Hurricane Hazards:
Local Threat Assessments

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2019 WMO RA-IV WORKSHOP ON HURRICANE FORECASTING AND WARNING

Outline

- Risk Tolerance & the Safety Margin Forecast
  - How it relates to probabilistic information
  - Customer thresholds; risk management for communities

- The Local Forecast & Hazard Threat Assessments
  - Deterministic and probabilistic information; threat assessments
    - Wind, Storm Surge, and Flooding Rain Hazards
    - Role of risk tolerance and safety margin forecast
  - *Examples:* Hurricane Threats & Potential Impacts Graphics (HTI), storm surge watch/warning graphic, inundation graphic, decision assistance tools, etc.

Threat *vs.* Risk

- **Threat -** As used in this presentation, refers to assessing the likelihood that something harmful may occur
  - such as hurricane wind speeds at a given community

- **Risk** - the potential of gaining or losing something of value

- **Actual Risk = Probability × Consequence × Vulnerability**
  - When the threat of a hazard is considered in terms of potential impacts it might inflict in context of a given community's vulnerability

Actual Risk ≠ Perceived Risk (Subjective)

Community Decision-Makers

- Risk Tolerance
  - Within a hurricane emergency plan (pre-season)
    1. *"How much risk to the community is acceptable?"*
    2. *"What are the corresponding trigger thresholds/points, and resulting triggered actions?"*
  - As enacted during an actual hurricane emergency
    1. *"What is the latest forecast, and how accurate is it?"*
    2. *"What is a reasonable margin of safety?"*

Decision Support Services

Emergence of Probability Guidance

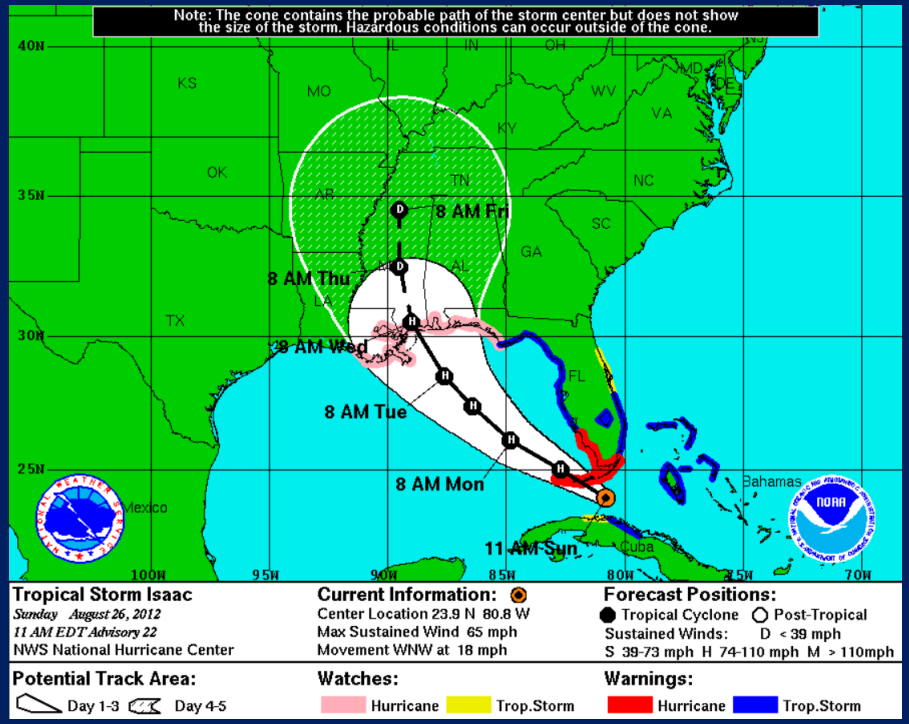
- Using Hazard Probabilities for Decision-Making:
  - *"How can community decision-makers best use it?"*
  - *"How can NWS forecasters best interpret and communicate it for decision support?"*

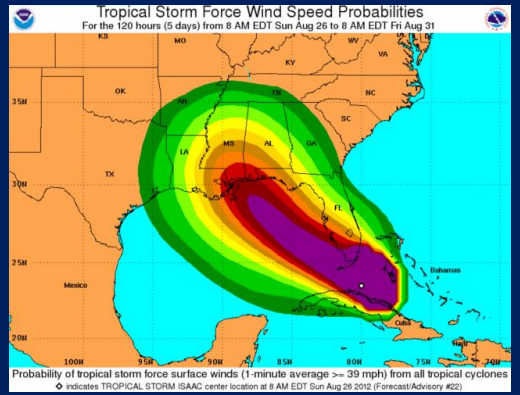
Scenario References:

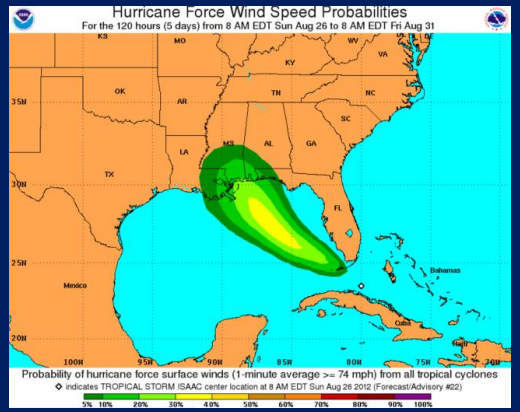
- Most Likely
- Reasonable Worst Case
- Reasonable Best Case

from % exceedance probabilities

***SETUP**: Relative to the spectrum of plausible outcomes, what is a community's wind risk compared to its stated risk tolerance as baselined within its hurricane emergency plan? To what extent should the plan be implemented for the event at hand?*



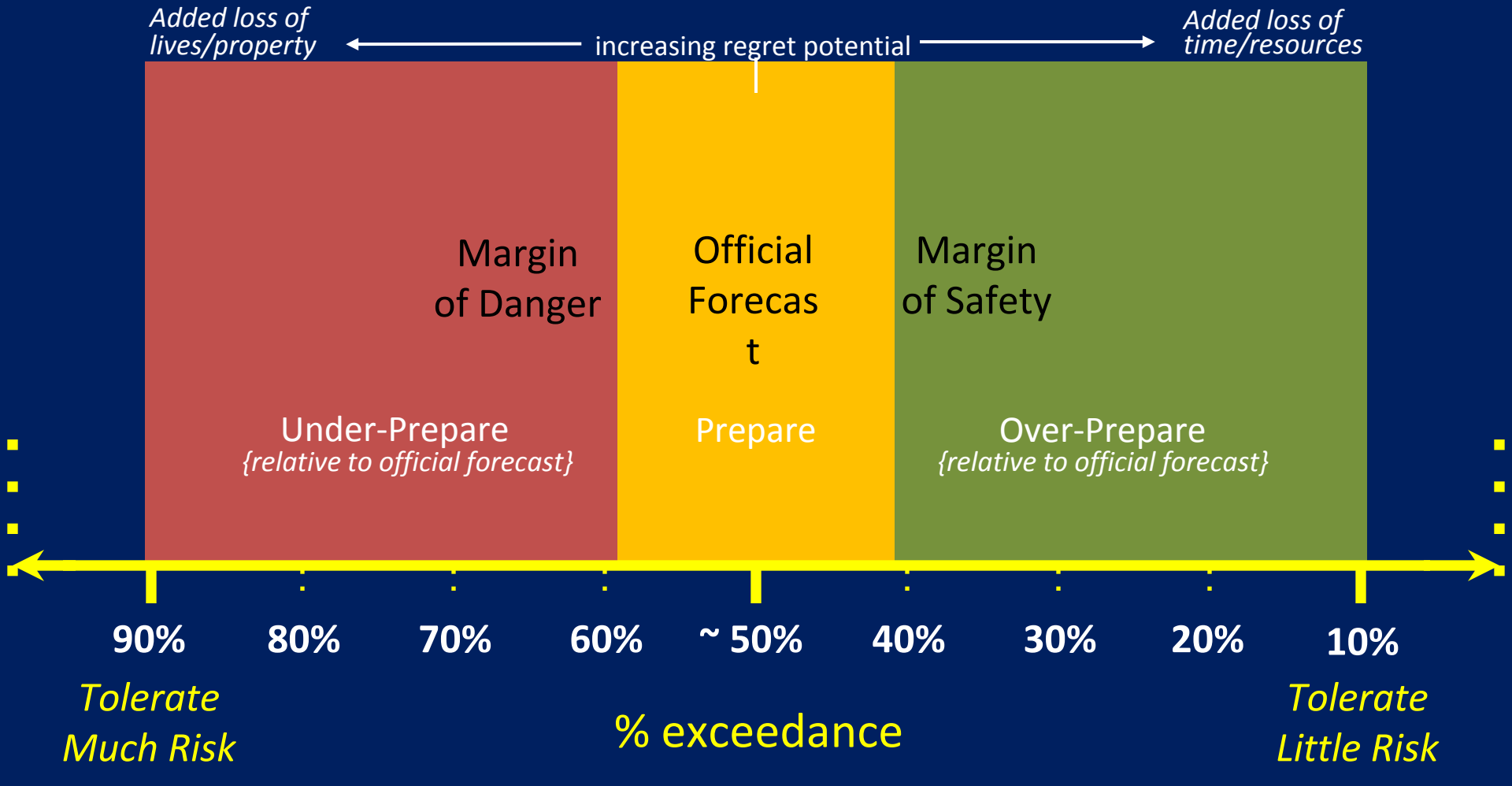




For example … Wind Hazard

Risk Tolerance: Spectrum of Plausible Outcomes (TC Wind)

(in event context; for a given community)



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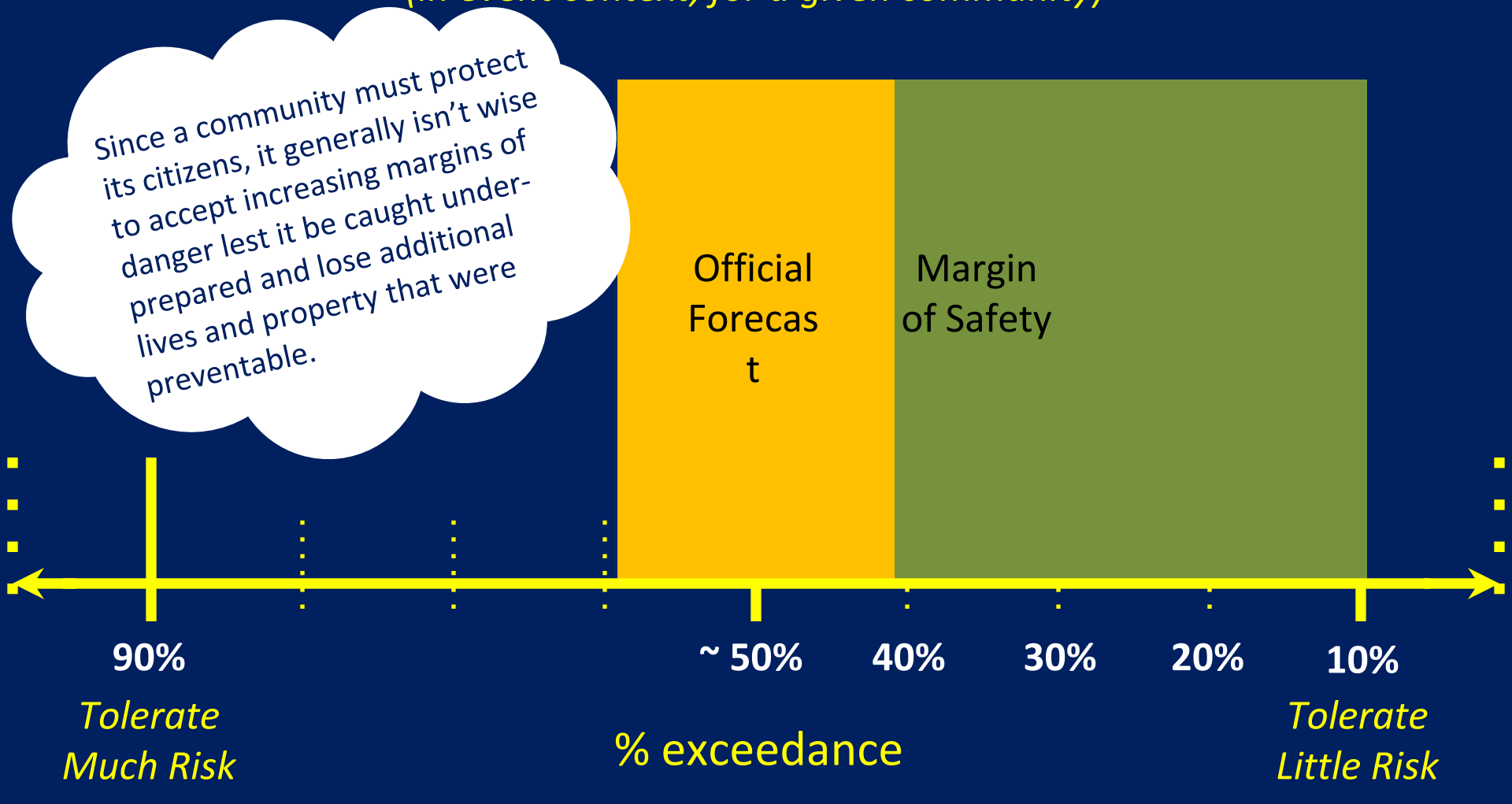

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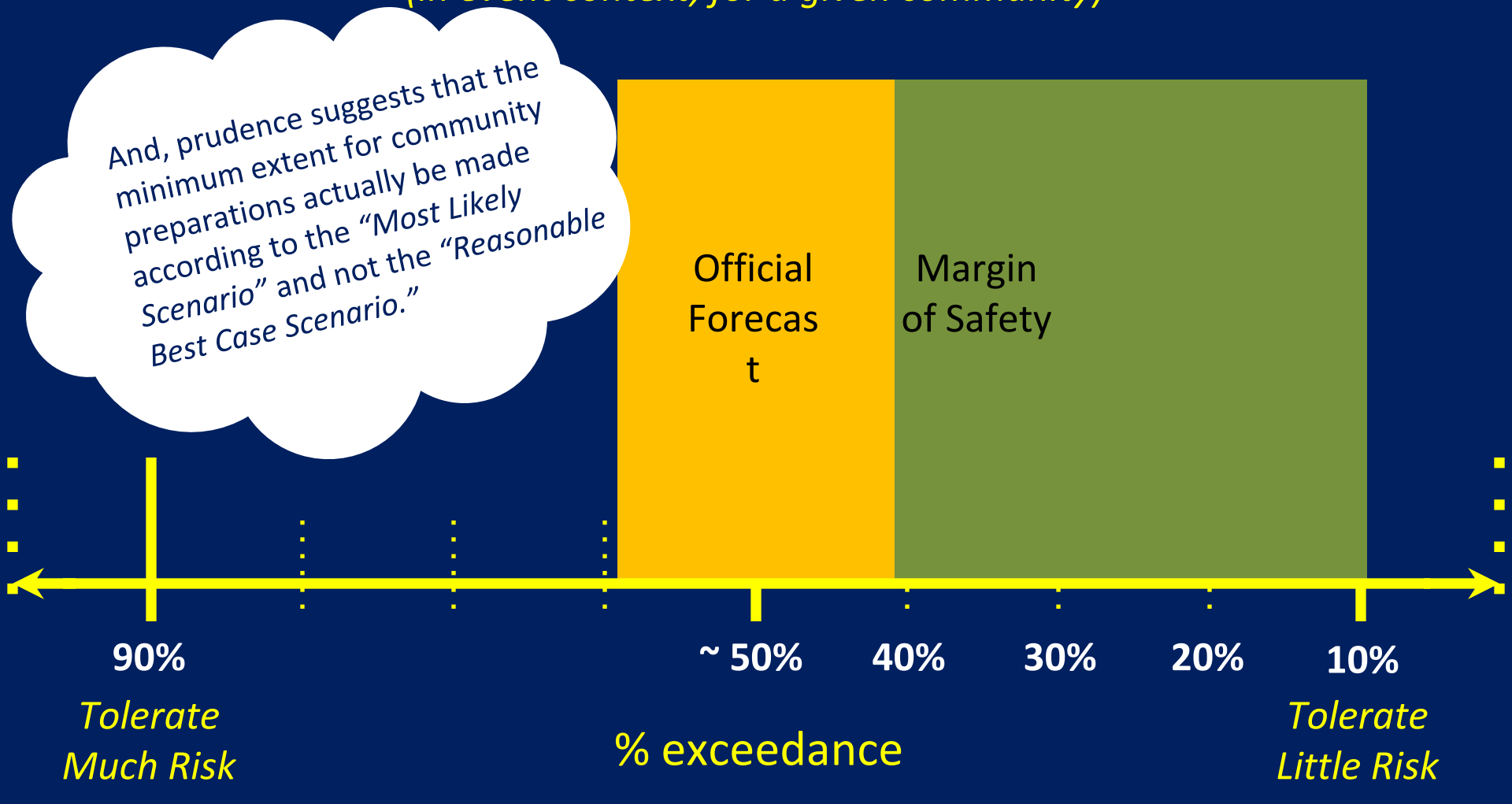

Risk Tolerance: Spectrum of Plausible Outcomes (TC Wind)

(in event context; for a given community)

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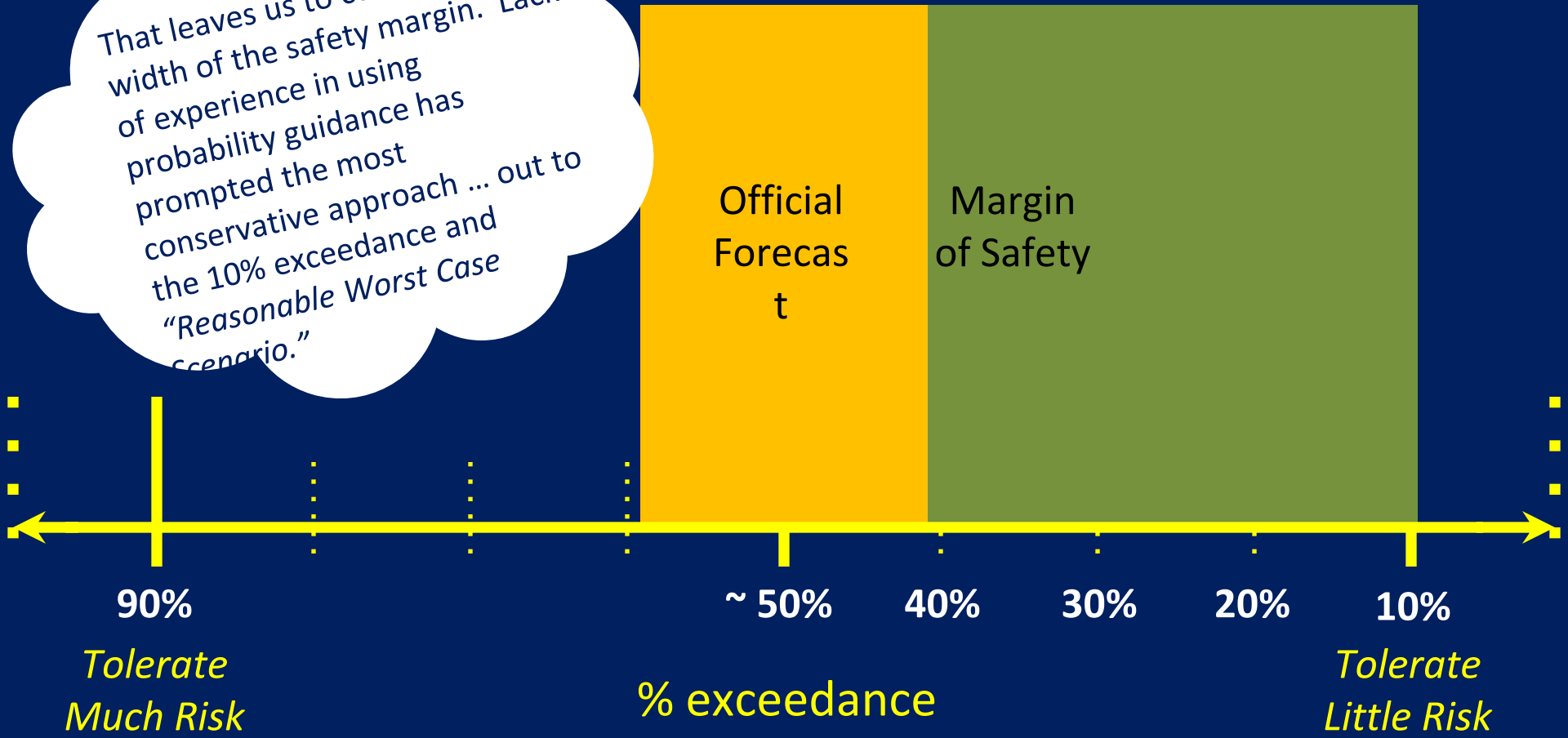

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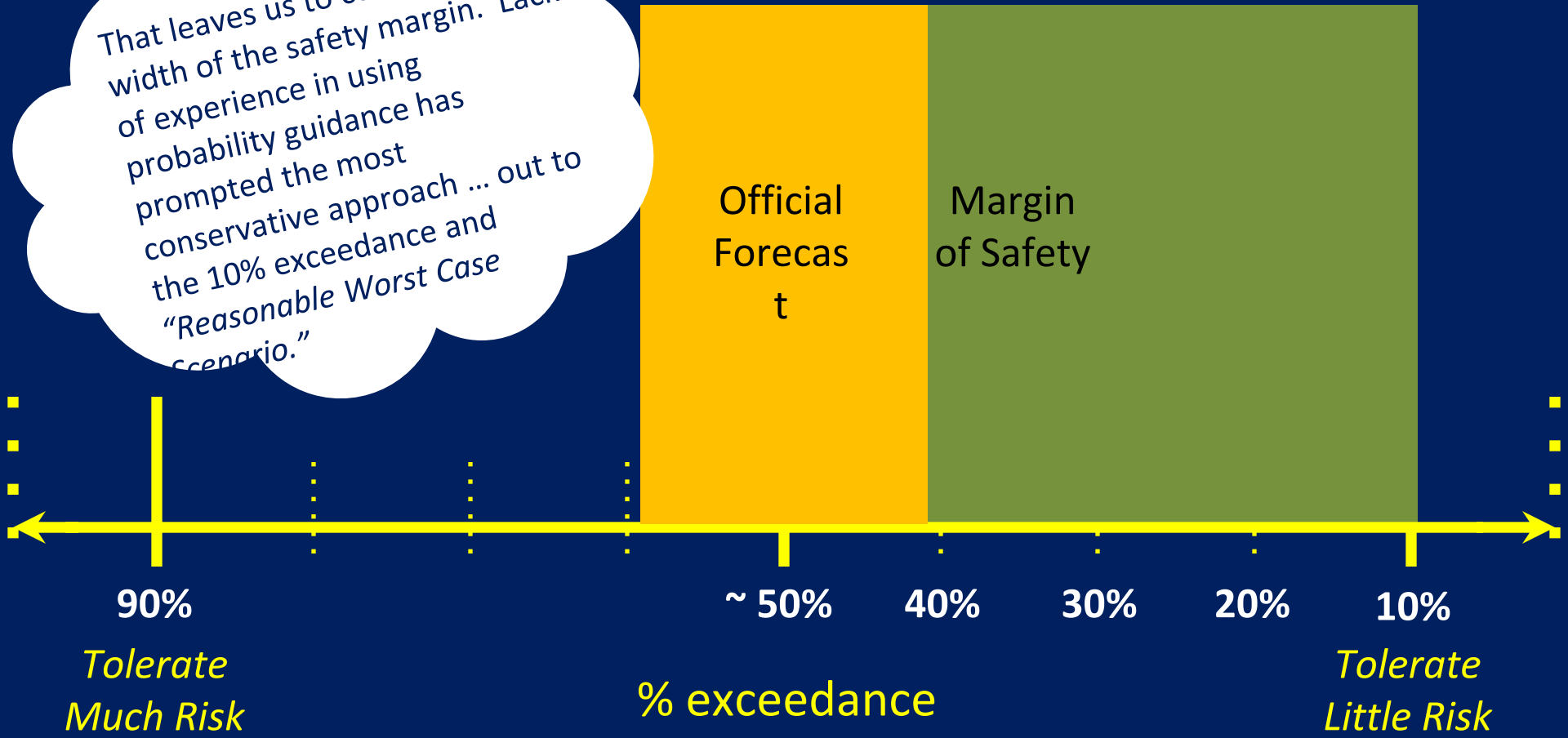

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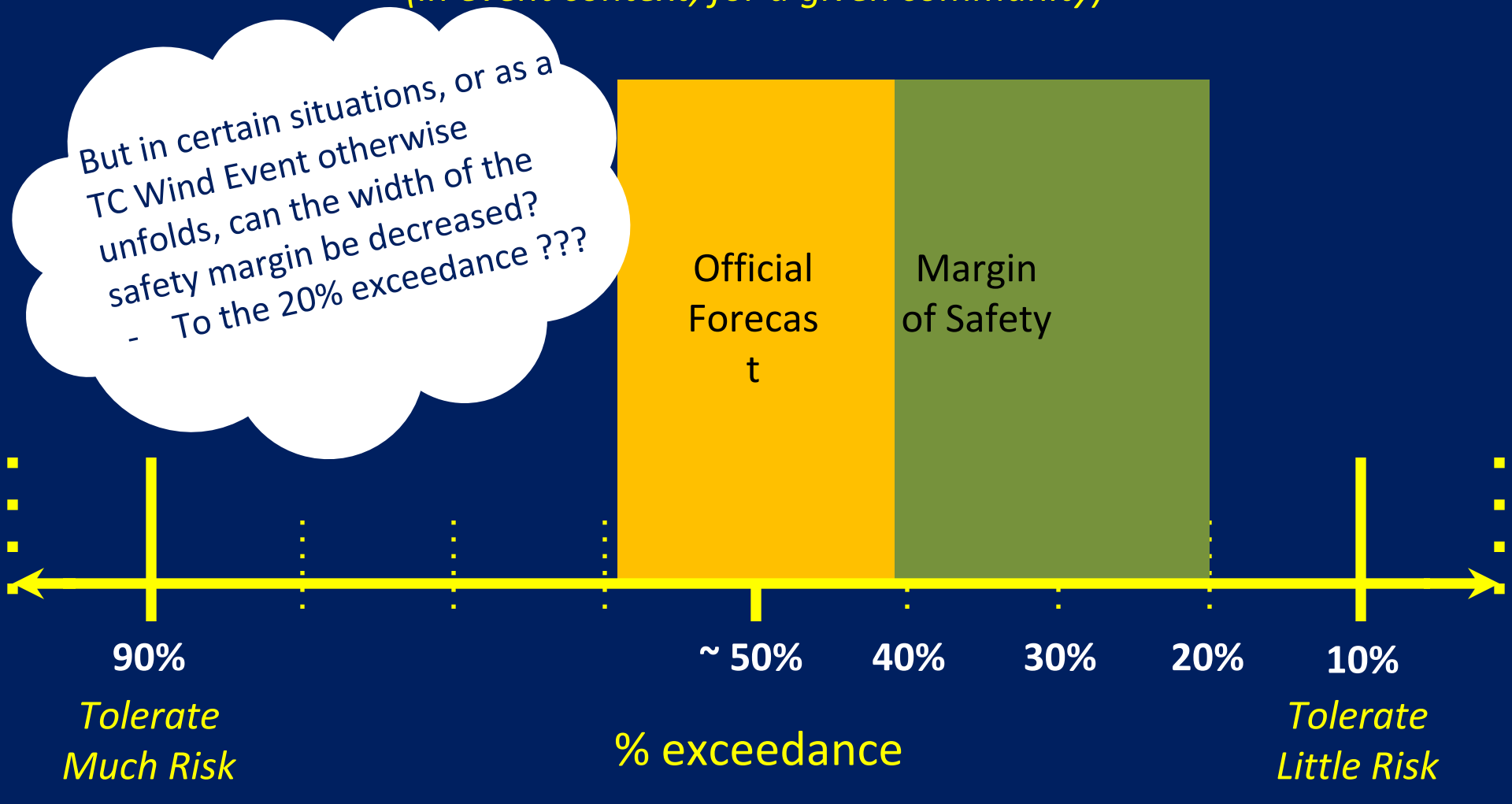

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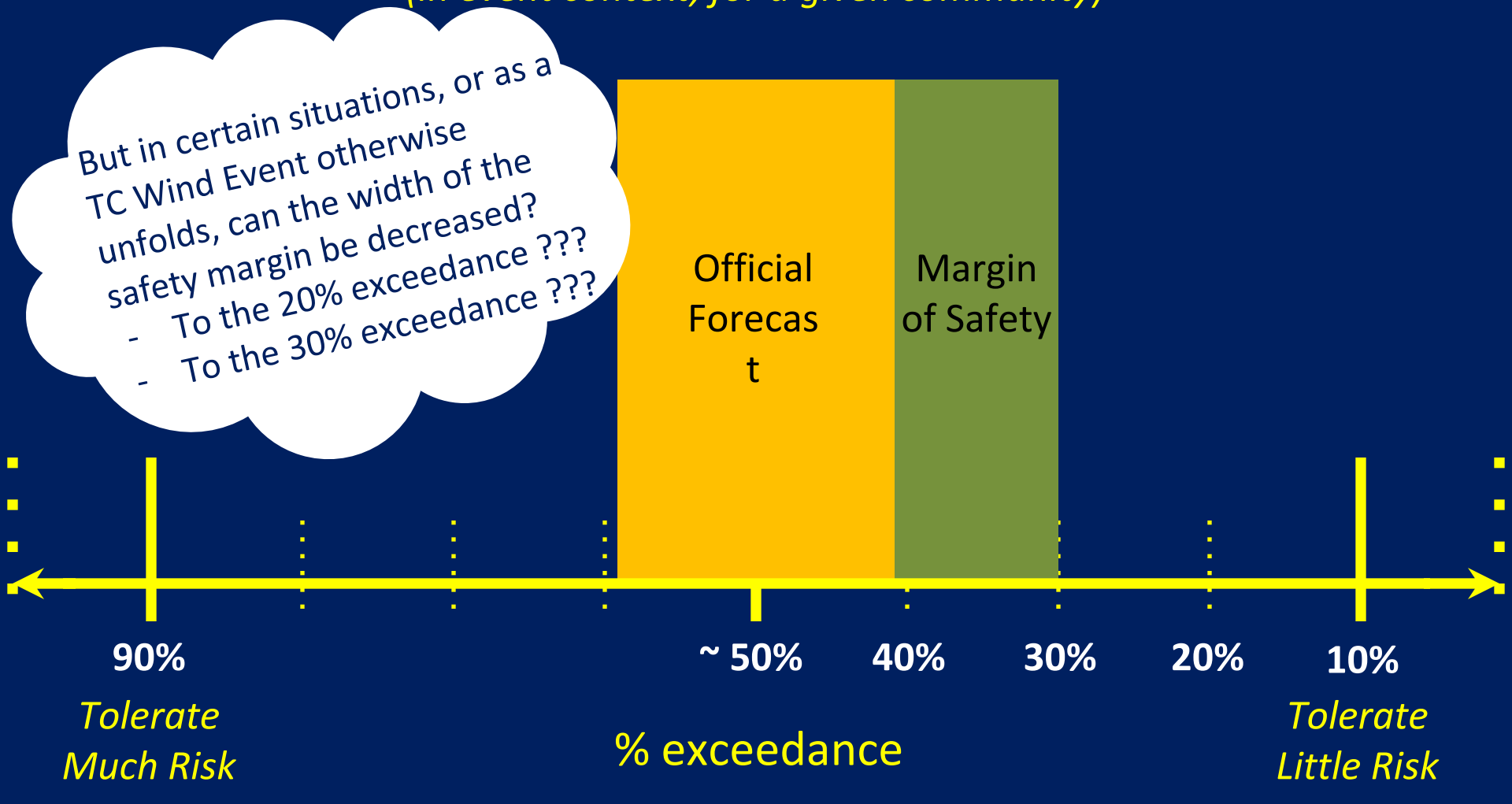


The Safety Margin Forecast

- **10% Exceedance Margin**
  - For preparation phase decisions, for any system within 48 hours of impact event
    - Especially for small/intense or ill-defined/-behaved cyclones
- **20% Exceedance Margin**
  - For refining final preparation phase decisions, for most well-behaved systems within 12 hours of impact event
- **30% Exceedance Margin**
  - For initial response/recovery phase decisions, for well-behaved systems within 6 hours of impact event

One Approach

Learning Check

1. **When looking at the probability of hurricane force winds being exceeded, the lower it is the _____**

A. wider the safety margin

B. narrower the safety margin

C. wider the danger margin

D. narrower the danger margin

One Approach

Now Let's Consider
Local Wind Threat Assessments

PRESENT MOVEMENT TOWARD THE NORTHWEST OR 320 DEGREES AT 6 KT

ESTIMATED MINIMUM CENTRAL PRESSURE 949 MB
EYE DIAMETER 15 NM
MAX SUSTAINED WINDS 115 KT WITH GUSTS TO 140 KT.
64 KT..... 30NE 30SE 20SW 30NW.
50 KT..... 60NE 50SE 40SW 60NW.
34 KT.....120NE 100SE 80SW 100NW.
12 FT SEAS..210NE 180SE 150SW 210NW.
WINDS AND SEAS VARY GREATLY IN EACH QUADRANT. RADII IN NAUTICAL
MILES ARE THE LARGEST RADII EXPECTED ANYWHERE IN THAT QUADRANT.

REPEAT...CENTER LOCATED NEAR 17.3N 157.5W AT 23/2100Z
AT 23/1800Z CENTER WAS LOCATED NEAR 17.0N 157.5W

FORECAST VALID 24/0600Z 18.2N 157.7W
MAX WIND 110 KT...GUSTS 135 KT.
64 KT... 30NE 30SE 20SW 30NW.
50 KT... 60NE 50SE 40SW 50NW.
34 KT...120NE 100SE 80SW 100NW.

FORECAST VALID 24/1800Z 19.4N 157.6W
MAX WIND 105 KT...GUSTS 130 KT.
64 KT... 30NE 20SE 15SW 20NW.
50 KT... 50NE 40SE 30SW 40NW.
34 KT...110NE 90SE 50SW 100NW.

FORECAST VALID 25/0600Z 20.1N 158.0W
MAX WIND 85 KT...GUSTS 105 KT.
64 KT... 20NE 10SE 10SW 10NW.
50 KT... 40NE 30SE 20SW 30NW.
34 KT...100NE 80SE 50SW 80NW.

FORECAST VALID 25/1800Z 20.4N 158.7W
MAX WIND 75 KT...GUSTS 90 KT.
50 KT... 30NE 20SE 20SW 30NW.
34 KT... 90NE 70SE 40SW 80NW.

FORECAST VALID 26/1800Z 20.3N 161.4W
MAX WIND 55 KT...GUSTS 65 KT.
50 KT... 10NE   0SE   0SW 10NW.
34 KT... 70NE 40SE 20SW 70NW.

EXTENDED OUTLOOK. NOTE...ERRORS FOR TRACK HAVE AVERAGED NEAR 150 NM
ON DAY 4 AND 200 NM ON DAY 5...AND FOR INTENSITY NEAR 20 KT EACH DAY

OUTLOOK VALID 27/1800Z 20.4N 164.4W
MAX WIND 40 KT...GUSTS 50 KT.

OUTLOOK VALID 28/1800Z 22.3N 166.4W
MAX WIND 40 KT...GUSTS 50 KT.

NHC Official Forecast

12 hours out to 48 hours and 24 hours out to 120. Full Radii Only Out to 48 Hrs

50/34 kts Radii Only Out to 72 Hrs

No Radii Days 96/120 Hrs

NHC/WFO Wind Forecasts Limitations

- From NHC's forecast, local forecast and warning offices (WFOs) must make 2-D wind forecasts at the 1-hourly scale out to 48 hours, 3-hourly out to 72 hours, and 6-hourly out to 120 hours with this guidance on a 2.5 km grid.

- Intensity changes are depicted as a steady trend in space and time.

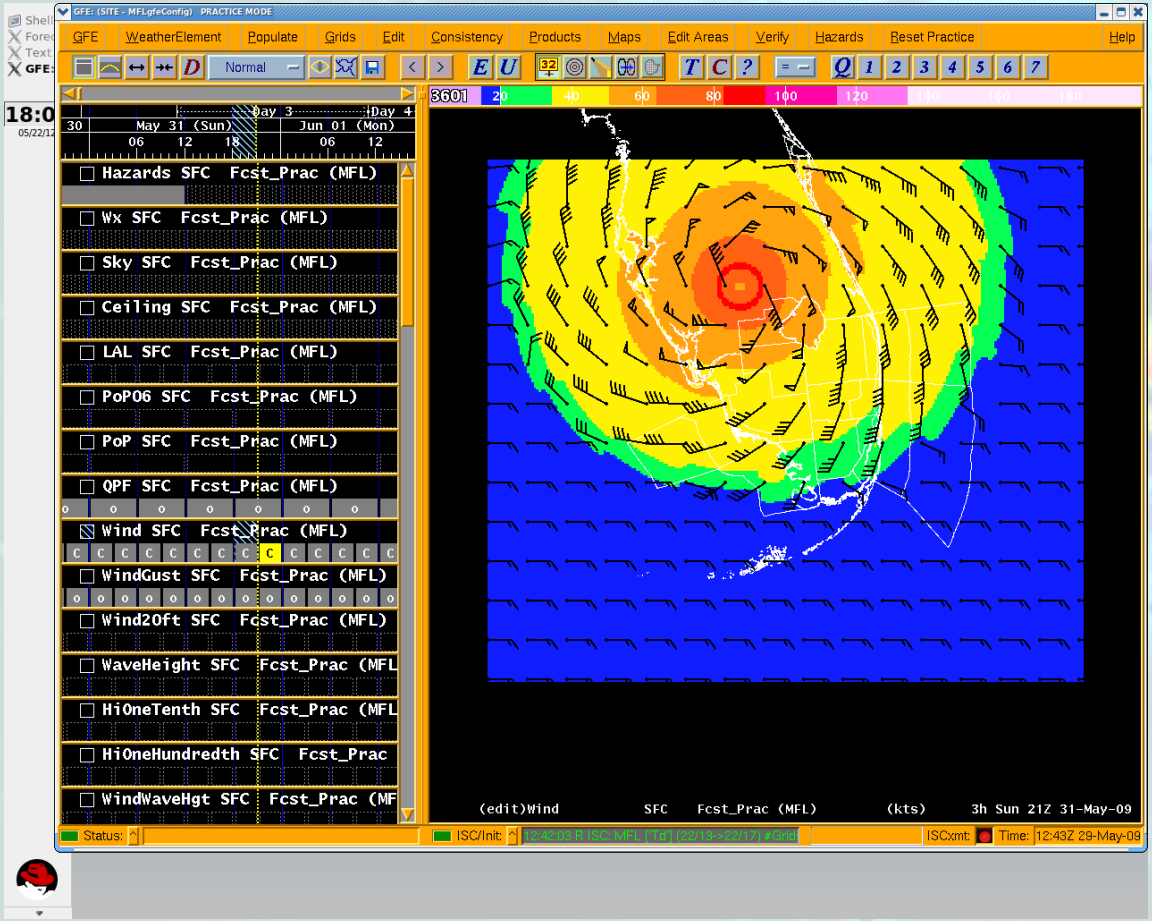
- Wind Speeds can be artificially reduced prior to landfall as they are interpolated between 12-hour forecast points. This artifact is made worse in days 4 and 5 due to 24-hour forecast points.

NHC/WFO Wind Forecasts

- So when constructing a local wind forecast from NHC's official forecast, NWS offices have to do so at a higher resolution than NHC provides using:
  - Conceptual models
  - Climatology-based data
  - Empirical algorithms

- **ASSUMPTIONS AND LIMITATIONS RESULT IN GREATLY MAGNIFIED ERRORS when looking at deterministic wind forecasts alone relative to a specific location. As shown earlier, HURRIVAC has the same limitations.**

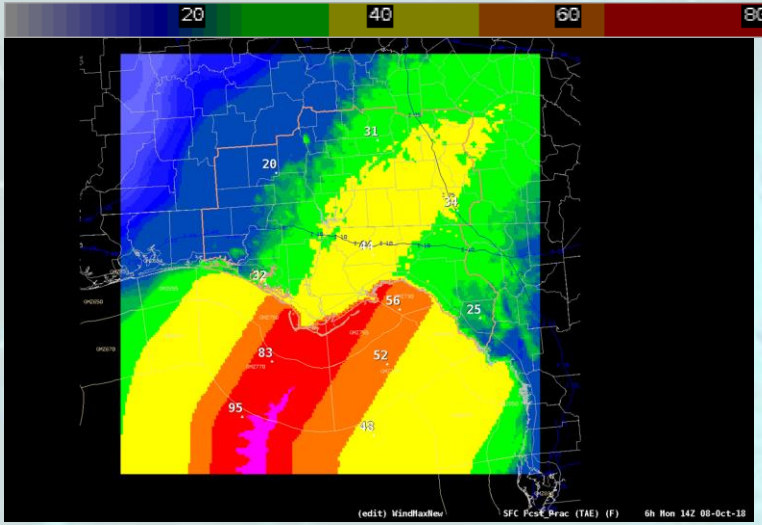
WFO Wind Grid Forecasts



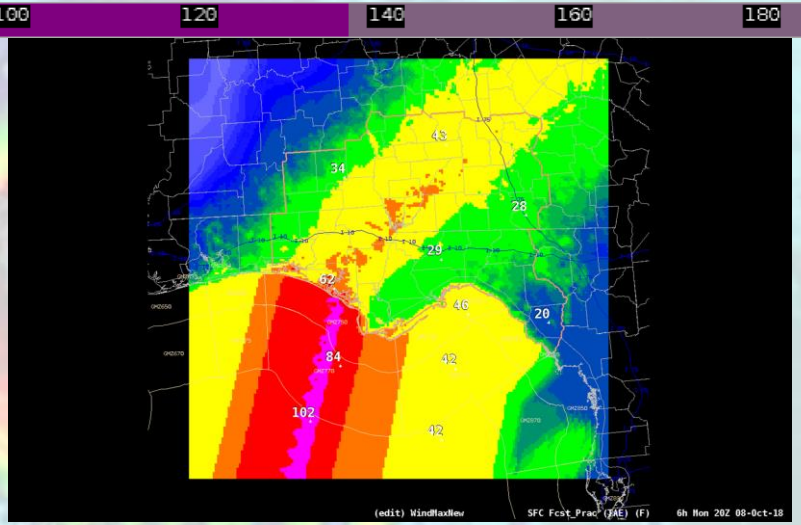
2D Forecast Wind Field

Artifacts of minor shift in forecast track

Michael Adv #8



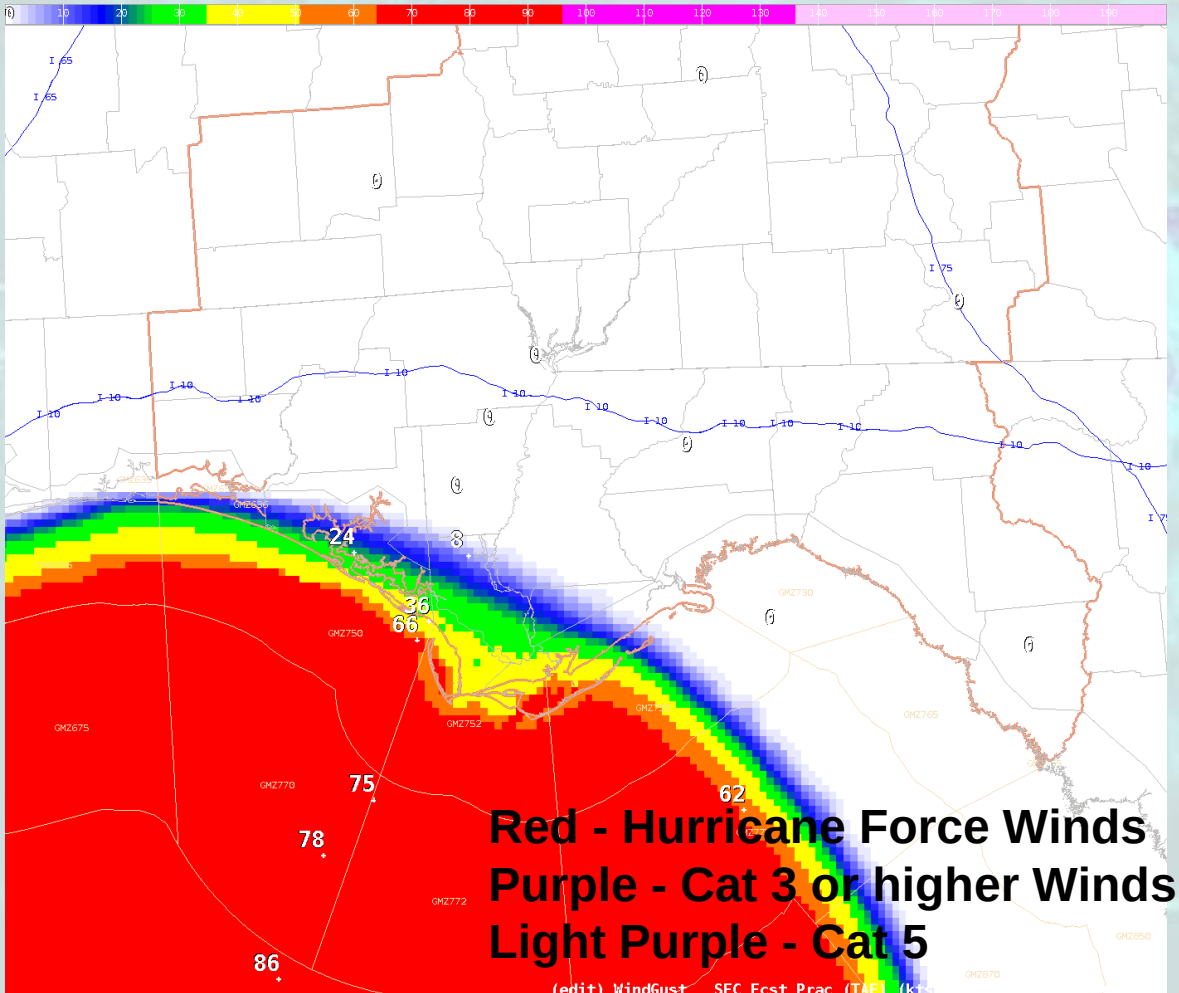
Michael Adv #9



- SHOWN: Max Wind swath built from NHC official forecast but with higher temporal resolution.
- Notice major hurricane force winds (purple) for adv # 8 are not brought to the coast because the coast falls between forecast points.
- Notice for specific points such as Panama City or Mexico Beach the dramatic difference in wind speeds from one adv to the next due to a 30 miles or so shift to the left in forecast track
- **This information feeds the wind forecasts in National Weather Service websites.**

Michael Best Track

2D Simulated Field



Local Wind Forecast

What is the Point?

- Approach currently used is science-based, but still limited with uncertainty and many sources of errors. **All of these limitations also apply to Hurrevac.**
- We are delivering information with greater precision, BUT IT DOES NOT IMPLY ACCURACY. Science is not where we would like it to be; service is outpacing the state of the science.
- This is in part why NHC delivers their advisory forecasts the way they do, but the need to provide more detailed local level info is pushing the envelope.
- Message From a Decision Making Perspective:
  - **AVOID OVER-RELYING ON DETERMINISTIC ONE SCENARIO/BEST GUEST ALONE!**
    - It is bad enough to rely in one scenario alone only without considering the issues raised so far.

Learning Check

2. **Used alone, two dimensional wind depictions in time derived from NHC's official forecast offer adequate means of depicting the threat of tropical storm and/or hurricane force winds.**

A. True

B. False

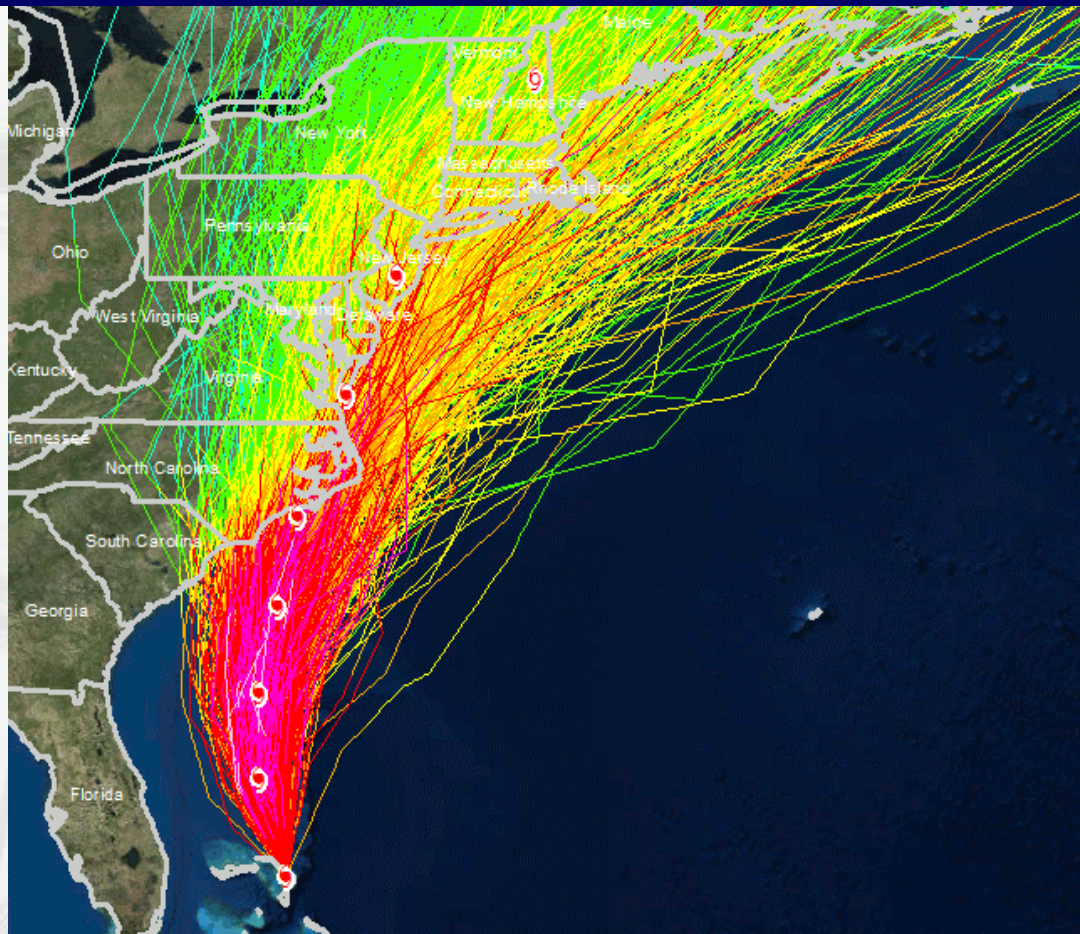
One Approach

Wind Speed Probabilities

How are they generated?

- **1,000 realistic alternative scenarios are created**
  - Official NHC forecast
  - Historical NHC track and intensity forecast errors
  - Climatology and persistence wind radii model
- **Weakening over land**
- ***Track model spread***

  Past NHC track forecast errors are correlated to the spread of track model guidance



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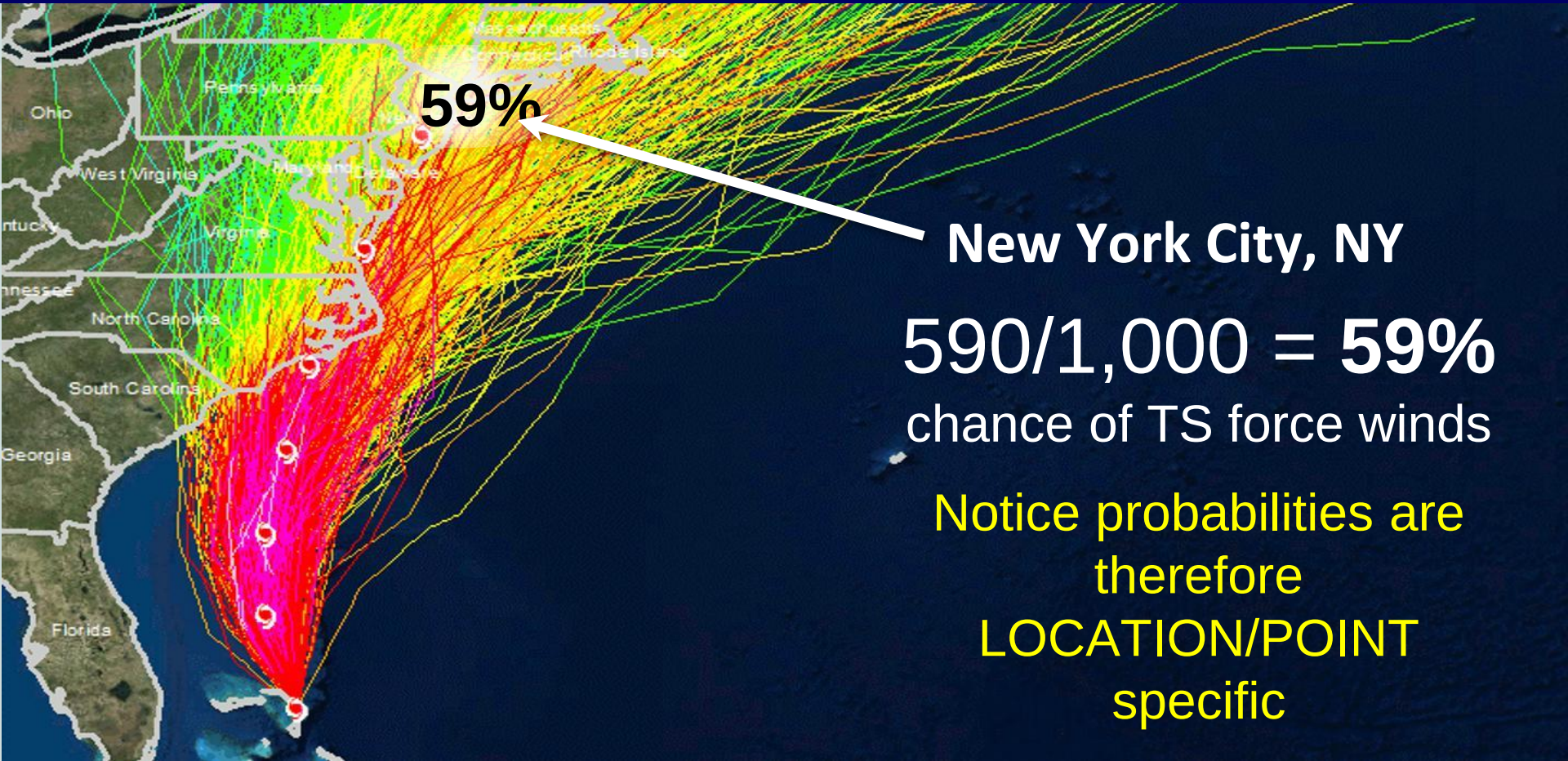


Full Spectrum of Probabilities
What Questions do They Answer?

- Cumulative (Available in NHC Graphic and PWSAT#; coarse time resolution*) – What are the chances that tropical storm or hurricane conditions will occur between hour 00 and XX out to 120 hours with this event **at my location**? Time dependent.
- Onset (Available in PWSAT#; coarse time resolution*) – What are the chances that tropical storm or hurricane conditions will begin during a particular time period **at my location**? What is the most likely period of onset or earliest reasonable start time of these conditions?

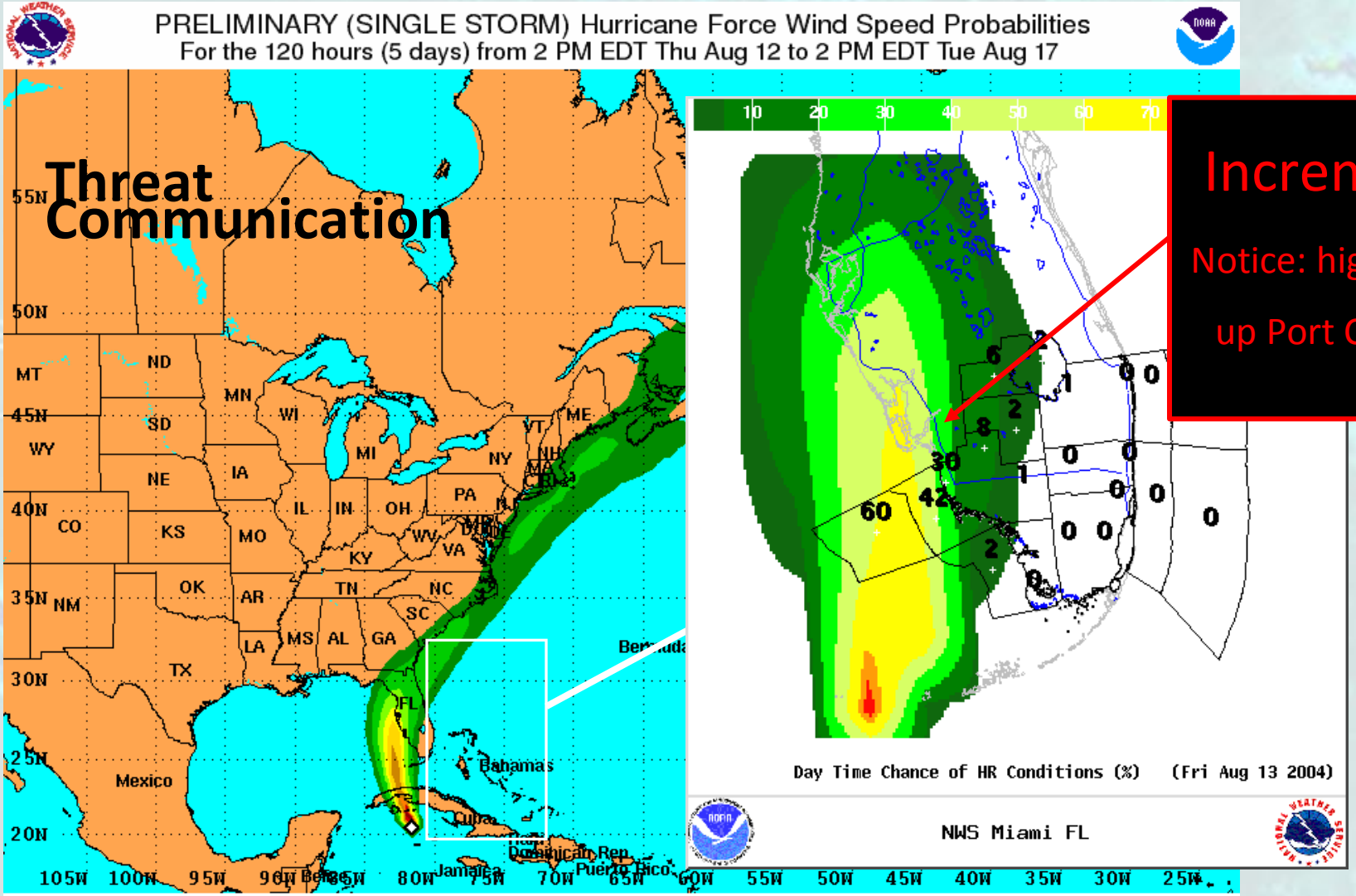
- Incremental (Not used by NHC; but by NWS offices*) – What are the chances that tropical storm or hurricane conditions will be experienced during a particular period **at my location**? How likely is the event to happen during that period? How likely is it to last? At what values is the event becoming more plausible (likely) than just possible?

*** Available with a resolution as high as 6 hours.**

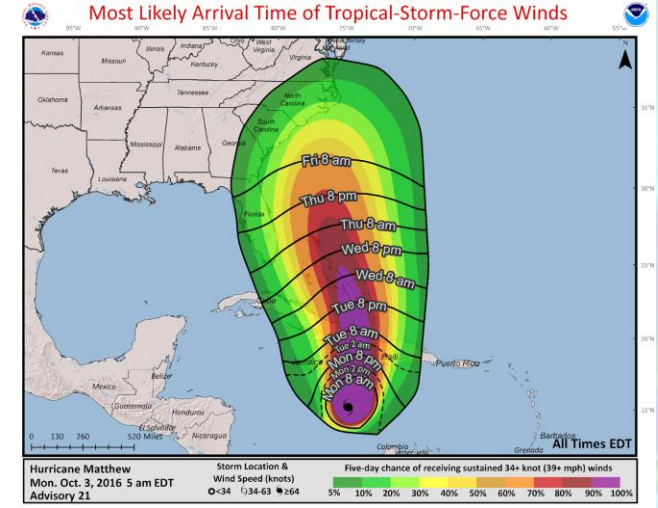
We consider trend from advisory to advisory

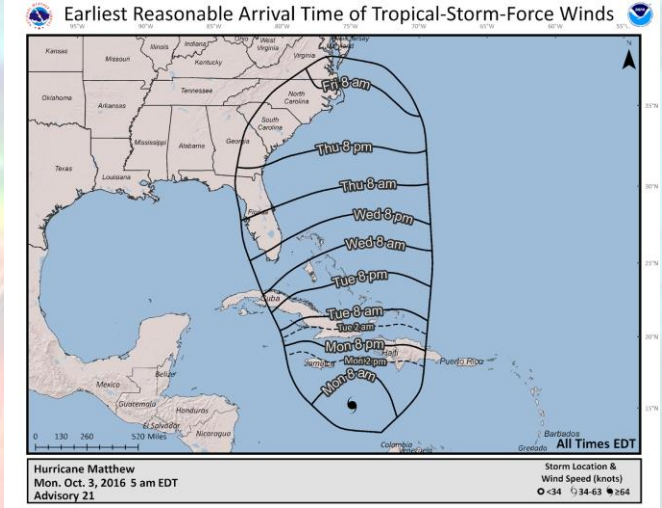
Application Examples

- Provide objective measures of uncertainty for:
  - Communicating Threat
  - Timing assessments with varying safety margins
  - Risk and threat assessments with varying safety margins - hurricane threat and impact graphics
  - For trend analysis of the threat from advisory to advisory for proper risk assessment


PRELIMINARY (SINGLE STORM) Hurricane Force Wind Speed Probabilities
For the 120 hours (5 days) from 2 PM EDT Thu Aug 12 to 2 PM EDT Tue Aug 17
Threat Communication
Incremental
Notice: highest right up Port Charlotte
Day Time Chance of HR Conditions (%) (Fri Aug 13 2004)
NWS Miami FL
Probabilities of sustained hurricane force surface winds (1-minute average of 74 mph or greater) from all active tropical cyclones
indicates HURRICANE CHARLEY center location at 2 PM EDT Thu Aug 12 2004 (Forecast/Advisory #14)
5% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

NHC Arrival of Tropical Storm Force Winds





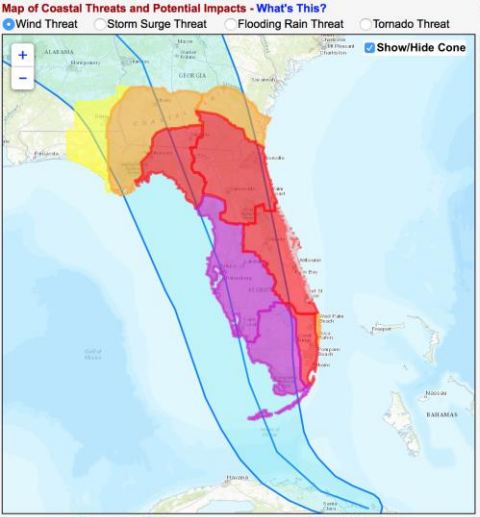
- **Arrival of TS-force winds is a critical planning/action threshold for communities.**
- ***"Most Likely"* arrival time - the time before or after which the onset of tropical storm force winds is equally likely. Often used during the warning period.**
- ***"Earliest Reasonable"* arrival time - time window that individuals can safely assume will be free from tropical storm force winds (no more than a 10% chance of onset). Often used during the watch period and earlier.**

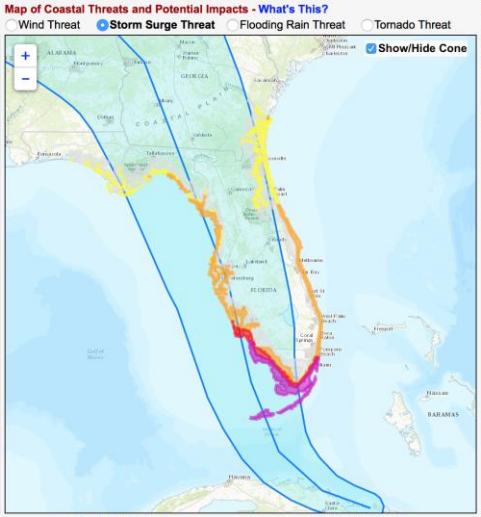
HTI

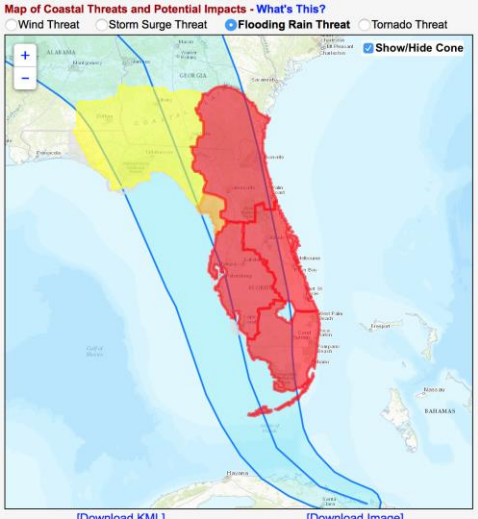
Hurricane Threat and Potential Impacts

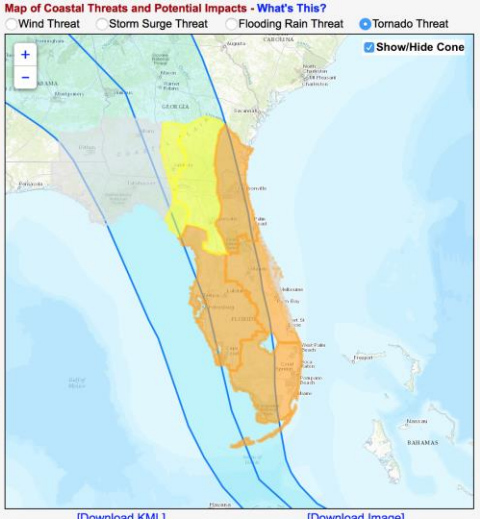
A Risk Communications Tool

(varying safety margins)









Hurricane Threats and Impacts (HTI) Products

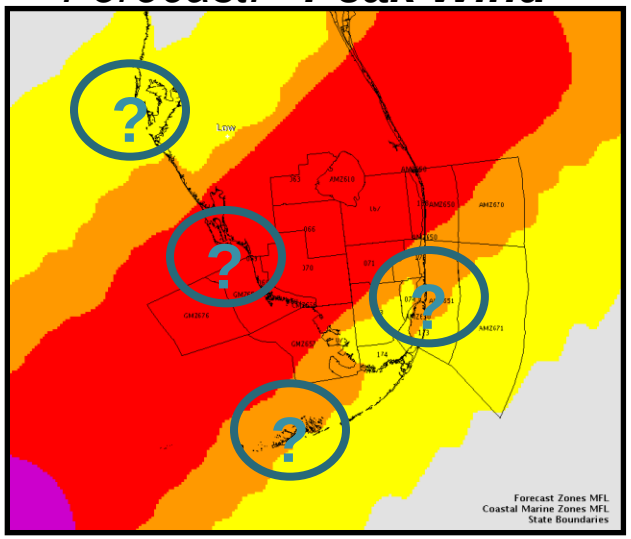
- Clicking on the map provides latest information from the TCV text product for your area relative to the four main tropical cyclone hazards: **Wind, Storm Surge, Flooding Rains, and Tornadoes**.
- You will be able to find information on the meteorological forecast parameters including ***what*** and ***when*** type information, threat level (factoring safety margin and therefore what you should plan for), and corresponding potential impact information (what you should be preparing for) relative to each of those hazards.
- The threat levels account for forecast error and consider a safety margin or "***what conditions to plan for***".
- The potential impact information describes the potential effects or "***what impacts to prepare for***".

A Risk Communications Tool

(varying safety margins)

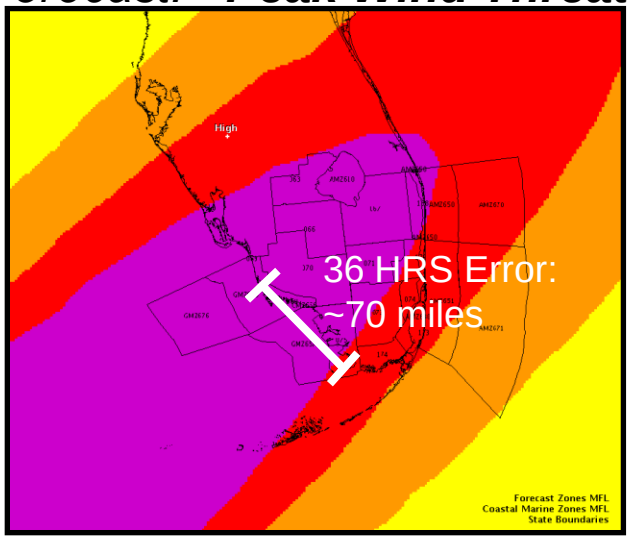
When a hurricane threatens a coastal community, to what extent should wind preparations be undertaken?

*Forecast: "**Peak Wind**"*



Deterministic-only; zero error

*Forecast: "**Peak Wind Threat**"*



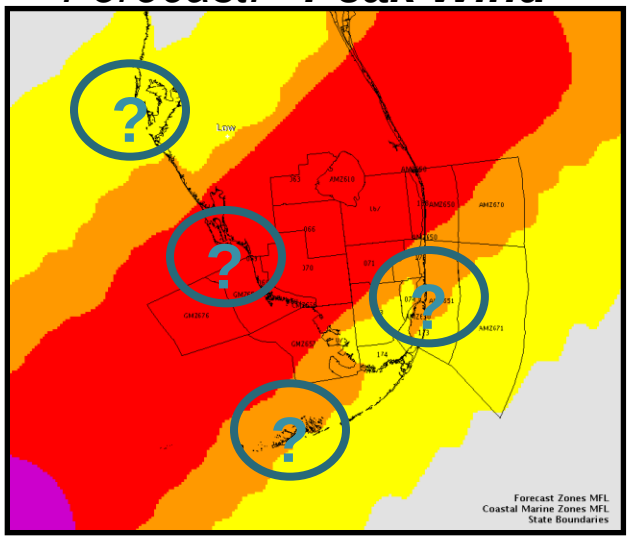
Probability included; 10% exceedance

Example: A major hurricane approaching southwest Florida at the onset of the warning period (~ 36 hours)

Wind Threat
Potential for wind greater than 110 mph
Potential for wind 74 to 110 mph
Potential for wind 58 to 73 mph
Potential for wind 39 to 57 mph
Wind less than 39 mph

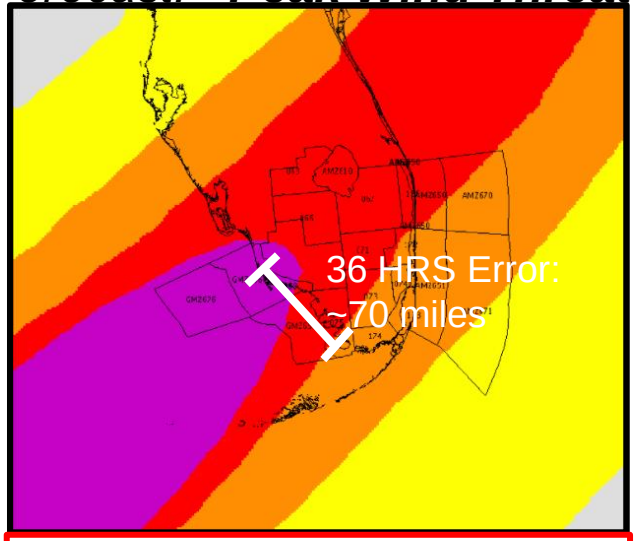
Decision Support: For a higher risk tolerance/narrower safety margin - What should one be preparing for?

*Forecast: "**Peak Wind**"*



Deterministic-only; zero error

*Forecast: "**Peak Wind Threat**"*



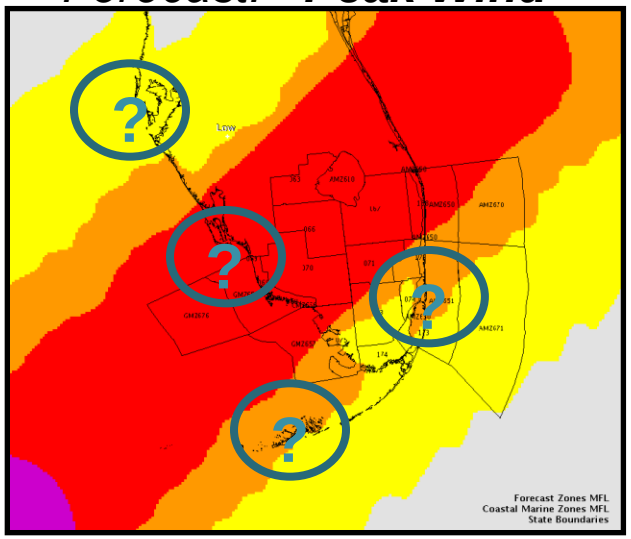
Probability included; 20% exceedance

Example: A major hurricane approaching southwest Florida at the onset of the warning period (~ 36 hours)

Wind Threat
Potential for wind greater than 110 mph
Potential for wind 74 to 110 mph
Potential for wind 58 to 73 mph
Potential for wind 39 to 57 mph
Wind less than 39 mph

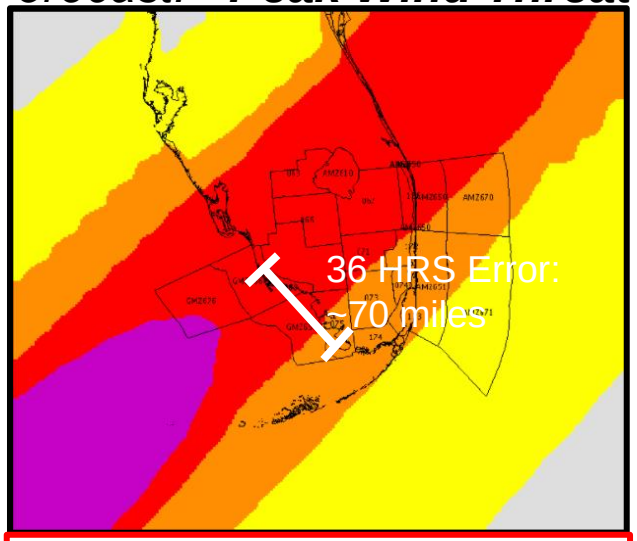
Decision Support: For a higher risk tolerance/narrower safety margin - What should one be preparing for?

*Forecast: "**Peak Wind**"*



Deterministic-only; zero error

*Forecast: "**Peak Wind Threat**"*



Probability included; 30% exceedance

Example: A major hurricane approaching southwest Florida at the onset of the warning period (~ 36 hours)

Wind Threat
Potential for wind greater than 110 mph
Potential for wind 74 to 110 mph
Potential for wind 58 to 73 mph
Potential for wind 39 to 57 mph
Wind less than 39 mph

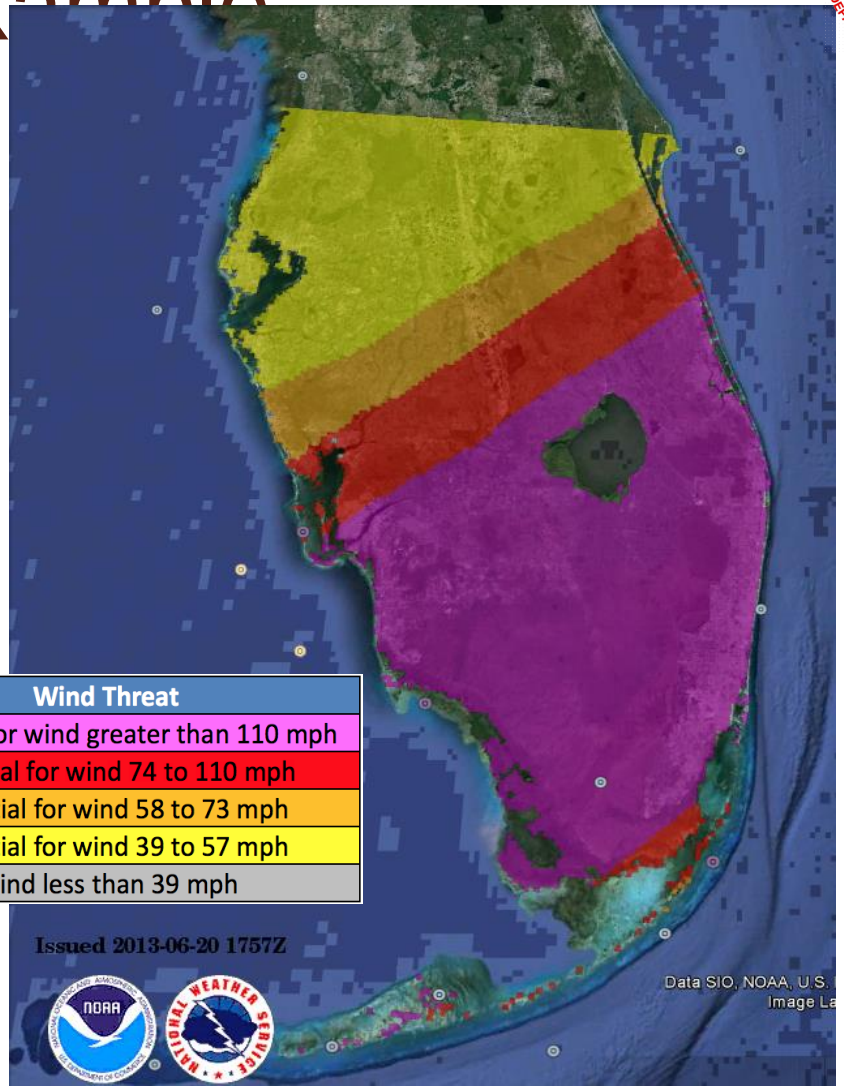
More on Trend – Wilma Example

HTI offer an implicit use probabilistic guidance.

What about their trend from advisory to advisory also?

- **Advisory 30**
- **Advisory 31**
- **Advisory 32**
- **Advisory 35**

Probability included; 10% exceedance



Learning Check

3. What decision-making guidance does HTI convey?

A. What should be planned/prepared for

B. What is expected

C. What is likely to happen

D. They are useless

One Approach

Learning Check

4. **HTI can be adjusted with varying safety margins factored in as the event evolves**

A. True

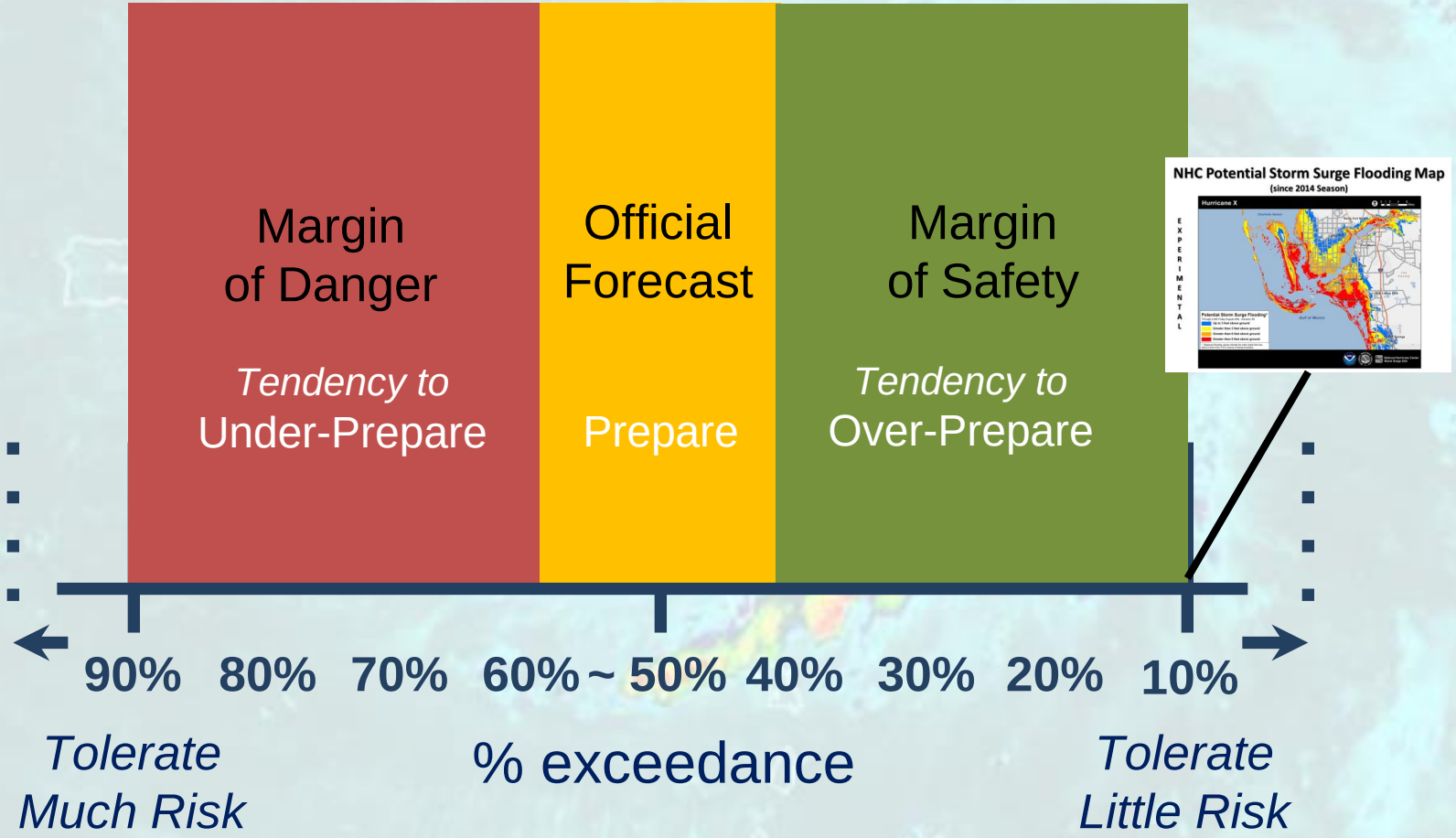
B. False

Storm Surge Threat Assessment

- In the same context of risk tolerance and safety margin
- Example Graphical Products
  - ➢ NHC high resolution inundation map
  - ➢ Storm surge watch/warning graphic
  - ➢ WFO local threat and potential impact graphics
- Decision Support Services
  - ➢ Example of different risk tolerances (% exceedance levels) in coastal evacuation decision-making
  - ➢ Role of probabilistic data in emergency management decision-making guides
    - Customer thresholds

Risk Tolerance: Spectrum Of Plausible Outcomes

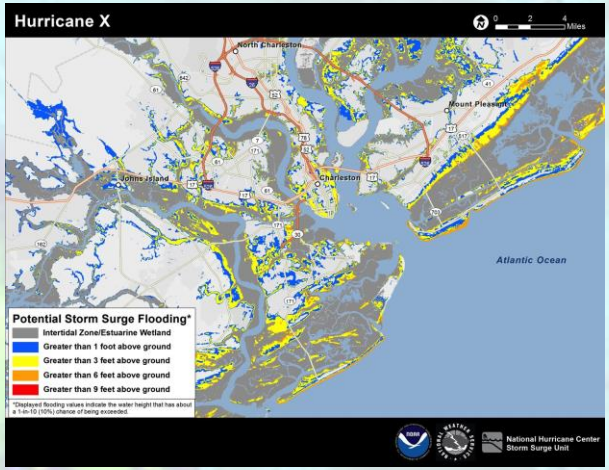
(in event context; for a given community)

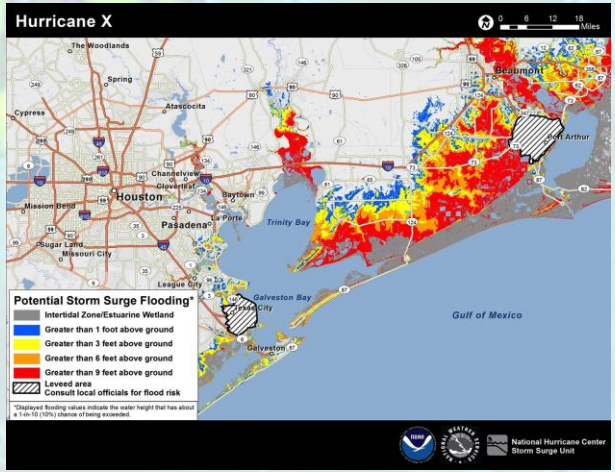


"Fate laughs at probabilities." – Novelist Edward Bulwer-Lytton (1803-1873)

Potential Storm Surge Flooding Map
(Inundation Map)

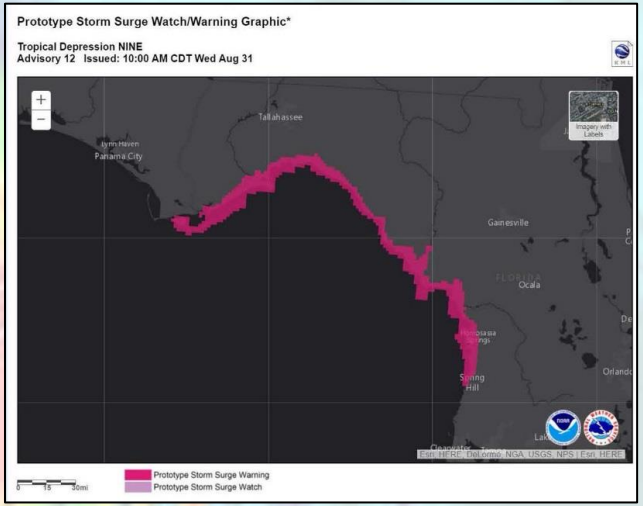
- Provides a quantitative risk assessment for decision makers. Not for public consumption necessarily.
- Shows height above ground that the water could reach.
  - Depicts the reasonable worst-case scenario at any individual location.
  - Shows inundation levels that have a 10% chance of being exceeded **ALWAYS!!!**
- First map issued with the initial hurricane watch or in some cases, with a tropical storm watch.
- Available about 60 to 90 minutes following the advisory release.





Storm Surge Watch/Warning Graphic

- Storm Surge Watch – possibility of life-threatening inundation somewhere within the watch area generally within 48 hours
- Storm Surge Warning – danger of life threatening inundation somewhere within warned area generally within 36 hours
- Consideration for continuity, areas subject to isolation, etc. Subjectivity plays a role.
- *Complements* the potential inundation graphic
- Together with WFO threat/impacts graphics, meant for public messaging/consumption



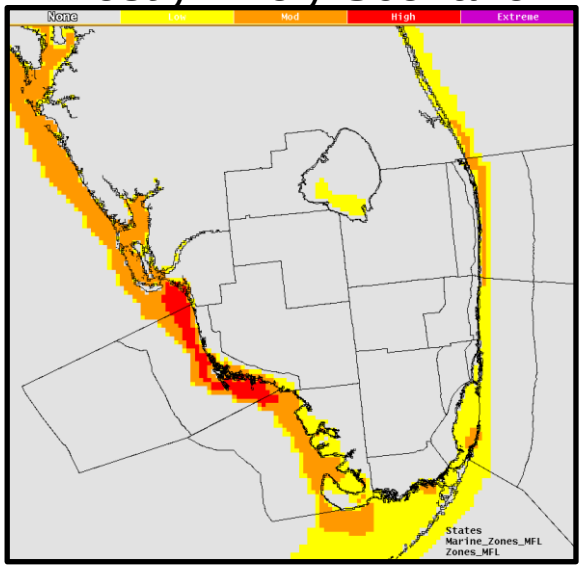
SUMMARY OF WATCHES AND WARNINGS IN EFFECT:

A Hurricane Warning is in effect for…
*** Anclote River to Indian Pass Florida**

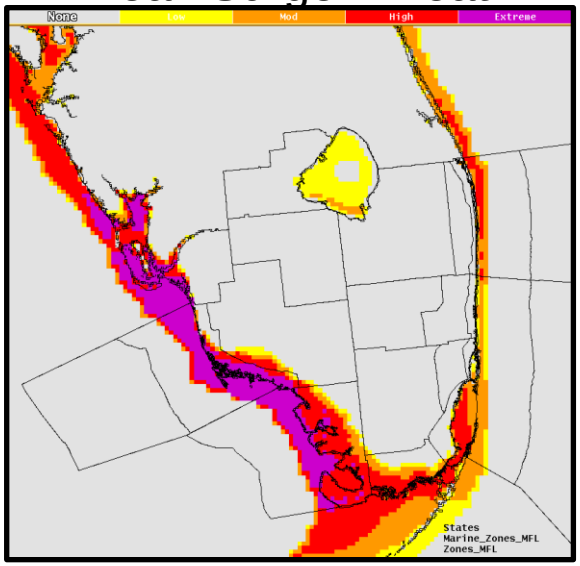
A Storm Surge Warning is in effect for…
*** Aripeka to Indian Pass Florida**

Surge Threat/Potential Impacts Graphic

Mostly Likely Scenario



Peak Surge Threat



Example: Major hurricane at the onset of the watch period (~ 48 hours).

QUESTION: When advocating the measure of protective actions according to surge impacts, which is

Storm Surge Threat
Potential for surge flooding > 9 feet above ground
Potential for surge flooding 6-9 feet above ground
Potential for surge flooding 3-6 feet above ground
Potential for surge flooding 1-3 feet above ground
Little to no surge flooding

Learning Check

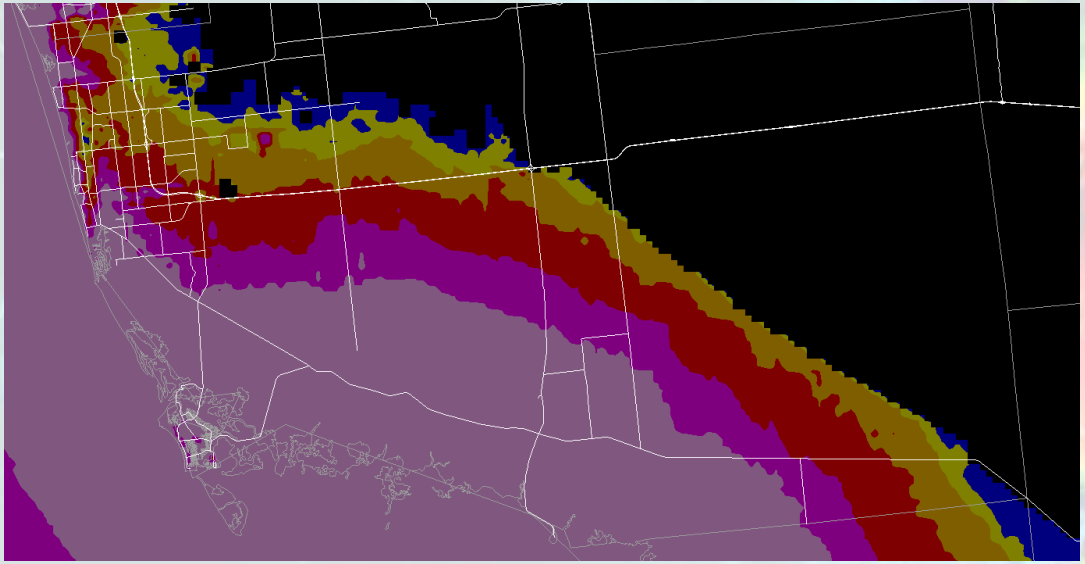
5. **The high resolution inundation graphic is always based on inundation values with a 10% chance of being exceeded.**

A. True

B. False

One Approach

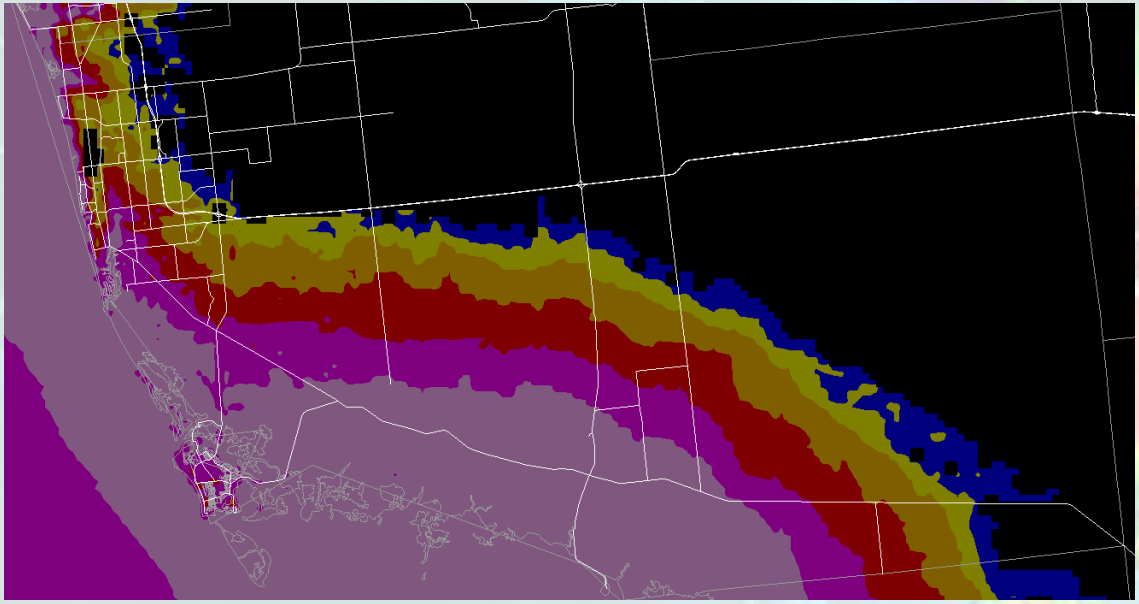
Irma Collier Surge Decision Point



Inundation
(AGL)
Adv 42
10% Exceedance
~ 24 hours to landfall

Blue: < 1 ft
Yellow: 1-3 ft
Orange: 3-6 ft
Red: 6-9 ft
Purple: 9-12 ft
Light Purple: > 12 ft

Irma Collier Surge Decision Point



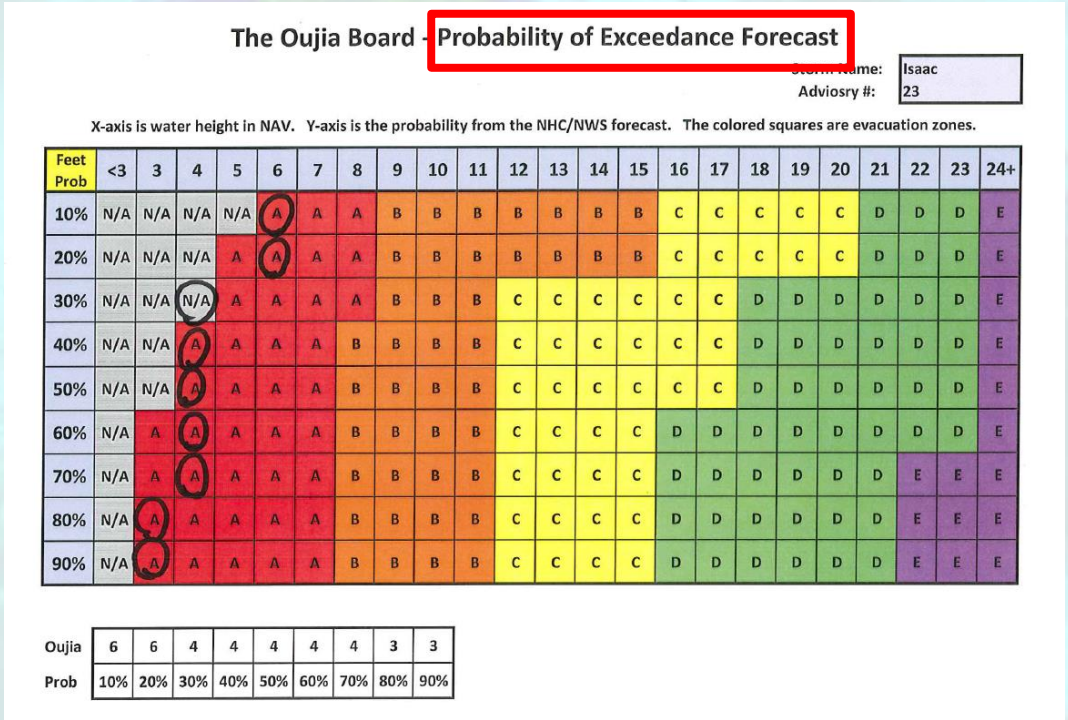
Emergency manager held from evacuating 10s thousands additional folks based on this.

Inundation
(AGL)
Adv 42
20% Exceedance
~24 hours to landfall

Blue: < 1 ft
Yellow: 1-3 ft
Orange: 3-6 ft
Red: 6-9 ft
Purple: 9-12 ft
Light Purple: > 12 ft

Risk Assessment Matrix

- Some EMs (Example from Lee County) have developed tools to incorporate probabilistic data into decision making process.
- Each county is different – some sophisticated, some not.



The Oujia Board - Probability of Exceedance Forecast

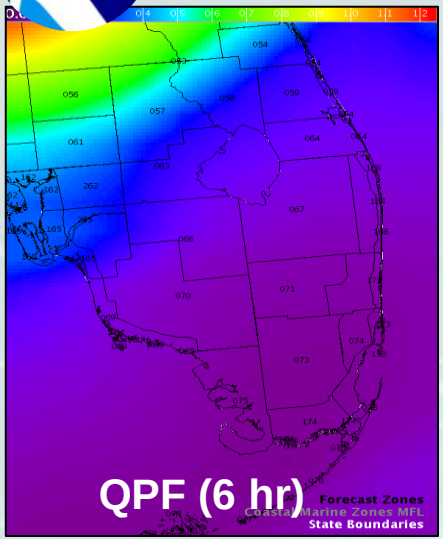
Storm Name: Isaac
Adviosry #: 23

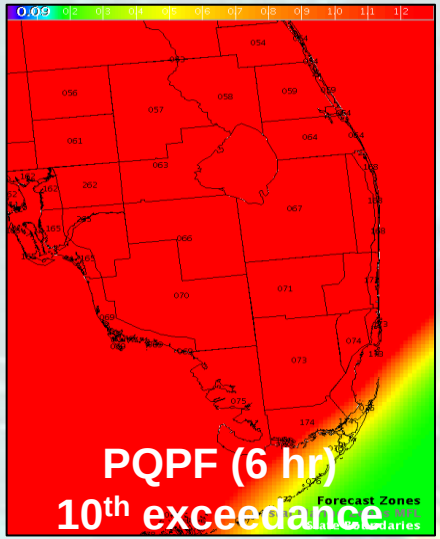
X-axis is water height in NAV. Y-axis is the probability from the NHC/NWS forecast. The colored squares are evacuation zones.

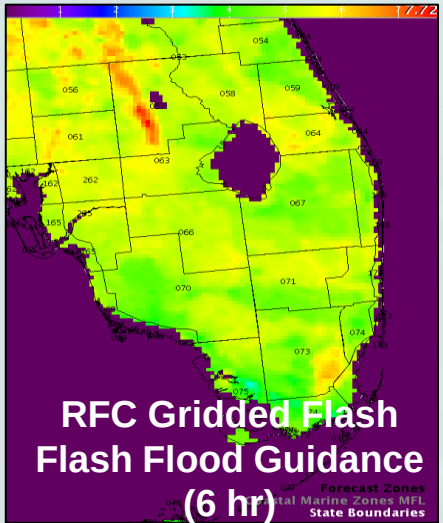
Feet / Prob	<3	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24+
10%	N/A	N/A	N/A	N/A	A	A	A	B	B	B	B	B	B	B	C	C	C	C	C	D	D	D	E
20%	N/A	N/A	N/A	A	A	A	A	B	B	B	B	B	B	B	C	C	C	C	C	D	D	D	E
30%	N/A	N/A	N/A	A	A	A	A	B	B	B	C	C	C	C	C	C	D	D	D	D	D	D	E
40%	N/A	N/A	A	A	A	A	B	B	B	B	C	C	C	C	C	C	D	D	D	D	D	D	E
50%	N/A	N/A	A	A	A	A	B	B	B	B	C	C	C	C	C	C	D	D	D	D	D	D	E
60%	N/A	A	A	A	A	A	B	B	B	B	C	C	C	C	D	D	D	D	D	D	D	D	E
70%	N/A	A	A	A	A	A	B	B	B	B	C	C	C	C	D	D	D	D	D	D	E	E	E
80%	N/A	A	A	A	A	A	B	B	B	B	C	C	C	C	D	D	D	D	D	D	E	E	E
90%	N/A	A	A	A	A	A	B	B	B	B	C	C	C	C	D	D	D	D	D	D	E	E	E

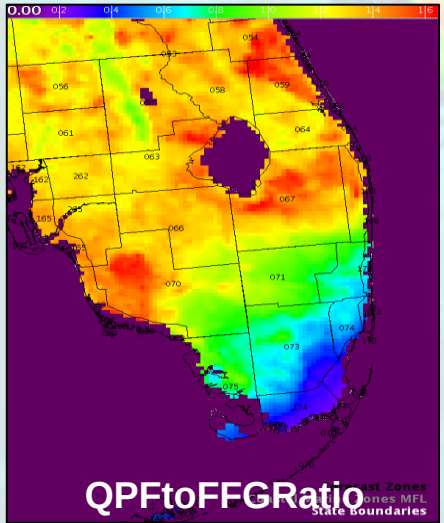
Oujia	6	6	4	4	4	4	4	3	3
Prob	10%	20%	30%	40%	50%	60%	70%	80%	90%

Flooding Rain Threat Assessment





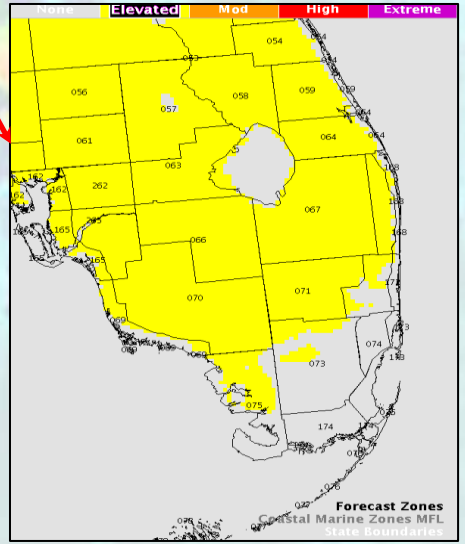




The tool uses the following inputs (to 72 hrs):

- WFO QPF (6 hourly)
- WPC PQPF (6 hourly)
- RFC FFG (6 hourly) – diagnostic field
- WPC Excessive Rainfall probabilities (ERP)
- Inputs checked for each 6 hr period to 72 hrs.
- The final FloodingRainThreat is based on a composite max for the 72 hr period.

Excessive Rainfall Probabilities (Days 1-3)



NOTE: Remember the text is locally adaptable (HTI).

Summary & Conclusions

- **You can brief threat/risk information to community decision-makers relative to:**
  - The Most Likely Scenario
  - The Reasonable Worst Case Scenario
  - The Most Likely Alternate Scenario pessimistic *(if requested)*
  - The Most Likely Alternate Scenario; optimistic *(if requested)*
  - The Reasonable Best Case Scenario *(if requested)*
- **The % Exceedance Probabilities can be harnessed to:**
  - Standardize scenario definitions *(from above)*
  - Help determine the width of the Safety Margin for varying levels of risk tolerances and customer thresholds community to community
- **Advanced tools are needed to exploit the use of probabilistic data in threat assessment especially for purposes of decision support and messaging to the public.**
  - For each hazard - hurricane threats and impacts graphic represent a good example
  - For forecasters and sophisticated decision-makers

The Local Hurricane Hazards Threat Assessment

QUESTIONS ???