numerical guidance biases
- Reality check
- Highlight areas significantly impacted by terrain effects



INVEST_AL96

Results ranked from best match to worst match, with ties being won by the earlier storm.
BETA 2005: No graphic available.
GERT 1993
HATTIE 1961: No graphic available.
JOAN 1988
MARCO 1996: No graphic available.
NOT NAMED 1964: No graphic available.
GORDON 1994
KATRINA 1999
MARTHA 1969: No graphic available.
THIRTEEN 1985: No graphic available.
BRET 1993: No graphic available.
ALMA 1970
IRENE 1971: No graphic available.
UNNAMED 1981: No graphic available.
FOURTEEN 2002: No graphic available.
SIX 1969: No graphic available.
LAURA 1971: No graphic available.
SEVENTEEN 1973: No graphic available.
CESAR 1996: No graphic available.



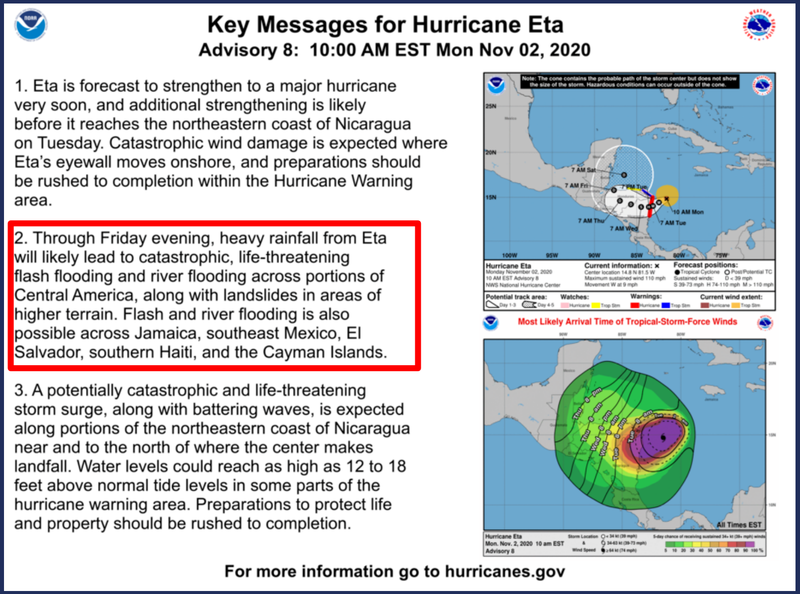
Summary

- Remember factors that influence TC rainfall
  - Size of storm, time of day, speed etc.
- Evaluate quality of the model data compared to 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
  - Satellite rainfall products, NWP models, etc.
- Remember, heavy rain can also occur well away from the TC itself
  - PREs, secondary disturbances, CAG, etc.

Role of the Weather Prediction Center (WPC)

WPC responsible for the wording of the rainfall statement included within NHC public advisories (TCP) beginning in 2005

- WPC produces QPF and excessive rainfall graphics for systems impacting the CONUS
- For all other NHC systems WPC is responsible for the rainfall statement and Key Message related to rainfall hazards
- The WPC Senior Branch Forecaster (SBF) is responsible for issuing these products in coordination with the WPC International Desk (ID). More info on that desk next.
- WPC SBF also coordinates these products with NHC and the NWC (for systems impacting Puerto Rico/Hawaii or CONUS)



Key Messages for Hurricane Eta
Advisory 8: 10:00 AM EST Mon Nov 02, 2020

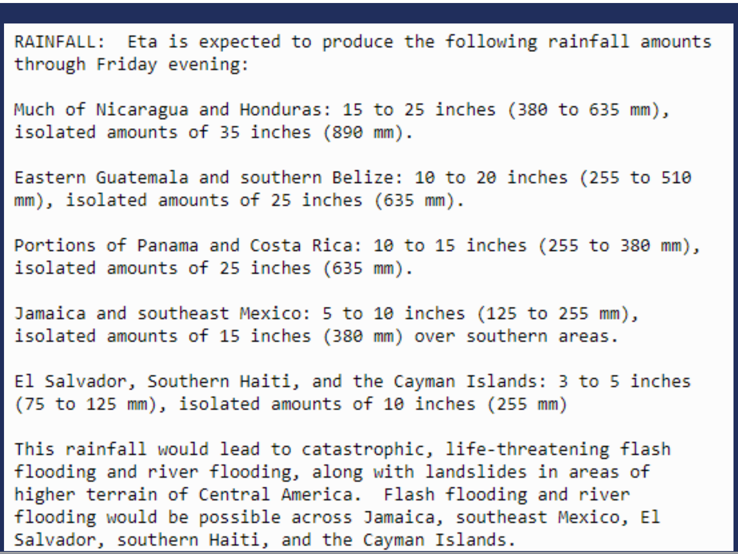
1. Eta is forecast to strengthen to a major hurricane very soon, and additional strengthening is likely before it reaches the northeastern coast of Nicaragua on Tuesday. Catastrophic wind damage is expected where Eta's eyewall moves onshore, and preparations should be rushed to completion within the Hurricane Warning area.

2. Through Friday evening, heavy rainfall from Eta will likely lead to catastrophic, life-threatening flash flooding and river flooding across portions of Central America, along with landslides in areas of higher terrain. Flash and river flooding is also possible across Jamaica, southeast Mexico, El Salvador, southern Haiti, and the Cayman Islands.

3. A potentially catastrophic and life-threatening storm surge, along with battering waves, is expected along portions of the northeastern coast of Nicaragua near and to the north of where the center makes landfall. Water levels could reach as high as 12 to 18 feet above normal tide levels in some parts of the hurricane warning area. Preparations to protect life and property should be rushed to completion.

Most Likely Arrival Time of Tropical-Storm-Force Winds

For more information go to hurricanes.gov



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RAINFALL:  Eta is expected to produce the following rainfall amounts
through Friday evening:

Much of Nicaragua and Honduras: 15 to 25 inches (380 to 635 mm),
isolated amounts of 35 inches (890 mm).

Eastern Guatemala and southern Belize: 10 to 20 inches (255 to 510
mm), isolated amounts of 25 inches (635 mm).

Portions of Panama and Costa Rica: 10 to 15 inches (255 to 380 mm),
isolated amounts of 25 inches (635 mm).

Jamaica and southeast Mexico: 5 to 10 inches (125 to 255 mm),
isolated amounts of 15 inches (380 mm) over southern areas.

El Salvador, Southern Haiti, and the Cayman Islands: 3 to 5 inches
(75 to 125 mm), isolated amounts of 10 inches (255 mm)

This rainfall would lead to catastrophic, life-threatening flash
flooding and river flooding, along with landslides in areas of
higher terrain of Central America.  Flash flooding and river
flooding would be possible across Jamaica, southeast Mexico, El
Salvador, southern Haiti, and the Cayman Islands.
```

Role of the WPC International Desks (ID)

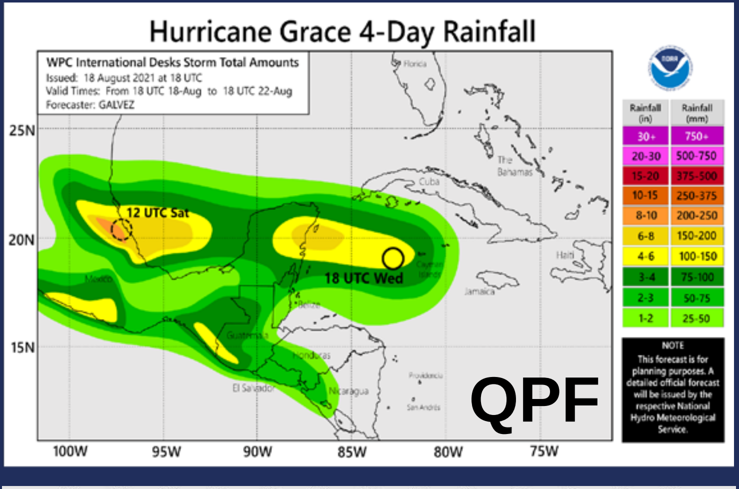
Provide support to Caribbean and Central American nations by producing products similar to those for the US

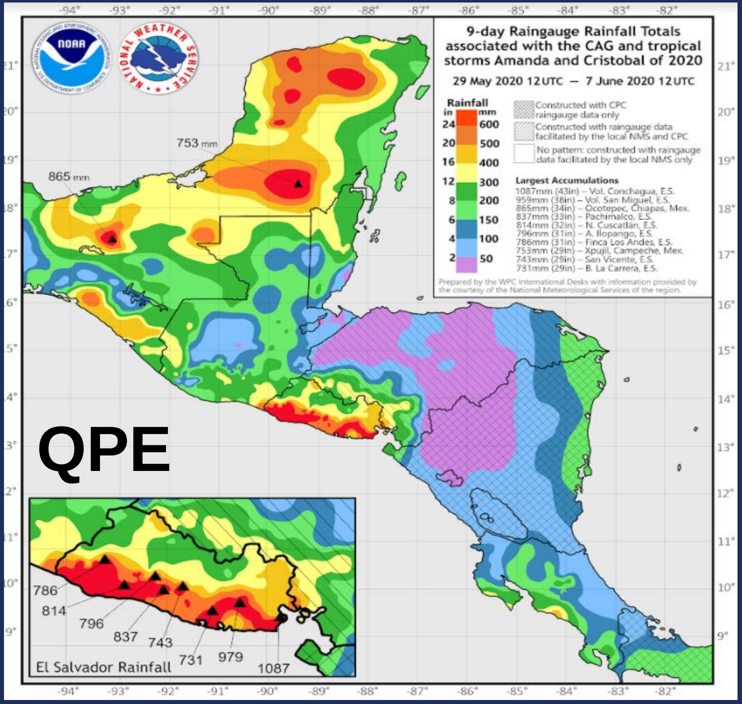
1) QPF Charts:

- Coordinated with NHC and WPC SBF.
- Charts follow WPC/NHC formats.
- Non-official forecasts, but they are largely valued by RA-IV NWS as tools to produce their official QPF; and by USAID and US SOUTHCOM for planning purposes.

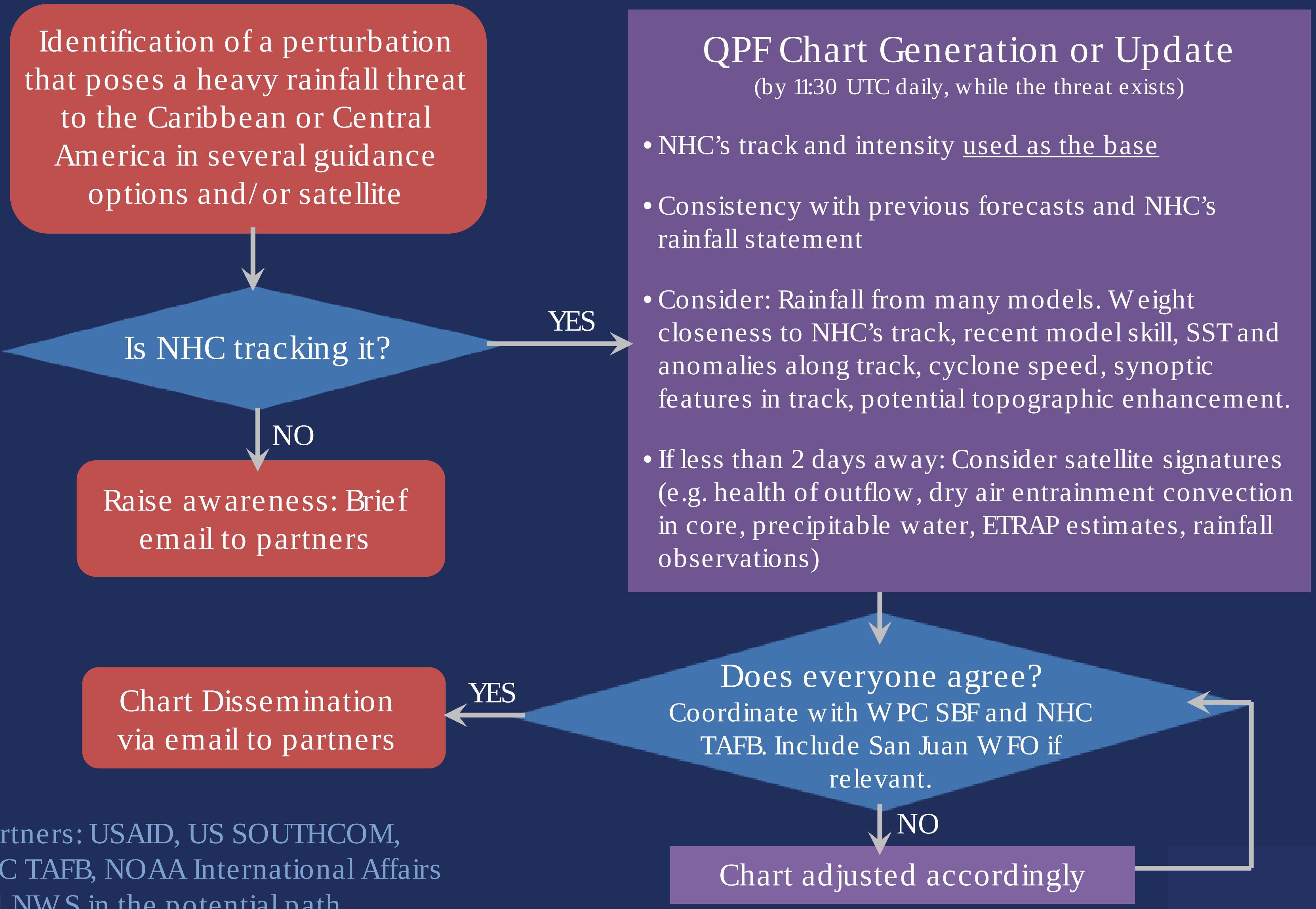
2) Input to NHC’s rainfall statements for non-US locations

3) Help generating or coordinating the generation of QPE charts.





Steps to generate an ID QPF Chart



Identification of a perturbation that poses a heavy rainfall threat to the Caribbean or Central America in several guidance options and/or satellite

Is NHC tracking it?

NO

Raise awareness: Brief email to partners

YES

QPF Chart Generation or Update

(by 11:30 UTC daily, while the threat exists)

- NHC's track and intensity used as the base
- Consistency with previous forecasts and NHC's rainfall statement
- Consider: Rainfall from many models. Weight closeness to NHC's track, recent model skill, SST and anomalies along track, cyclone speed, synoptic features in track, potential topographic enhancement.
- If less than 2 days away: Consider satellite signatures (e.g. health of outflow, dry air entrainment convection in core, precipitable water, ETRAP estimates, rainfall observations)

Does everyone agree?
Coordinate with WPC SBF and NHC TAFB. Include San Juan WFO if relevant.

YES

Chart Dissemination via email to partners

NO

Chart adjusted accordingly

*Partners: USAID, US SOUTHCOM, NHC TAFB, NOAA International Affairs and NWS in the potential path.

Thank You

Questions?