L0311: Hurricane Readiness for Coastal Communities

Student Manual

Date Released: January 2024

FEMA

Contents

Unit 0: Course Overview

Visual 1: Hurricane Readiness

L0311 Hurricane Readiness for Coastal Communities

Key Points

Welcome to the L0311 Hurricane Readiness for Coastal Communities. This 1-day course is intended to help you make more informed decisions when planning for and responding to hurricane threats. Hurricanes can be both deadly and costly. Better readiness for and forecasting of hurricanes saves lives and property.

Visual 2: Administration – Facility Orientation

• Sign-In Sheet • Emergency Procedures/Fire Exits • Restrooms • Breaks and Lunch • Parking • Smoking Policy • Emergency Cell Phone #'s	

Key Points

- Be sure that you checked your name on the sign-in sheet, and initial next to your name so that you receive proper credit for attendance.
- Please observe safety procedures and use emergency exits if needed.
- Know the location of restrooms.
- Breaks are scheduled throughout the course along with lunch.
- Parking Area (s) – park only in designated areas.
- Emergency Cell phone numbers will be provided.

Visual 3: Ground Rules

• Silence cell phones. • Return calls during breaks/lunch. • Please refrain from emails/texting during class. • Return from breaks and lunch on time. • Full participation is required!	

Key Points

- Please silence all cell phones and electronic devices. Don’t forget to silence your cells phone upon returning from breaks or lunch.
- Be respectful of the instructors by returning calls during breaks/lunch and returning from breaks and lunch on time.
- Please refrain from sending emails and texts during class.
- Full participation is required since there is a lot of information being covered. Questions are encouraged!

Visual 4: Course Administration

- Online NETC-EMI Application Process
    - Replaces paper application form.
- EMI Course Evaluation Form
- Final Exam
    - Passing score is 75%.
- EMI Certificate
    - Must attend the entire course.
    - Pass the final exam.
    - Submit an online application form.

Key Points

- The **NETC-EMI Application process** now uses an online course application form that replaces the paper application form.
- The **EMI Course Evaluation Form** is utilized to gather feedback on the course and instruction.
- A **final exam** consisting of multiple-choice questions will be administered at the end of the training to assess the achievement of the key teaching points and objectives. The passing score is 75%.
- An EMI Certificate will be emailed to all participants who successfully complete the course. You must attend the entire course, pass the final exam, and submit an online application form.

Visual 5: Online NETC-EMI Application Process

- EMI has transitioned to an Online Application System.
- Students must complete the online application form within **14 days** after the class ends to get EMI credit.
- Student Identification (SID) number is required to register for this training and any FEMA course.

NETC Application

Student ID Number

Key Points

NETC- EMI Online Application System

- The National Fire Academy and the Emergency Management Institute have transitioned to an online admissions system.
- The online application will open the day before the class and be open **14 days after the class is complete.** A failure to turn in an application will result in not receiving credit for the course.
- If you have any issues or a question regarding the online admissions system or the process, please contact: NETC Admissions Department (NETCAdmissions@fema.dhs.gov); (301) 447-1035.
- The Student Identification (SID) number replaces your SSN# and serves as a means of tracking your training completions.

- It is required for this course and any other FEMA course.
- For any questions on your SID#, please send an email to the FEMA SID Help Desk (femasidhelp@cdpemail.dhs.gov). They are also available by calling 1-866-291-0696.

Visual 6: EMI Evaluation Form

- Complete by the end of today.
- Rate topics and instructors from Scale of 1 (lowest)–5 (highest).
- Write in comments to improve the training!

Key Points

The EMI Course Evaluation Form will be used to document participant feedback at the end of the course on overall quality of content, instruction, and facilities.

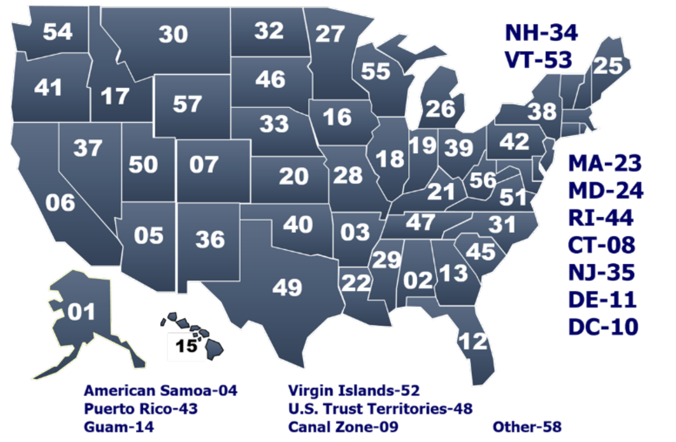
- It is important that you complete the course EMI Evaluation Scantron form after each unit of instruction, rating the topics and instruction documented on the back of the form after they are presented.
- Rate both content and quality of each unit of instruction located on the backside of the form in Block 18 (1 lowest–5 highest) and overall course rating in Block 19.
- There is space at the bottom of the form (the back) for written comments, which are strongly encouraged.
- Return completed EMI Evaluation form to the Course Manager at the end of the course.

Visual 7: Evaluation Form: Work Location

State Codes

Evaluation: Block #3

- Work Location
  (not where you live)



Key Points

Block #3 of the EMI Evaluation form asks for your work location. The above map shows the two-digit state code.

A copy of each state and its code is also provided along with the EMI Scantron form.

Visual 8: National Hurricane Program 1

Key Points

This course is presented by the National Hurricane Program (NHP), an interagency partnership administered by the Federal Emergency Management Agency (FEMA) and includes the U.S. Army Corps of Engineers (USACE) and the National Oceanic and Atmospheric Administration's (NOAA) National Hurricane Center (NHC).

It is offered in partnership with the Emergency Management Institute (EMI).

Visual 9: National Hurricane Program 2

Key Points

The NHP provides technical assistance to State, Local, Tribal, Territorial (SLTT) and Federal government partners. Technical assistance is focused on hurricane evacuation and response, spanning from steady-state deliberate planning to operational decision support and crisis planning when tropical storms or hurricanes threaten the United States.

By leveraging staff and resources across all three Federal partners, the NHP is best able to meet the mission to save lives by supporting informed evacuation decision making.

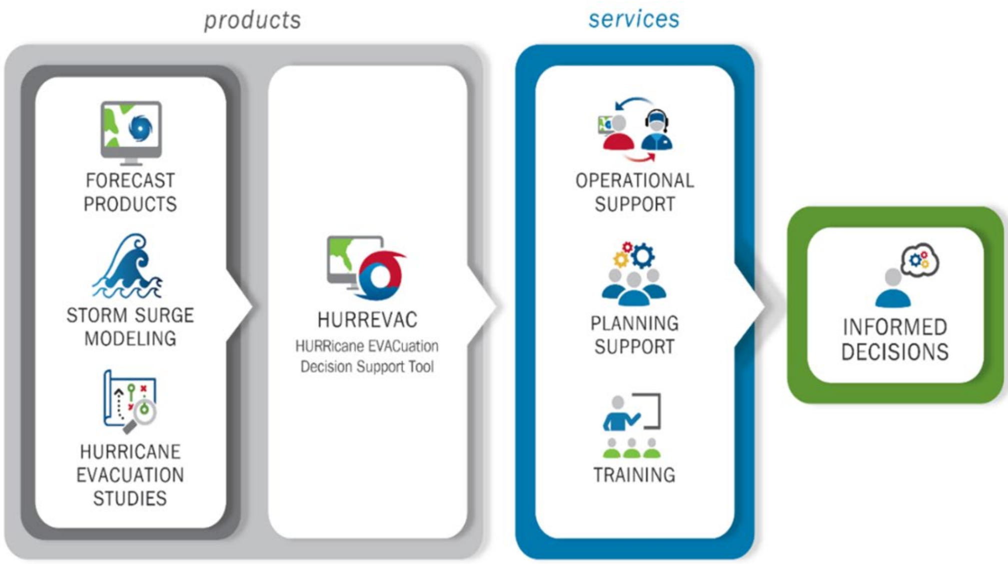
The NHP has established three central goals designed to fulfill its mission:

1. Provide OPERATIONAL tools, information, and technical assistance to Emergency Managers (EMs) to support their hurricane evacuation and response decisions during hurricane threats.
2. Provide data, resources, and technical assistance to support hurricane evacuation and response PLANNING.
3. Deliver comprehensive hurricane preparedness TRAINING to EMs and partners.

These overarching goal of all these actions (operational support, planning efforts, and training) is to assist our SLTT partners in making informed timely response and evacuation decisions.

For more information about the NHP, visit the NHP website.

Visual 10: NHP Products and Services



Key Points

- **Column 1 of the graphic:** The NHP provides products and services to SLTT Emergency Managers. The NOAA NHC issues forecast products when there is storm threat. Through the partnership with the NHP, the NOAA NHC also develops storm surge models to create storm surge risk products that can be used for planning. Both products inform the development of Hurricane Evacuation studies. The USACE leads the coordination of Hurricane Evacuation Studies (HES) in partnership with the states.
- **Column 2 of the graphic:** These products (forecast wind speed data, storm surge risk products, and evacuation zones and clearance times from HES) are available in the NHP decision support tool HURREVAC. HURREVAC is a web-based tool available to Emergency Managers to provide a one-stop-shop to see all this information with their specific evacuation parameters in one place.
- **Column 3 of the graphic:** These products, individually and collectively in HURREVAC, support the three NHP goals:
  - Provide OPERATIONAL tools, information, and technical assistance to EMs to support their hurricane evacuation and response decisions during hurricane threats.
  - Provide data, resources, and technical assistance to support hurricane evacuation and response PLANNING.
  - Deliver comprehensive hurricane preparedness TRAINING to EMs and partners.
- **Column 4 of the graphic:** The overarching goal of these actions (operational support, planning efforts, and training) is to assist our SLTT partners in making informed timely response and evacuation decisions.

Visual 11: Course Goal

This course will enable participants to better plan for a hurricane threat by ensuring that they understand hurricane hazards, forecast uncertainty, and resources for hurricane planning and response such as National Hurricane Center (NHC) forecast products and hurricane evacuation studies.	

Visual 12: Course Objectives

After completing this course, you should be able to:

- Explain the hurricane life cycle, climatology, and associated hazards to coastal communities.
- Describe when NHC products are available for tropical cyclone events and how to use them to determine threats from an approaching storm.
- Explain the uncertainties of NHC forecasts that must be considered in emergency management decision making.
- Describe the storm surge threat and how to assess potential impacts.
- Explain the components of Hurricane Evacuation Studies (HES) and how they can inform planning for hurricanes.
- Identify the resources available for evacuation planning and response and how to use them.

Visual 13: Course Agenda

COURSE AGENDA	Length
Unit 0: Course Overview	30 minutes
Unit 1: Hurricane Basics	105 minutes
Unit 2: National Weather Service (NWS) Products	90 minutes
LUNCH	
Unit 3: Forecast Uncertainty	75 minutes
Unit 4: Making Better Decisions	90 minutes

Key Points

This course has four units of instruction, and each unit builds upon the previous unit. Please refer to the course agenda for times and instructor names for each of the units.

Visual 14: Course Materials

• Agenda • L0311 Student Manual • Handouts	

NHC Outreach Materials
www.NHC.noaa.gov/outreach/

Key Points

The Student Manual includes copies of all the visuals (PowerPoint slides), key points, and notetaking space as well as the names of or links to any resource materials. Other materials will be handed out throughout the course as needed.

Visual 15: Instructor Introductions

Instructors

- Name
- Position
- Synopsis of hurricane experience

Visual 16: Student Introductions

Please introduce yourself.

- Name
- Title
- Agency/Organization

Visual 17: Questions/Comments

Visual 18: Poll Question 1

Poll Question

How long have you been in Emergency Management?

A. Less than 1 year
B. 1 to 5 years
C. 5 to 15 years
D. More than 15 years

Visual 19: Poll Question 2

Poll Question

What level of Emergency Management do you represent?

A. Local
B. State
C. Tribal or Territory
D. Federal
E. Other

Visual 20: Poll Question 3

Poll Question

What is your primary role in Emergency Management?

A. Plans
B. Operations
C. Public Information Specialist
D. Training and Exercise
E. Other

Visual 21: Poll Question 4

Poll Question

In your role, what is your level of experience with hurricanes?

A. None, just starting out
B. Little
C. Moderate
D. Extensive

Visual 22: Poll Question 5

Poll Question

Have you attended a NHP course in the past?

A. Yes, L0311, Hurricane Readiness for Coastal Communities
B. Yes, L8324, Hurricane Preparedness for Decision Makers (at NHC)
C. Yes, L0320, Hurricane Preparedness for Decision Makers (State Hosted)
D. Yes, L0310, Hurricane Readiness for Inland Communities.
E. Yes, HURREVAC Training Courses
F. This is my first NHP class.

Unit 1: Hurricane Basics

Visual 1: Unit 1

Unit 1:
Hurricane Basics

Visual 2: Unit 1 Objectives

Unit Objectives At the end of this unit, you should be able to: 1. Describe the characteristics and life cycle of a tropical cyclone. 2. Describe Atlantic Hurricane Climatology. Explain the hurricane hazards and how water is responsible for the vast majority of direct fatalities.

Visual 3: Tropical Cyclones Defined

Tropical Cyclones • Large, long-lived, low-pressure system (can be hundreds of miles wide, lasting for days) • Form over sub/tropical oceans • No fronts attached • Produce organized thunderstorm activity Have a closed surface wind circulation around a well-defined center	

Key Points

Tropical cyclone is the generic term for a non-frontal, relatively large and long-lasting, low-pressure system that forms over tropical or subtropical waters (as this is their source of energy). No fronts are attached to a tropical cyclone.

To be defined as a tropical cyclone, it must have organized thunderstorm activity and a closed surface wind circulation around a well-defined center.

Tropical cyclones rotate counterclockwise in the Northern Hemisphere.

Visual 4: Tropical Cyclone Classification

By Maximum Wind Speed:

- Tropical Depression: <39 mph
- Tropical Storm: 39–73 mph
- Hurricane: 74 mph or greater

Major Hurricane: 111 mph or greater

Key Points

There are several types of tropical cyclones. Wind speed is the most common metric used to categorize them. Storms strong enough to be called hurricanes will be categorized and named differently depending on the region of the world in which they originate.

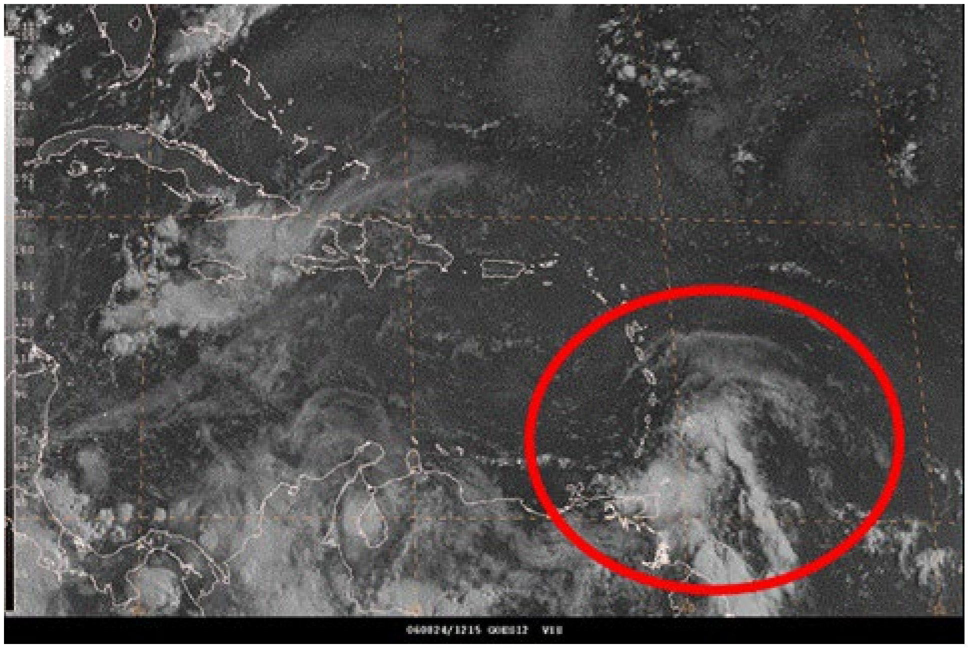
Tropical cyclones are classified by their maximum sustained surface wind speeds.

- Tropical depression: <39 miles per hour (mph)
- Tropical storm: 39–73 mph
- Hurricane: 74 mph or greater (Major hurricane: 111 mph or greater)

If a tropical cyclone achieves maximum sustained winds of 74 mph and originates in the Atlantic or the eastern and central North Pacific Ocean basin, it is called a hurricane. If the same size storm originates in the Northwest Pacific Ocean basin, it is called a typhoon. If it originates in the Southwest Pacific or Indian Oceans, then it is simply called a cyclone.

This course will concentrate on hurricanes because those are what affect the United States.

Visual 5: Surface circulation? Organized?

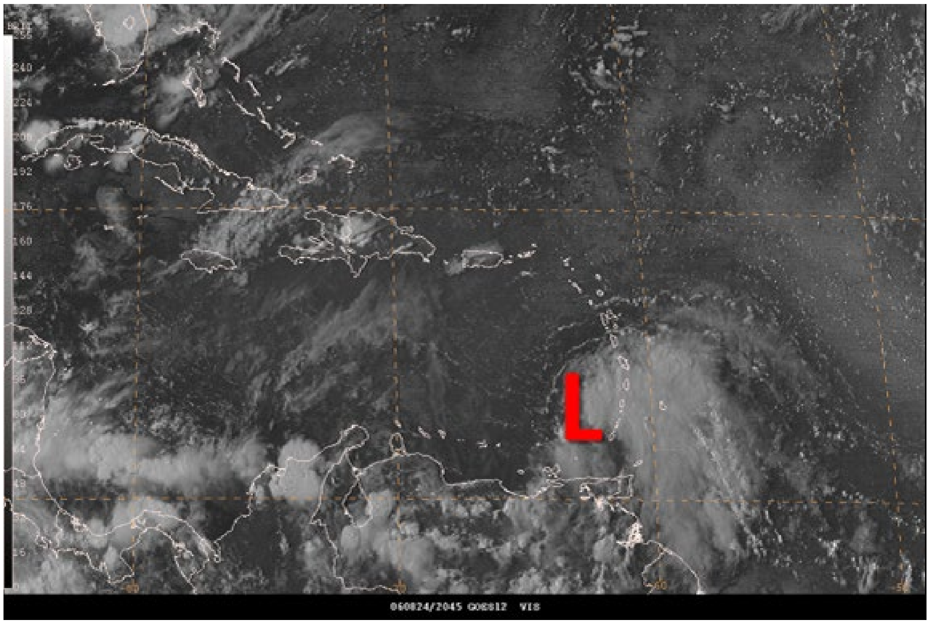


Key Points

To determine if it is the beginning of a tropical cyclone, ask the following questions:

- Are there any fronts attached?
- Is there organized thunderstorm activity?
- Is there a closed surface circulation?

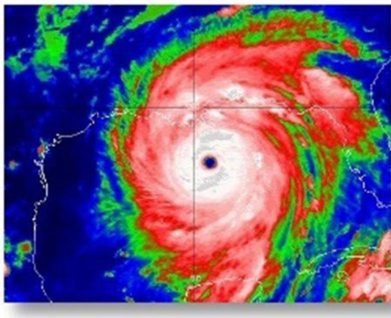
Visual 6: Ernesto 2006



Key Points

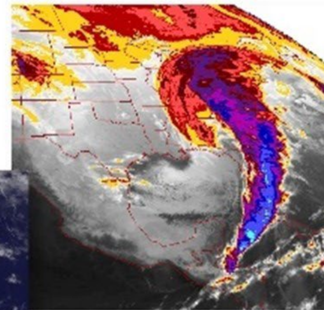
This depression later grew into Hurricane Ernesto.

Visual 7: Tropical, Subtropical, & Extratropical



Hurricane Katrina
2005

Subtropical Storm Ana
2015



March Superstorm
1993

Key Points

Coastal storms include both tropical and non-tropical cyclones. Tropical and post-tropical systems are typically associated with greater impacts than coastal storms that never acquire tropical characteristics. When a system loses its tropical characteristics, it may still retain hurricane or tropical storm-force winds, along with storm surge and heavy rainfall that can cause catastrophic impacts under certain conditions.

Tropical cyclones originate over tropical or subtropical waters, which means they have little significant temperature differences across the breadth of the storm. This is different from winter storms that get their energy from temperature differences along fronts that are connected to the cyclone. Tropical cyclones are warmest near the center and are referred to as ‘warm-core.” The release of this warmth gives the storm its energy.

Extratropical cyclones, also called “mid-latitude cyclones” or “wintertime cyclones,” originate in waters outside of the tropics, otherwise known as the region of the middle-latitude of the earth. Temperatures here are not as consistently warm.

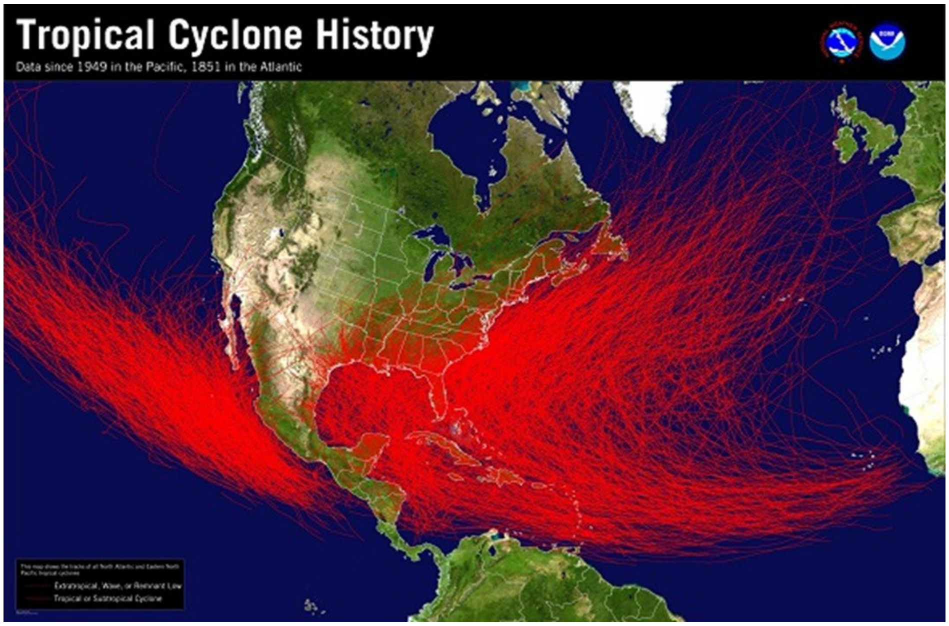
Whereas the energy for a tropical cyclone comes from the warmth, the primary energy source for an extratropical storm results from the temperature contrast between warm and cold air masses. Therefore, the two types of storms, although similar in many ways, behave differently and have different characteristics.

Extratropical cyclones are associated with cold fronts, warm fronts, and occluded fronts. Structurally, extratropical cyclones are “cold-core,” meaning that the center is colder than the surroundings at the same height in the troposphere.

It is possible for a tropical cyclone to become extratropical and vice versa as the storm moves northward into the mid-latitudes.

Subtropical cyclones have a non-frontal low-pressure system that has characteristics of both tropical and extratropical cyclones. Like tropical cyclones, they are non-frontal, synoptic-scale cyclones that originate over tropical or subtropical waters and have a closed surface wind circulation around a well-defined center. In addition, they have organized moderate to deep convection but lack a central dense overcast. Unlike tropical cyclones, subtropical cyclones derive a significant proportion of their energy from baroclinic sources and are generally cold-core in the upper troposphere, often being associated with an upper-level low or trough. In comparison to tropical cyclones, these systems generally have a radius of maximum winds occurring relatively far from the center (usually greater than 60 nautical miles) and generally have a less symmetric wind field and distribution of convection.

Visual 8: Tropical Cyclone History

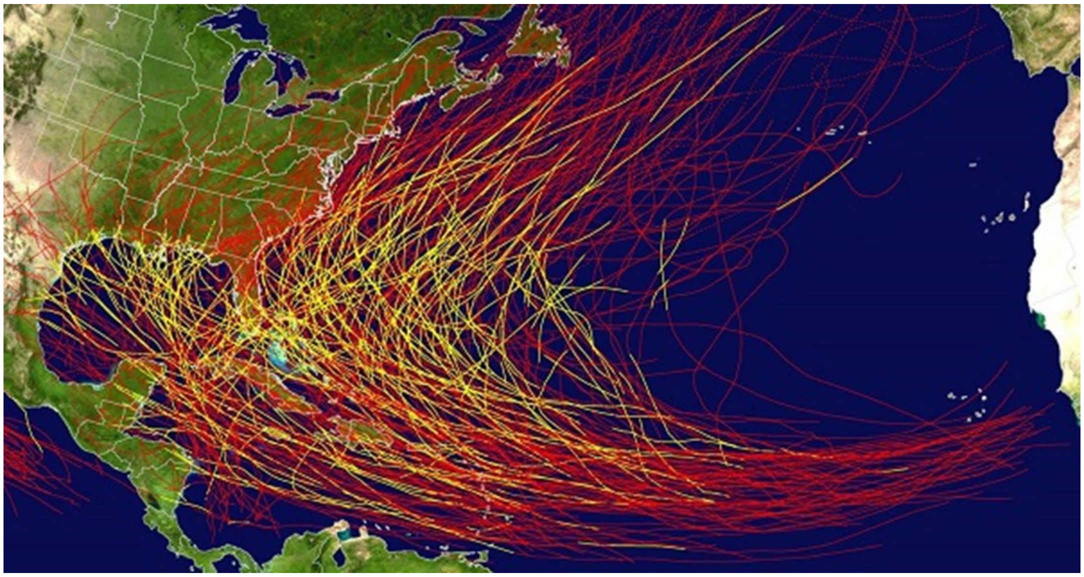


Data since 1949 in Pacific, 1851 in Atlantic

Key Points

This map shows the tracks of all tropical cyclones in the Atlantic Ocean since 1851 and all in the Pacific Ocean since 1949.

Visual 9: Major Hurricane History



Data since 1949 in Pacific, 1851 in Atlantic

Key Points

This map shows all the tropical cyclones strong enough to be classified as major hurricanes during the same time period.

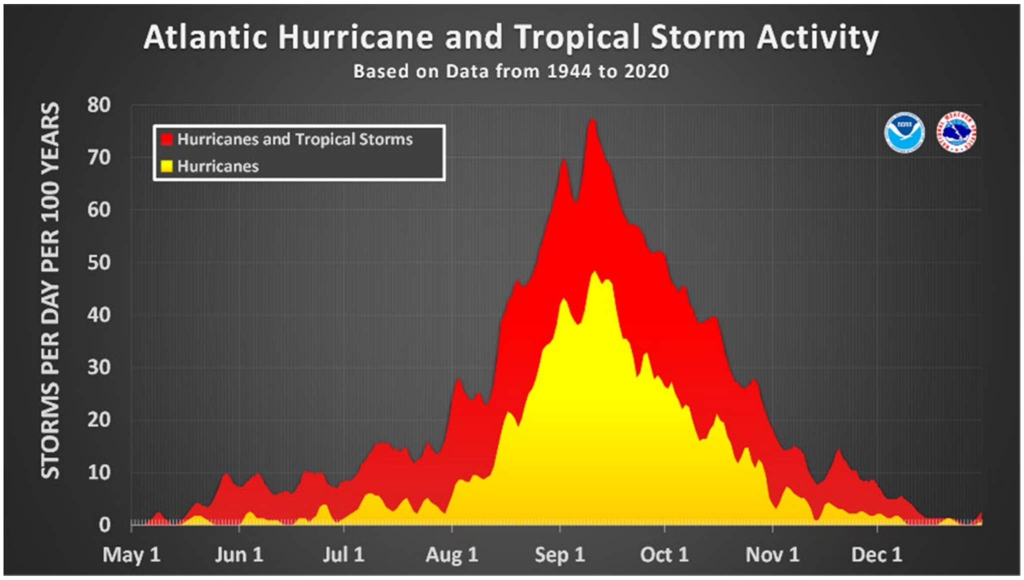
Remember, a major hurricane has wind speeds of 111 mph or greater. The time each storm was a major hurricane is shown with the yellow portion of the lines. Notice the large number of major hurricanes over the southwestern Atlantic Ocean, Caribbean Sea, and the Gulf of Mexico.

Visual 10: Climatology – Knowledge Check

What month has the most hurricane activity in the Atlantic?

A. December
B. August
C. June
D. September

Visual 11: Annual Atlantic Storm Activity



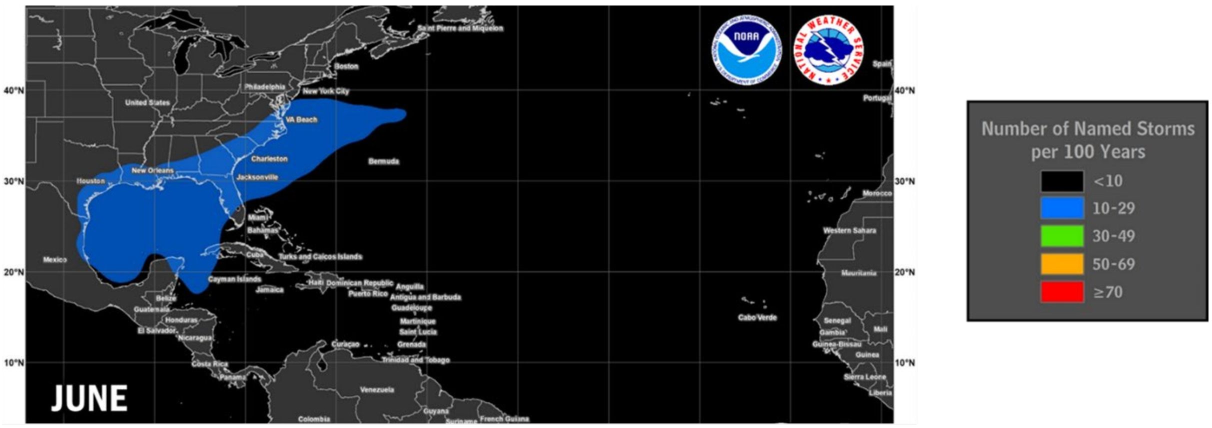
Key Points

The official hurricane season for the Atlantic Basin (the Atlantic Ocean, the Caribbean Sea, and the Gulf of Mexico) is from June 1 to November 30. However, activity does sometimes occur before June 1 (a named storm typically forms in May once every 3 years).

As seen in the visual, the peak of the season is from mid-August to late October. However, deadly and destructive hurricanes can occur any time during the hurricane season.

More information on Atlantic hurricane and tropical storm activity can be found at the NHC & CPHC Tropical Cyclone Climatology page.

Visual 12: June Occurrence Areas



- On average, about one storm every year.
- Most June storms form in the NW Caribbean Sea or Gulf of Mexico.

Key Points

Tropical cyclones form and originate in predictable ways.

Precisely where they form and move depends on general weather trends, which change month to month. These products are climatology based, and weather patterns at the moment of a storm could vary.

These visuals show likely occurrence areas for named storms and hurricanes for June. In June, there is, on average, about one storm every year. Most tropical cyclones in June occur in the Northwest Caribbean Sea, the Gulf of Mexico, or off the Southeast U.S. coast.

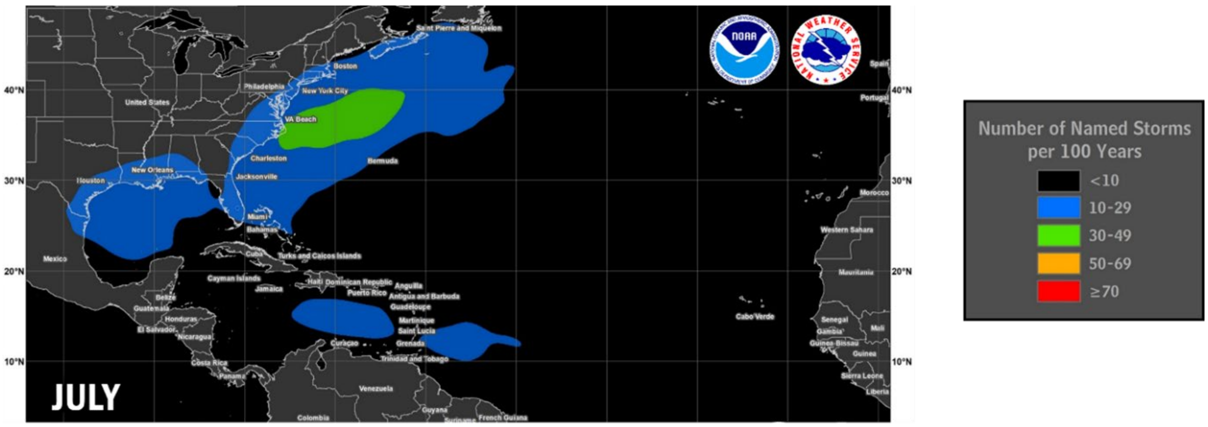
Over the next few pages, we will see typical formation patterns for the other months of the hurricane season.

In general, the areas of occurrence typically lie in the western portion of the basin during the early part of the hurricane season. The average occurrence areas then shift eastward to across the entire Atlantic Basin by the peak of the season, before shifting back into the western Caribbean Sea and Gulf of Mexico in October and November.

Remember that these figures represent the typical occurrence areas, but tropical cyclones can originate and move in different locations and travel different paths from the average.

More information can be found at the NHC Tropical Cyclone Occurrence Areas by Month.

Visual 13: July Occurrence Areas

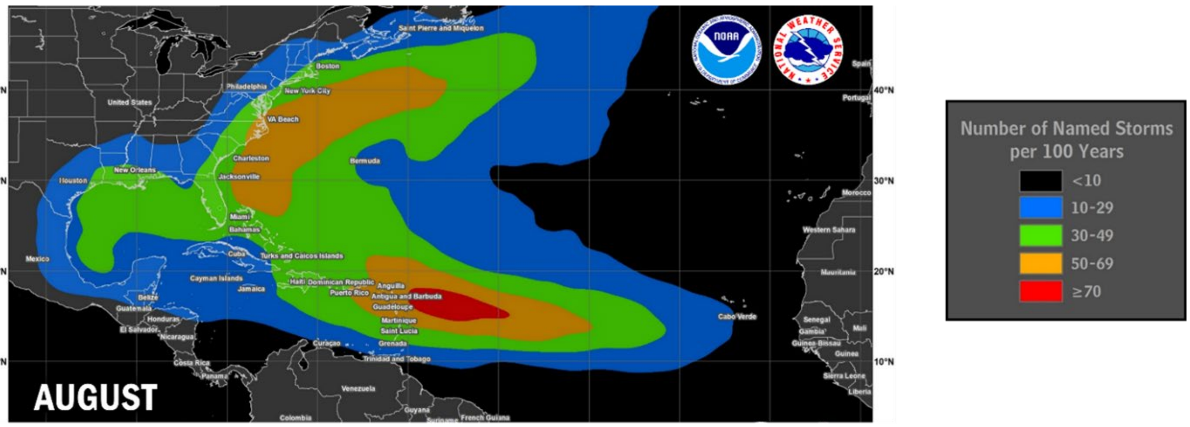


- On average, one to two named storms every year.
- July occurrence areas spread east and cover the western Atlantic, Caribbean, and Gulf of Mexico.

Key Points

July also sees about one or two tropical cyclones form per year, on average. During July, tropical cyclone occurrence typically extends eastward and includes a larger area including the western Atlantic Ocean, Caribbean Sea, and Gulf of Mexico.

Visual 14: August Occurrence Areas



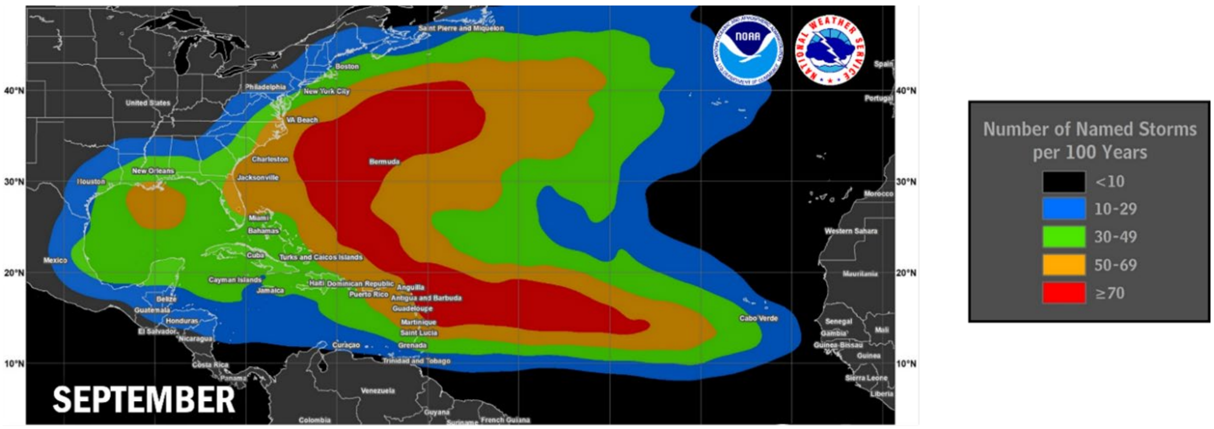
- On average, about three to four storms form each year.
- The Cape Verde season usually begins in August.

Key Points

August sees an average of three or four tropical cyclones form per year. During August, as waters warm in the Atlantic, tropical cyclone occurrence extends even farther eastward.

The Cape Verde season usually begins in August. Cape Verde hurricanes (named for the islands near where they form, off the western African coast) are generally the most intense and longest lasting storms of the season because they travel great distances across the Atlantic Ocean.

Visual 15: September Occurrence Areas

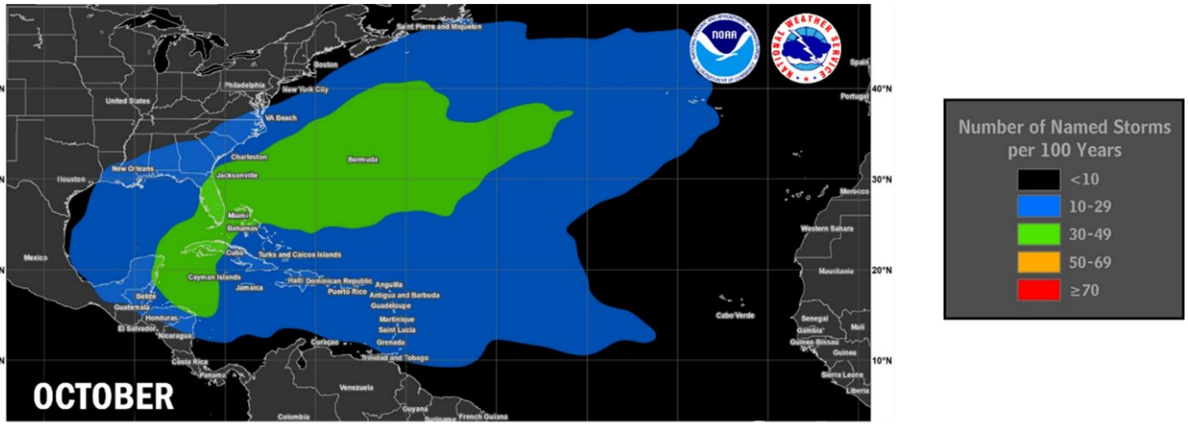


- Climatological peak of the season; on average, four to five storms every year.
- Storms can form nearly anywhere in the basin; long-track Cape Verde storms are more likely.

Key Points

September is the climatological peak of the tropical cyclone season. On average, four to five storms form every year and can form nearly anywhere in the basin. The risk for powerful, long-track Cape Verde hurricanes is greatest in September.

Visual 16: October Occurrence Areas

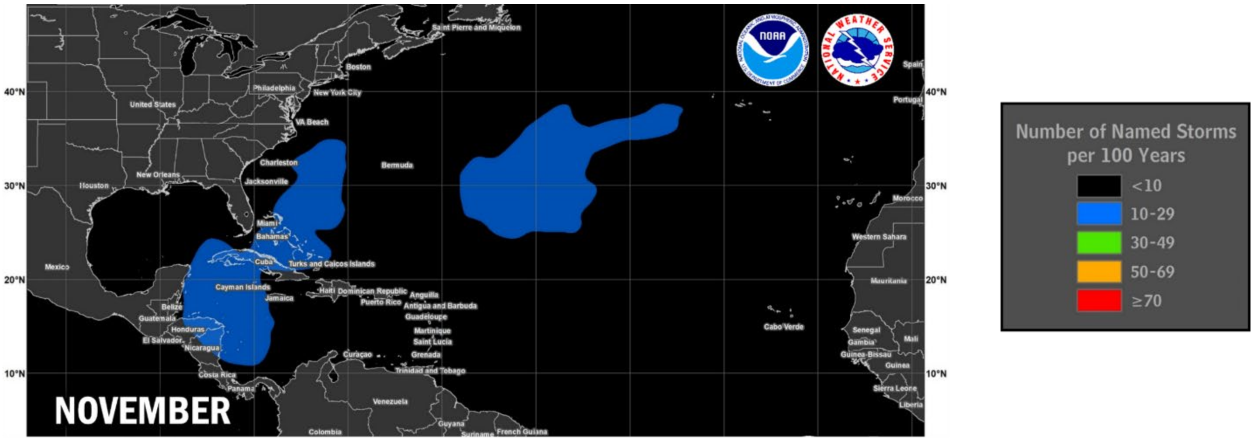


- On average, two to three storms every year.
- Cape Verde season ends, and activity shifts to the Gulf of Mexico, Caribbean Sea, and western Atlantic Ocean.

Key Points

On average, October sees two to three named storms form each year. Cape Verde season ends, and activity shifts back to the Gulf of Mexico, Caribbean Sea, and western Atlantic Ocean. October storms often threaten Florida.

Visual 17: November Occurrence Areas

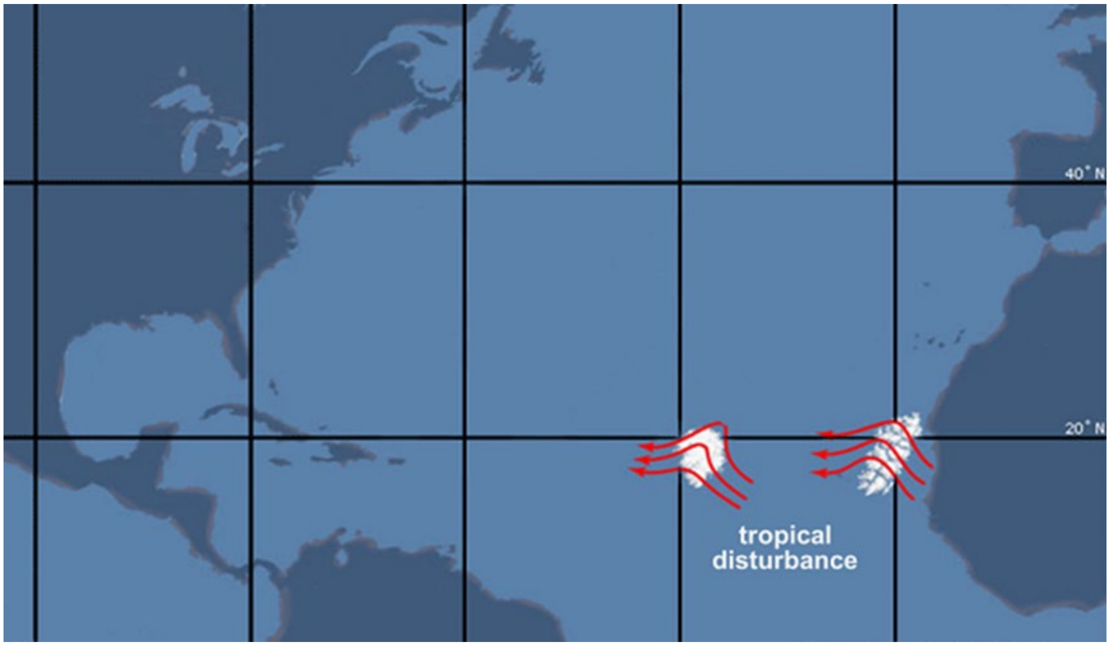


- On average, about one storm every other year.
- Storms typically occur in the western Caribbean Sea or western and central Atlantic Ocean.

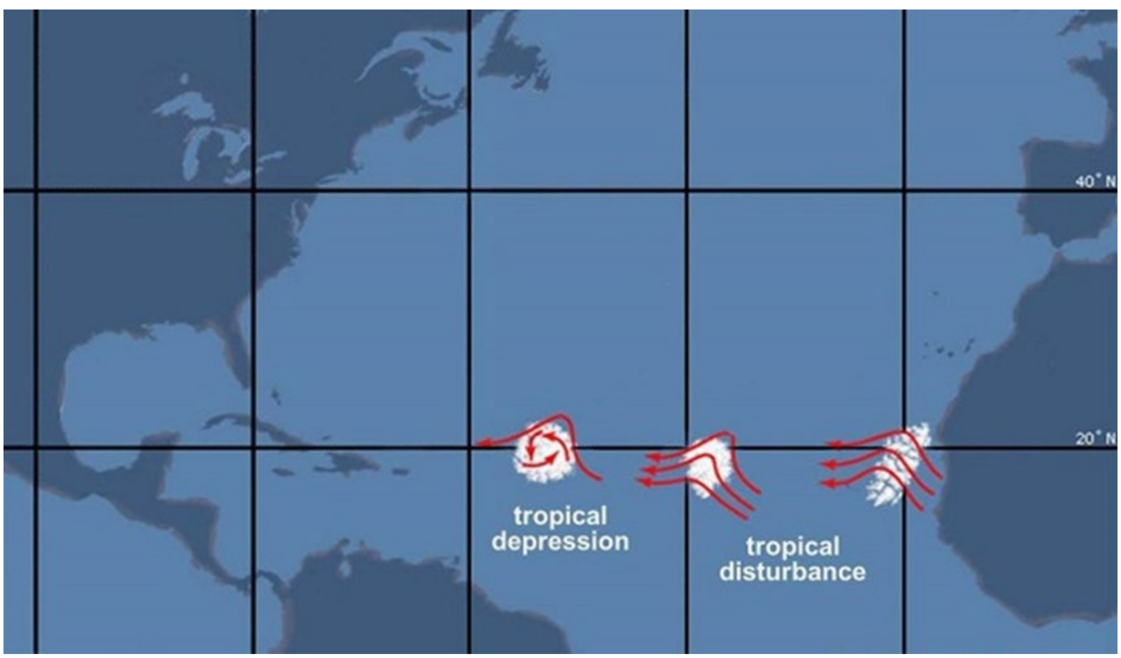
Key Points

With the chill of November, hurricane formation decreases to an average of only one storm every other year. Typically, tropical cyclones occur in the northwestern Caribbean Sea or the western and central Atlantic during this month.

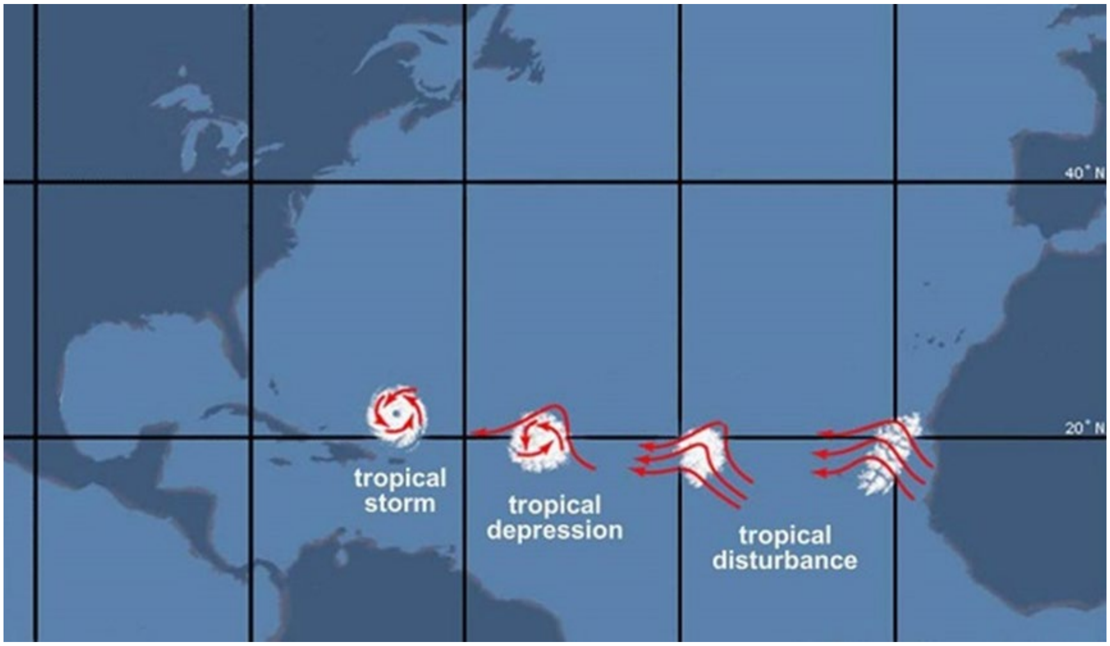
Visual 18: Cape Verde Hurricane Life



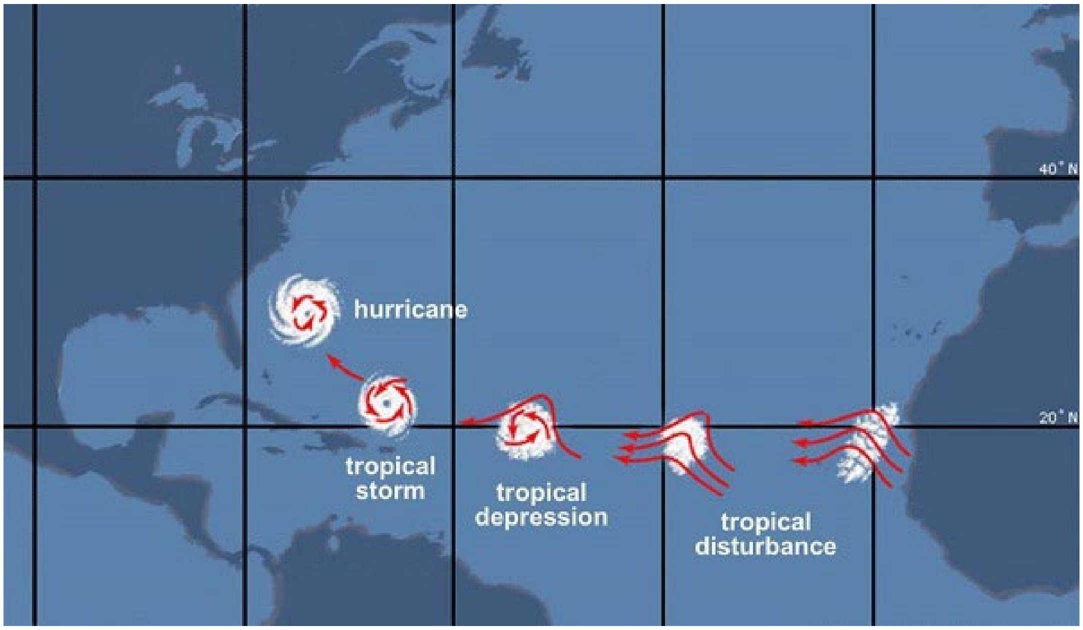
The tropical wave continues to move westward over the tropical Atlantic, gradually organizing.



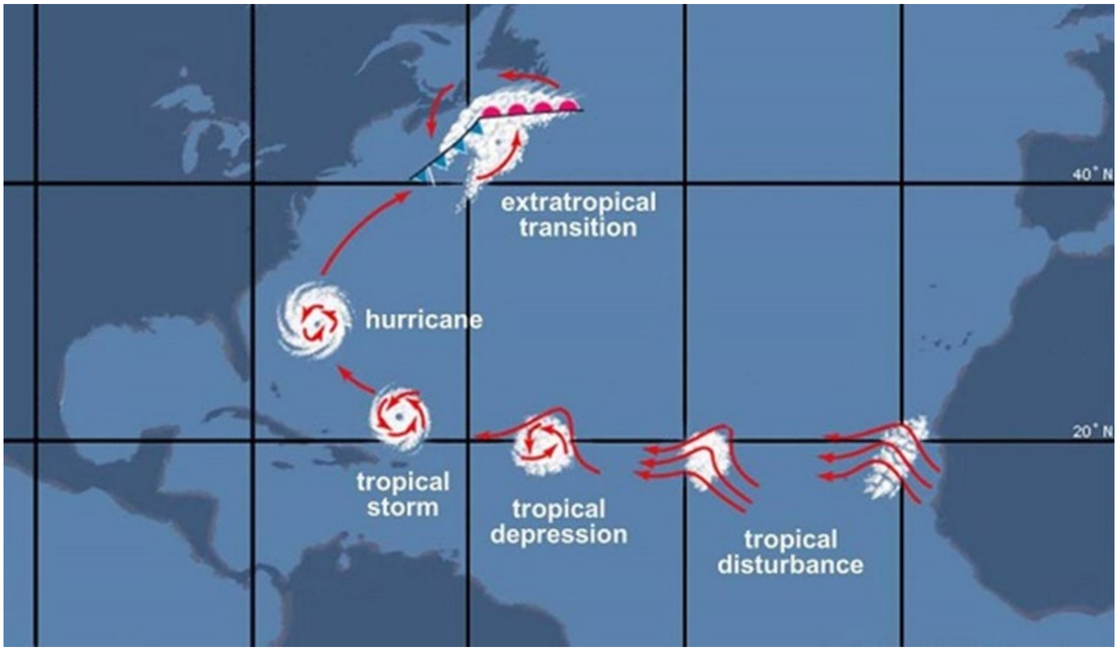
As the tropical wave continues west over the Tropical Atlantic, a tropical depression forms.



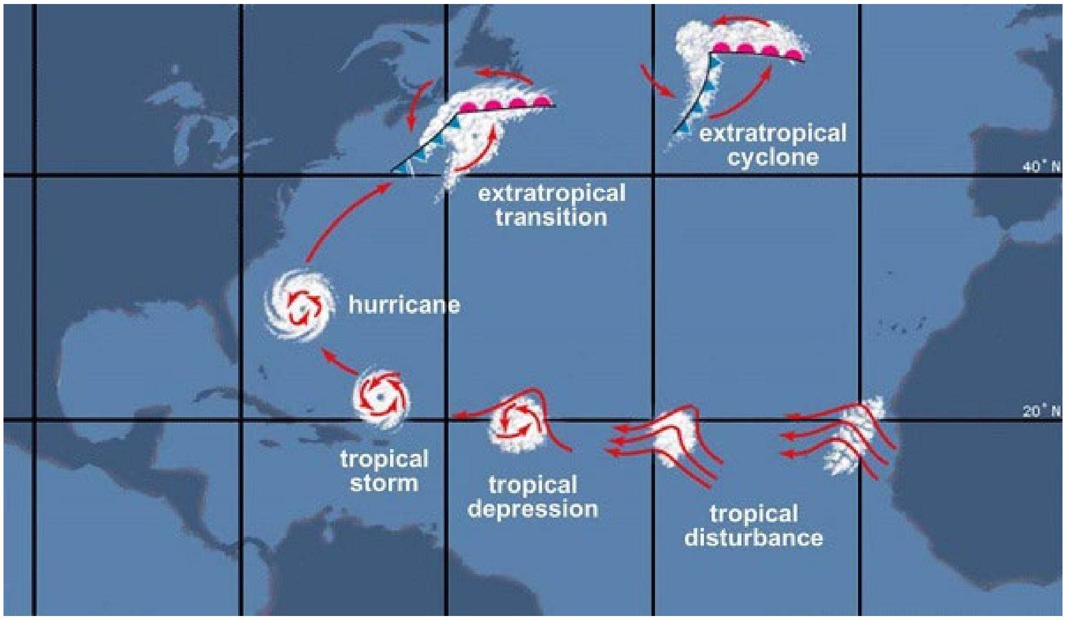
This tropical depression strengthens into a tropical storm as it moves into the southwestern Atlantic and near the Lesser Antilles.



The tropical storm strengthens into a hurricane as it moves into the western Atlantic, reaching peak intensity.



The hurricane begins extratropical transition as it moves into the North Atlantic.



The hurricane is now post-tropical over the north Atlantic, absorbed into a frontal system.

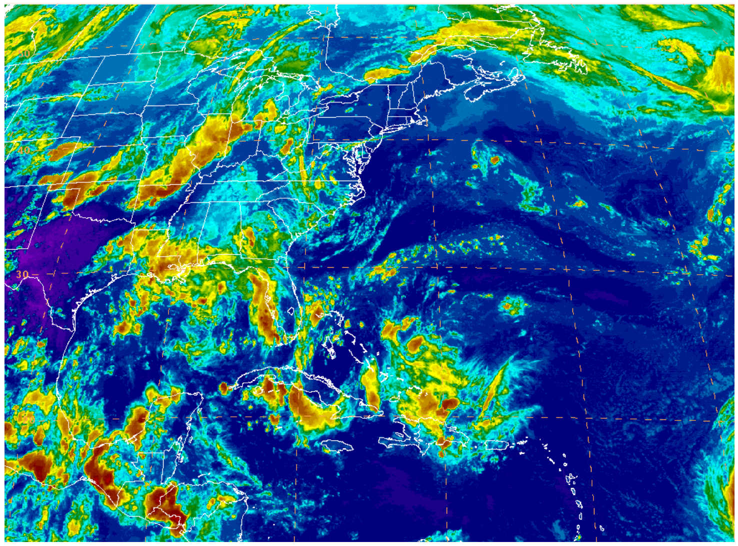
Key Points

Tropical cyclones progress through various stages during their existence. They form from a pre-existing **disturbance** over tropical or subtropical waters and then usually go through an **intensification phase** to reach maturity and peak intensity.

Cape Verde hurricanes have an abundance of warm water over which to travel and typically gather strength before hitting land. For this reason, these hurricanes are usually the longest lasting and most intense storms compared to tropical cyclones originating in other areas. They are named after the geographical area where they first develop off the west coast of Africa.

Weakening typically occurs when a tropical cyclone enters a hostile environment often caused by unfavorable wind conditions in the middle or upper atmosphere, moves over cooler waters, or interacts with land. Sometimes the weakening phase leads to **dissipation** of the tropical storm or hurricane.

Visual 19: Hurricane Bill (2009)



Key Points

This example shows the life cycle of Hurricane Bill in 2009. The satellite loop shows the tropical cyclone becoming a mature hurricane over the Atlantic Ocean before it turns northward and moves over high latitudes. When that occurs, the storm begins to move over cooler waters and interacts with other weather features. This causes Hurricane Bill to transition into an extratropical- or wintertime-type, low-pressure area.

Visual 20: Forecasting – Knowledge Check

Which of these are ingredients for hurricane development?

A. Warm Water
B. Cold Air
C. Lots of Moisture
D. Strong Winds Aloft
E. Icebergs

Visual 21: Ingredients for a Tropical Cyclone

Building Blocks

1. A pre-existing disturbance (vorticity or spin)

2. Location several degrees north of the equator

3. Little change in wind speed or direction with height (vertical wind shear)

Fuel

1. Warm sea-surface temperatures (usually at least 80°F)

2. Unstable atmosphere (temperature goes down as you go up)

3. High atmospheric moisture content (relative humidity)

Key Points

To help you understand the ingredients needed for a tropical cyclone to form, we are going to use the metaphor of a car and the parts needed to build it.

If you want to build a car, what do you need?

First, we'll break these parts into two groups, depending on what type of energy they require:

- Mechanical, or force-related energy
- Thermodynamic, or heat-related energy

We'll start with mechanical. A car frame comes first.

For a tropical cyclone, consider the frame to be a pre-existing disturbance in the proper location over the ocean, at least several degrees north of the equator.

If it were at the equator, the disturbance would not get the existing spin from the earth; this is called the Coriolis Effect. Think of this as the spin of car tires.

Next in the analogy is the car windshield. Wind shear is the comparable part in a tropical cyclone. Vertical wind shear is when the wind changes in speed or direction with height.

A hurricane wants low vertical wind shear just as a streamlined car windshield makes your car aerodynamic.

Next is fuel. For a tropical cyclone, the fuel is warmth—a water surface temperature of at least 80 degrees Fahrenheit. The deeper the warmth goes in the ocean water, the better the fuel for a hurricane.

Like spark plugs, the next ingredient needed for a hurricane is an unstable atmosphere where the temperature goes down and gets colder the higher you go up into the atmosphere.

Mixing the cold temperatures with the warm temperatures begins the cycle that leads to thunderstorm activity.

Like oil for the car, high relative humidity is a lubricant to keep the system running efficiently.

Mechanical (force-related) mechanisms are the building blocks of the storm.

1. Pre-existing disturbance (vorticity or spin): Frame
2. Location several degrees north of the equator: Tires
3. Little change in wind speed or direction with height (vertical wind shear): Windshield
4. Thermodynamic (heat-related) energy provides fuel for the storm. Warm sea-surface temperature (usually at least 80°F): Fuel
5. Unstable atmosphere (temperature goes down as you go up): Spark plugs
6. High atmosphere moisture content (relative humidity): Oil

We look at all these factors when we are trying to determine if a system will become a tropical cyclone.

Visual 22: Pre-existing Disturbances

Tropical waves

- About 70% of all Atlantic basin formations
- Most major hurricanes

Decaying cold fronts

- Formation often near Gulf of Mexico and southeastern United States
- Typically, early- or late-season storms

Non-tropical lows and thunderstorm complexes

- Often subtropical systems

Key Points

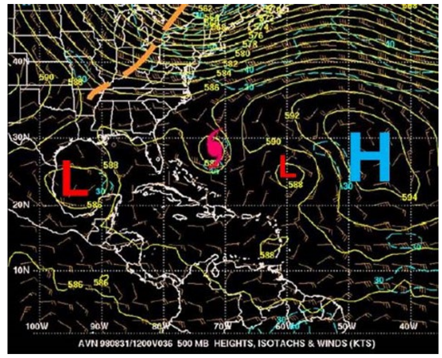
Tropical waves are troughs of low pressure in the low levels of the atmosphere that originate over Africa and move westward off of the west coast of Africa every few days from May through November. Tropical waves are the most common type of pre-existing disturbance that leads to tropical storm formations. About 70% of all Atlantic Basin tropical cyclones, and most major hurricanes, form from tropical waves.

Decaying cold fronts can also cause a disturbance and lead to tropical cyclone formation in the Gulf of Mexico or near the southeastern United States. Storms caused by decaying frontal systems are most likely to occur very early or late in the season. For example, in 2014, Hurricane Arthur developed in late June off the coast of the Carolinas.

Non-tropical lows and thunderstorm complexes can also lead to storm formation. Examples include Hurricane Danny (1997) and Hurricane Barry (2019).

Visual 23: Storm Motion and Track

- Track forecasting is usually controlled by large-scale weather features.
    - Cork-in-stream analogy
- Numerical computer models forecast the track quite well.
    - Constantly upgrading model physics and resolution
    - Long ago surpassed statistical models in accuracy



Key Points

Tropical cyclone track forecasting is a relatively simple problem with well-understood physics. Consider how a cork in a stream will bob along as the moving water pushes it. Likewise, tropical cyclones (the cork) are steered by large-scale weather features (the atmosphere, which is like a river of air), including high- and low-pressure systems, troughs, and ridges in the middle- to upper-atmosphere.

Numerical computer models typically forecast the track of a tropical cyclone quite well and have improved greatly during the past couple of decades due to constantly upgrading model physics and resolution. They surpassed statistical models in accuracy long ago. Statistical models have limited information on how the atmosphere will evolve and use past cases to predict what will occur. Dynamical or numerical models solve physical equations to predict how features in the atmosphere will move over the next several days.

The anticipated vertical depth of a tropical cyclone in the atmosphere (weaker systems are shallow with stronger systems being deeper) can be the challenging part for the forecaster. The depth of a tropical cyclone has implications on which layer of the atmosphere will provide the steering flow.

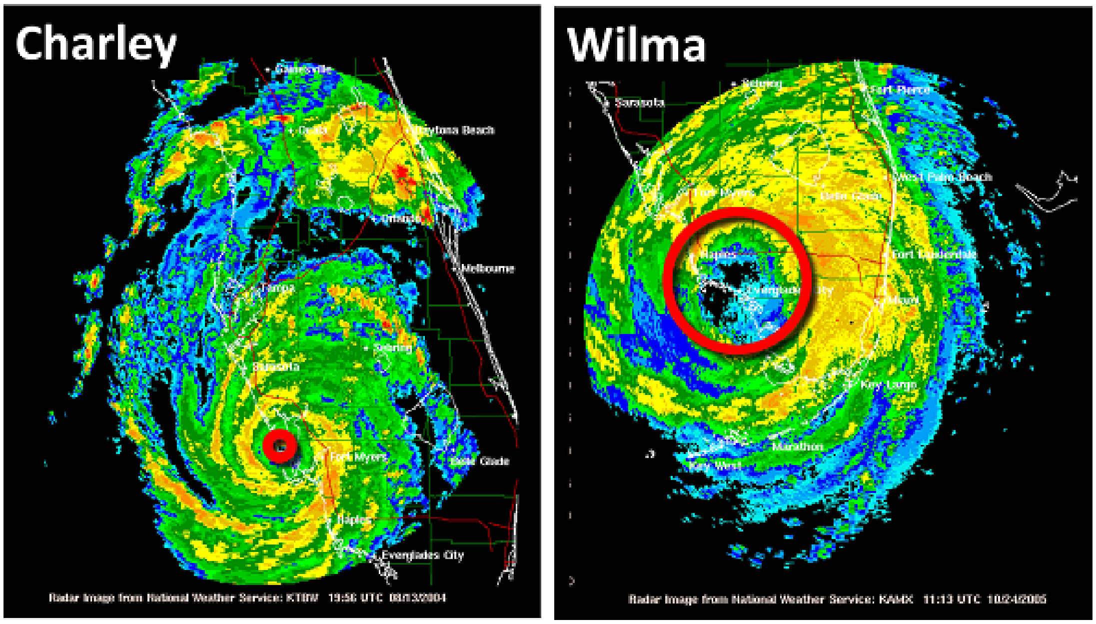
Visual 24: Factors Affecting Intensity

- Upper-Ocean Temperatures
  - More heat favors a stronger storm.
- Interaction with Land/Topography
  - Land weakens the storm.
- Vertical Wind Shear
  - Shear limits strengthening.
- Moisture in Storm Environment
  - Dry air can limit strengthening.
- Structural Changes and Eyewall Replacement
  - Difficult to forecast and not straightforward.
- Interactions with other weather systems

Key Points

- Upper-Ocean Temperatures
  - Tropical cyclones generally need deep, warm water (>80F) to strengthen.
- Interaction with Land and Topography
  - Tropical cyclones weaken wind strength as they make landfall. This does not mean that the impacts are weaker.
- Vertical Wind Shear
  - Tropical cyclones require low vertical wind shear (little change in wind speed or direction with height) to strengthen.
- Interactions with Other Weather Systems
  - When a tropical cyclone interacts with another weather system, it can either strengthen or weaken depending on the interaction.
- Moisture in Storm Environment
  - Tropical cyclones need an unstable atmosphere (decreasing temperature with height) and a moist atmosphere for strengthening. Dry air can cause weakening.
- Structural Changes and Eyewall Replacement
  - Eyewall replacements typically cause fluctuations in intensity in strong hurricanes. These fluctuations are difficult to forecast and are not straightforward.

Visual 25: Tropical Cyclones Come in All Sizes



Key Points

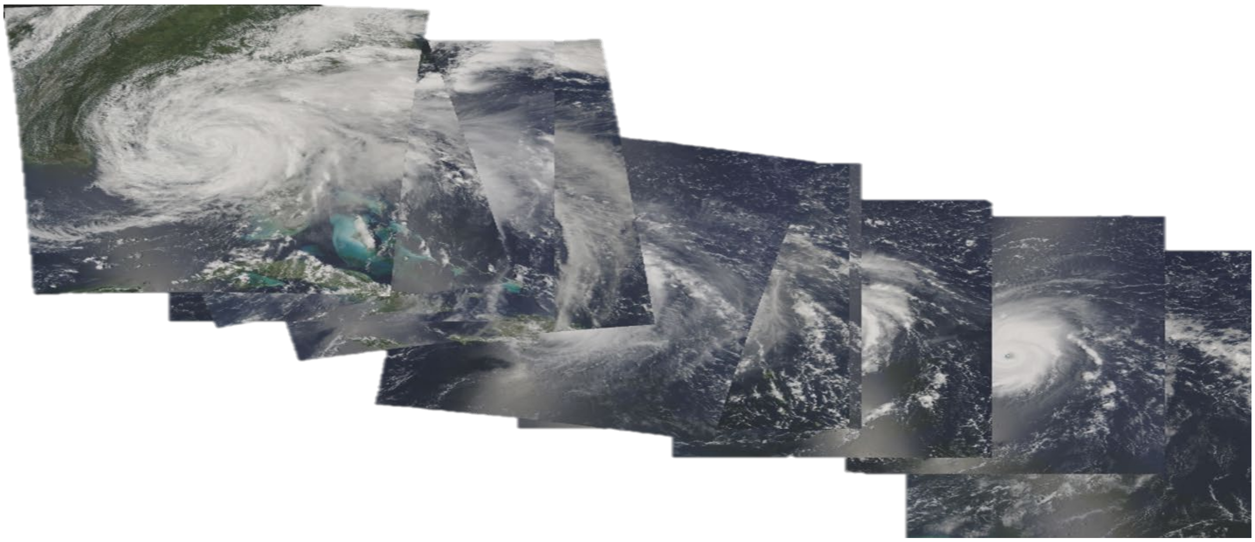
No two tropical cyclones are the same. The size of the eyes can vary considerably, which affects how the storm behaves.

As an example, we can look at Charley and Wilma, two storms that made landfall in Southwest Florida.

Charley had a tiny eye with a secondary eyewall forming around the small eye. The strongest winds in Charley only occurred within about 6 miles of the center. Wilma had a much larger eye, over 40 miles across when it made landfall. This difference significantly impacted the level of storm surge and the areas impacted by damaging winds.

Charley had a 4- to 6-foot storm surge and was categorized a Category 4. Although Wilma's winds were less intense as a Category 3, the eye size differential brought a more intense storm surge of up to 9 feet.

Visual 26: Questions?



Visual 27: Hazards – Knowledge Check

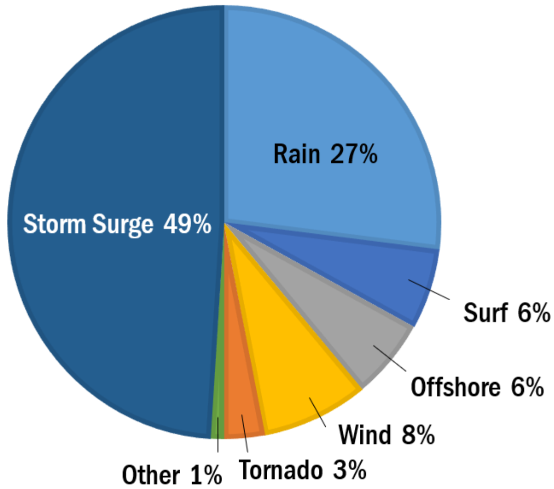
Which hazard has the greatest potential for large loss of life?

A. Wind
B. Rain-induced flooding
C. Tornadoes
D. Storm Surge

Visual 28: Atlantic Tropical Cyclone Deaths

U.S. tropical cyclone direct fatalities

- from 1963–2012



Key Points

Hurricane water in one of its many forms (surge, flooding, or waves) accounts for about 88% of the direct fatalities from tropical cyclones in the United States.

When this is broken down to specific causes, as shown on the pie chart, you can see that storm surge has been the deadliest hazard associated with tropical cyclones in the United States during the past 50 years. Storm surge is responsible for roughly 50% of all deaths associated with tropical cyclones.

Rainfall-induced flooding accounts for about 27% of all deaths, while wind, tornadoes, surf, and offshore flooding combined account for only 23% of deaths caused by tropical cyclones.

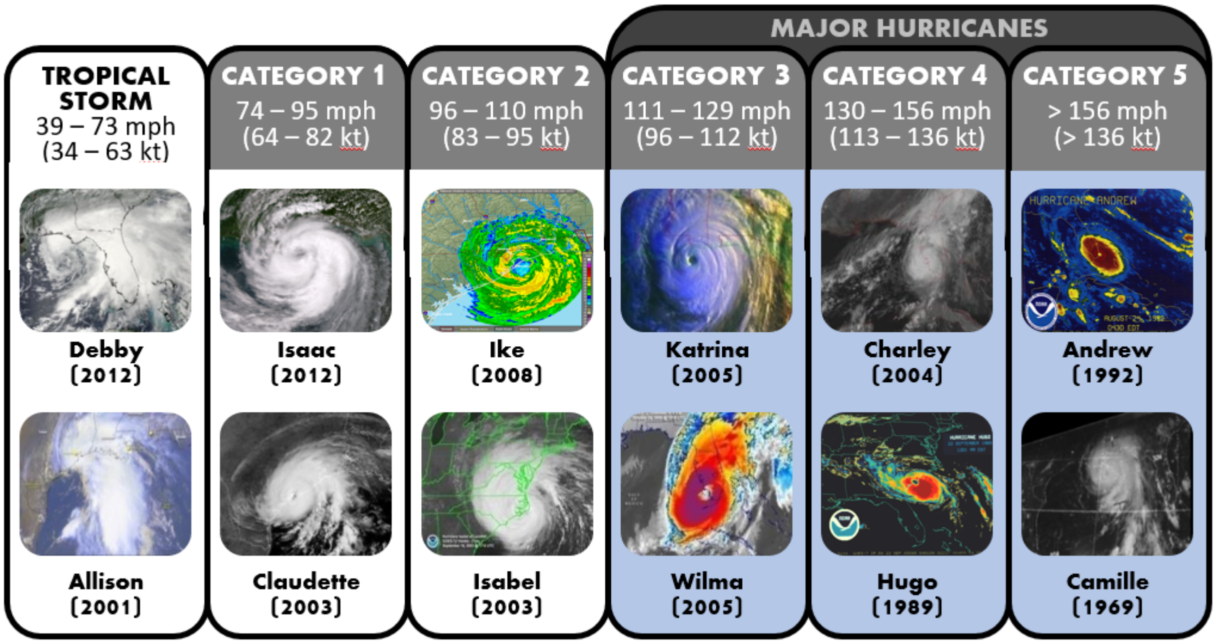
Visual 29: Hurricane Hazards

Key Points

Hurricanes pose multiple hazards to life and property. We will go into detail about these hazards in the rest of this unit. The primary hazards posed by tropical cyclones include:

- Storm surge
- Wind
- Freshwater or inland flooding
- Tornadoes
- Waves and rip currents

Visual 30: Saffir-Simpson Scale



Key Points

Hurricane-force winds can cause tremendous damage to structures and trees. Wind-blown debris can become deadly projectiles.

The force of the wind increases significantly with an increase in wind speed (force ~ velocity of the wind squared).

It should be noted that high winds affect more than just the coast. Although hurricanes do begin to weaken once they hit land, inland areas are often subject to hurricane-force winds.

The most well-known way of categorizing tropical cyclones is by wind speed using the **Saffir-Simpson Hurricane Wind Scale.** It classifies hurricanes into five categories based on their maximum sustained wind speed.

Category	Wind Speed in MPH	Degree of Damage
1	74–95	Some damage
2	96–110	Extensive damage
3	111–129	Devastating damage
4	130–156	Catastrophic damage
5	157 and above	Catastrophic damage

This rating highlights potential damage and impacts from the wind but does not address potential for other hurricane-related impacts, such as storm surge, rainfall-induced floods, and tornadoes.

Visual 31: Category 1 (74–95 mph)


Humberto (2007) Southeast TX


Isaias (2020) Oak Island, NC


Lili (2002) Louisiana

Some damage

- Well-constructed frame homes could have roof damage.
- Large tree branches will snap; shallow-rooted trees may topple.
- Damage to power lines and poles; outages could last several days.

Key Points

Category 1

Tropical cyclones are labeled Category 1 on the Saffir-Simpson Hurricane Wind Scale if their maximum sustainable wind speed is 74 to 95 mph.

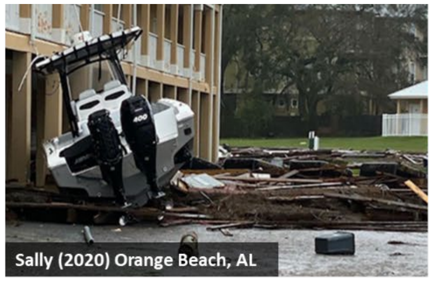
Hurricane Isaias made landfall in North Carolina as a Category 1 in 2020.

Although these hurricanes produce very dangerous winds and will certainly cause damage, it is usually not extensive.

For example, trees and power lines are blown down, and some roof damage occurs.

Subject	Potential Effect in a Category 1 Hurricane
People, Livestock, and Pets	People, livestock, and pets struck by flying or falling debris could be injured or killed.
Mobile Homes	Older (mainly pre-1994 construction) mobile homes could be destroyed, especially if they are not anchored properly because they tend to shift or roll off their foundations. Newer mobile homes that are anchored properly can sustain damage involving the removal of shingle or metal roof coverings, and loss of vinyl siding, as well as damage to carports, sunrooms, or lanais.
Frame Homes	Some poorly constructed frame homes can experience major damage involving loss of the roof covering and damage to gable ends, as well as the removal of porch coverings and awnings. Unprotected windows might break if struck by flying debris. Masonry chimneys can be toppled. Well-constructed frame homes could have damage to roof shingles, vinyl siding, soffit panels, and gutters. Failure of aluminum, screened-in swimming pool enclosures can occur.
Apartments, Shopping Centers, and Industrial Buildings	Some apartment building and shopping center roof coverings could be partially removed. Industrial buildings can lose roofing and siding, especially from windward corners, rakes, and eaves. Failures to overhead doors and unprotected windows will be common.
High-Rise Windows and Glass	Flying debris can break windows in high-rise buildings. Falling and broken glass will pose a significant danger, even after the storm.
Signage, Fences, and Canopies	There will be occasional damage to commercial signage, fences, and canopies.
Trees	Large branches of trees will snap, and shallow rooted trees can be toppled.
Power and Water	Extensive damage to power lines and poles will likely result in power outages that could last a few to several days.

Visual 32: Category 2 (96–110 mph)



Extensive damage

- Well-constructed frame homes could sustain major roof damage.
- Many shallow-rooted trees will be snapped or uprooted.
- Near total power loss is expected that could last several weeks.

Key Points

Category 2

Category 2 hurricanes produce extremely dangerous winds and will cause extensive damage. The wind speed of a Category 2 hurricane is 96 to 110 mph.

You may recall Hurricanes Ike in 2008, Wilma (over Southeast Florida) in 2005, and Sally in 2020 as examples of Category 2 storms on the Saffir-Simpson Hurricane Wind Scale.

Subject	Potential Effect in a Category 2 Hurricane
People, Livestock, and Pets	There is a substantial risk of injury or death to people, livestock, and pets because of flying and falling debris.
Mobile Homes	Older (mainly pre-1994 construction) mobile homes have a very high chance of being destroyed, and the flying debris generated can shred nearby mobile homes. Newer mobile homes can also be destroyed.
Frame Homes	Poorly constructed frame homes have a high chance of having their roof structures removed, especially if they are not anchored properly. Unprotected windows will have a high probability of being broken by flying debris. Well-constructed frame homes could sustain major roof and siding damage. Failure of aluminum, screened-in swimming pool enclosures will be common.
Apartments, Shopping Centers, and Industrial Buildings	There will be a substantial percentage of roof and siding damage to apartment buildings and industrial buildings. Unreinforced masonry walls can collapse.
High-Rise Windows and Glass	Flying debris can break windows in high-rise buildings. Falling and broken glass will pose a significant danger, even after the storm.
Signage, Fences, and Canopies	Commercial signage, fences, and canopies will be damaged and often destroyed.
Trees	Many shallowly rooted trees will be snapped or uprooted and block numerous roads.
Power and Water	Near-total power loss is expected, with outages that could last from several days to weeks. Potable water could become scarce as filtration systems begin to fail.

Visual 33: Category 3 (111–129 mph)


Jeanne (2004) Cape Canaveral, FL


Zeta (2020) Metairie, LA


Rita (2005) Orange, TX

Devastating damage

- Well-constructed frame homes may incur major damage.
- Many trees will be snapped or uprooted.
- Electricity and water will be unavailable for several days to weeks.

Key Points

Category 3

Category 3 storms include those with wind speeds measured at 111 to 129 mph. Winds of this speed will cause devastating damage.

Rita in 2005, Jeanne in 2004, and Zeta in 2020 were Category 3 hurricanes.

Subject	Potential Effect in a Category 3 Hurricane
People, Livestock, and Pets	There is a high risk of injury or death to people, livestock, and pets because of flying and falling debris.
Mobile Homes	Nearly all older (pre-1994) mobile homes will be destroyed. Newer mobile homes will sustain severe damage with the potential for complete roof failure and wall collapse.
Frame Homes	Poorly constructed frame homes can be destroyed by the removal of the roof and exterior walls. Unprotected windows will be broken by flying debris. Well-built frame homes can experience major damage involving the removal of roof decking and gable ends.
Apartments, Shopping Centers, and Industrial Buildings	There will be a high percentage of roof covering and siding damage to apartment buildings and industrial buildings. Isolated structural damage to wood or steel framing can occur. Complete failure of older metal buildings is possible, and older unreinforced masonry buildings can collapse.
High-Rise Windows and Glass	Numerous windows will be blown out of high-rise buildings resulting in falling glass, which will pose a threat for days to weeks after the storm.
Signage, Fences, and Canopies	Most commercial signage, fences, and canopies will be destroyed.
Trees	Many trees will be snapped or uprooted, blocking numerous roads.
Power and Water	Electricity and water will be unavailable for several days to a few weeks after the storm passes.

Visual 34: Category 4 (130–156 mph)

Catastrophic damage

- Well-built frame homes may sustain severe damage.
- Most trees will be snapped or uprooted; power poles downed.
- Power outages will last weeks to possibly months.

Key Points

Category 4

Category 4 storms will cause catastrophic damage, with wind speeds of 130 to 156 mph. Charley, Hugo, and Maria are three Category 4 hurricanes you are likely to remember because of the devastating damage.

Subject	Potential Effect in a Category 4 Hurricane
People, Livestock, and Pets	There is a very high risk of injury or death to people, livestock, and pets because of flying and falling debris.
Mobile Homes	Nearly all older (pre-1994) mobile homes will be destroyed. A high percentage of newer mobile homes also will be destroyed.
Frame Homes	Poorly constructed homes can sustain complete collapse of all walls, as well as the loss of the roof structure. Well-built homes also can sustain severe damage with loss of most of the roof structure or some exterior walls. Extensive damage to roof coverings, windows, and doors will occur. Large amounts of windborne debris will be lofted into the air. Windborne debris damage will break most unprotected windows and penetrate some protected windows.
Apartments, Shopping Centers, and Industrial Buildings	There will be a high percentage of structural damage to the top floors of apartment buildings. Steel frames in older industrial buildings can collapse. There will be a high percentage of collapse to older unreinforced masonry buildings.
High-Rise Windows and Glass	Most windows will be blown out of high-rise buildings resulting in falling glass, which will pose a threat for days to weeks after the storm.
Signage, Fences, and Canopies	Nearly all commercial signage, fences, and canopies will be destroyed.
Trees	Most trees will be snapped or uprooted, and power poles downed. Fallen trees and power poles will isolate residential areas.
Power and Water	Power outages will last for weeks or possibly months. Long-term water shortages will increase human suffering. Most of the area will be uninhabitable for weeks or months.

Visual 35: Category 5 (Greater than 156 mph)


Michael (2018) Florida– Getty Images


Felix (2007) Nicaragua


Andrew (1992) South Dade, FL

Catastrophic damage

- A high percentage of framed homes will be destroyed.
- Fallen trees and power poles will isolate residential areas.
- Power outages will last weeks to possibly months.

Key Points

Category 5

Category 5 is the highest rating on the Saffir-Simpson Hurricane Wind Scale. This category is reserved for hurricanes with maximum sustained wind speeds above 156 mph. Fortunately, these are fairly rare.

There have been only four storms at Category 5 strength when they made landfall in the United States:

- The Labor Day Hurricane in the Florida Keys on September 2, 1935
- Hurricane Camille in Mississippi on August 17, 1969
- Hurricane Andrew in Southeast Florida on August 24, 1992
- Hurricane Michael in the Florida Panhandle on October 10, 2018

The highest-recorded wind speed of a hurricane at landfall was with Camille (1969), which produced gusts greater than 200 mph and estimated sustained winds at landfall of 190 mph.

Subject	Potential Effect in a Category 5 Hurricane
People, Livestock, and Pets	People, livestock, and pets are at very high risk of injury or death from flying or falling debris, even if indoors in mobile homes or framed homes.
Mobile Homes	Almost complete destruction of all mobile homes will occur, regardless of age or construction.
Frame Homes	A high percentage of frame homes will be destroyed, with total roof failure and wall collapse. Extensive damage to roof covers, windows, and doors will occur. Large amounts of windborne debris will be lofted into the air. Windborne debris damage will occur to nearly all unprotected windows and many protected windows.
Apartments, Shopping Centers, and Industrial Buildings	Significant damage to wood-roof commercial buildings will occur due to loss of roof sheathing. Complete collapse of many older metal buildings can occur. Most unreinforced masonry walls will fail, which can lead to buildings collapsing. A high percentage of industrial buildings and low-rise apartment buildings will be destroyed.
High-Rise Windows and Glass	Nearly all windows will be blown out of high-rise buildings resulting in falling glass, which will pose a threat for days to weeks after the storm.
Signage, Fences, and Canopies	Nearly all commercial signage, fences, and canopies will be destroyed.
Trees	Nearly all trees will be snapped or uprooted, and power poles downed. Fallen trees and power poles will isolate residential areas.
Power and Water	Power outages will last for weeks or possibly months. Long-term water shortages will increase human suffering. Most of the area will be uninhabitable for weeks or months.

Visual 36: Category 5 Landfalls – 5 Days Out

Cat 5 Landfalls

- Labor Day (1935)
- Camille (1969)
- Andrea (1992)
- Michael (2018)

Where were these hurricanes **5 days** before landfall?

Key Points

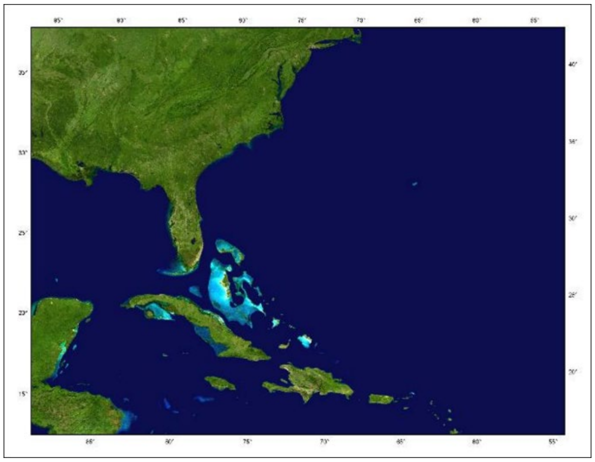
Tropical cyclones often strengthen close to land in the immediate days before making landfall. For the recorded Category 5 landfalls in the United States, 3 of them didn't exist 5 days before landfall, and 1 (Andrew) was a tropical storm.

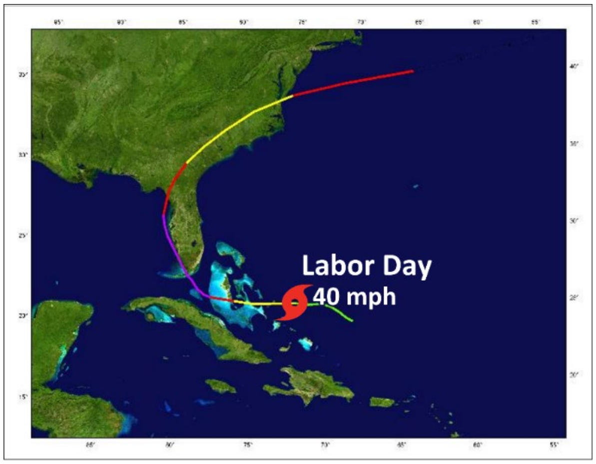
Visual 37: Category 5 landfalls – 3 Days Out

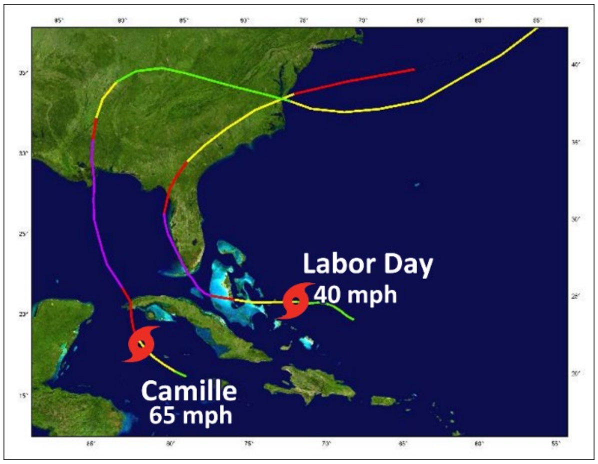
Cat 5 Landfalls

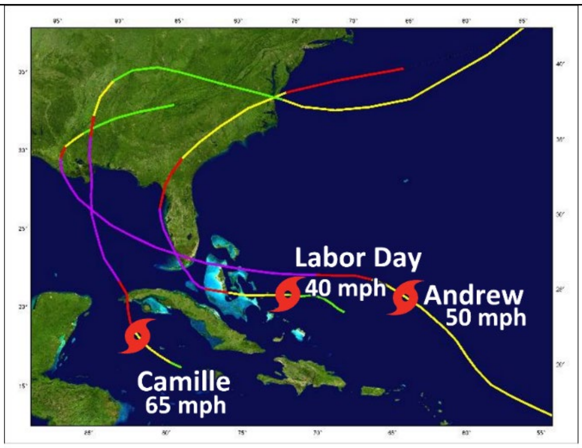
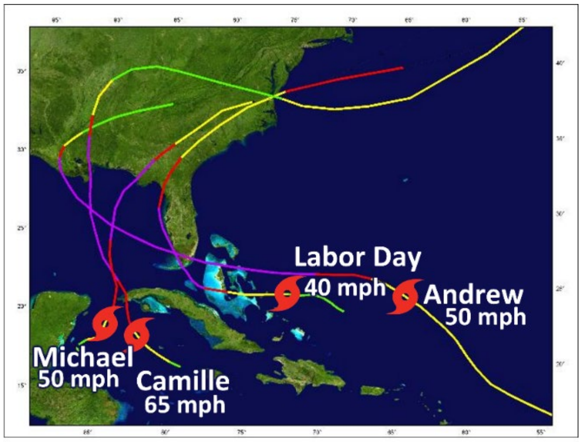
- Labor Day (1935)
- Camille (1969)
- Andrea (1992)
- Michael (2018)

Where were these hurricanes **3 days** before landfall?







Key Points

For recorded Category 5 landfalls in the United States, all were only tropical storms 3 days before landfall.

Visual 38: Storm Surge

Key Points

As previously stated, storm surge is responsible for more deaths than any other hurricane hazard. Half of all hurricane deaths can be attributed to storm surge.

Storm surge is an abnormal rise of water generated by a storm, over and above the predicted astronomical tide. In other words, it is the change in the water level that is caused by the storm's presence.

Storm surge can penetrate well inland from the coastline. During Hurricane Ike (2008), the surge moved inland nearly 30 miles in some locations in southeastern Texas and southwestern Louisiana. All locations along the U.S. East Coast and Gulf Coasts are vulnerable to storm surge.

It is important to understand that the Saffir-Simpson Hurricane Wind Scale does not account for storm surge. For example, Hurricane Katrina was rated a Category 3 when it made landfall in Louisiana, but it produced catastrophic damage with a 28-foot storm surge.

Hurricane Ike, a Category 2 at landfall in Texas, also produced catastrophic damage with a 20-foot storm surge. Hurricane Charley, a Category 4 hurricane at landfall in Florida, produced a storm surge of just 6 to 8 feet.

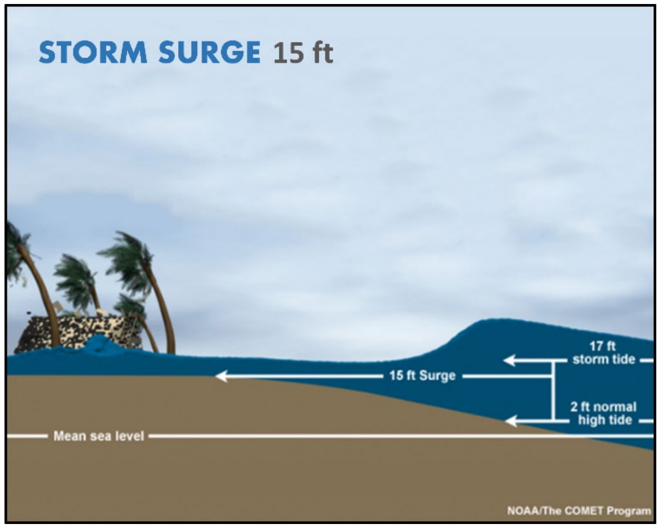
There are many variables that affect how high storm surge will be. It is not solely related on a storm's maximum wind speed.

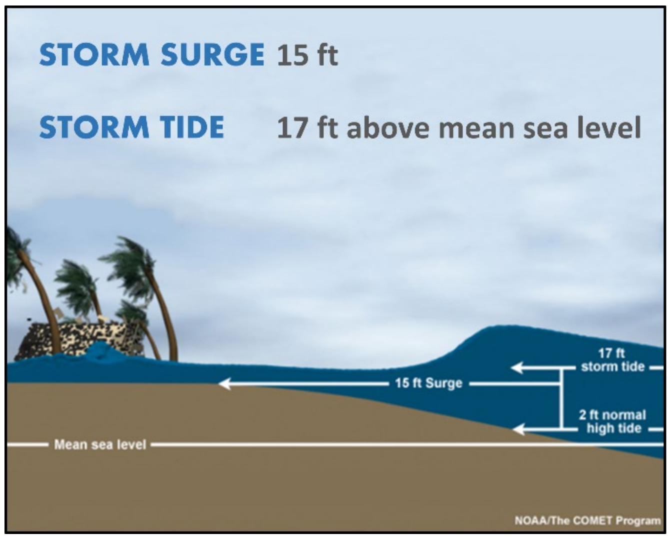
Visual 39: Storm Surge Definitions

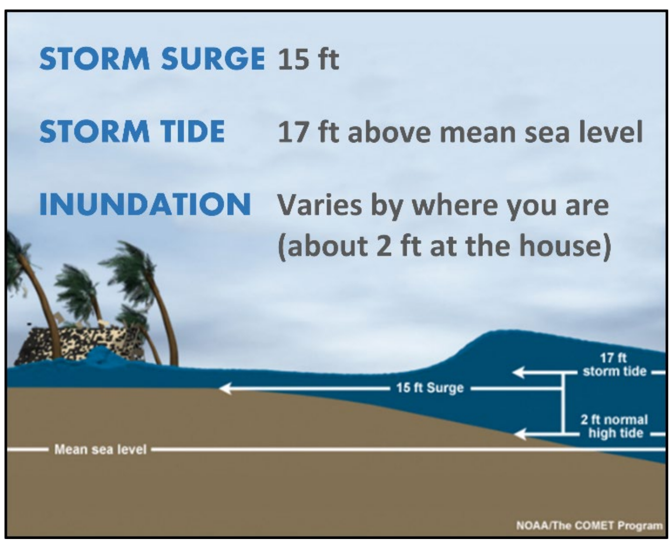
STORM SURGE – An abnormal rise of water generated by a storm, over and above the predicted astronomical tide.

STORM TIDE – Water level due to the combination of storm surge and the astronomical tide.

INUNDATION – The flooding of normally dry land, resulting from storm tide and possibly other factors.







Key Points

Storm Surge is the abnormal rise of water generated by a storm, over and above the predicted astronomical tide. Storm tide is the water level during a storm caused by the combination of normal tide fluctuations and the storm surge. For example, a 15-foot storm surge on top of a high tide that is 2 feet produces a 17-foot storm tide. Because storm surge is a difference between water levels, it does not have a reference level. Storm tide, on the other hand, is the combination of surge and tide, and it does require a reference level, such as mean sea level or a vertical datum. Unfortunately, we are unable to time a storm's arrival within the tidal cycle, so it is safer to assume high tide when making decisions. Inundation is the flooding of normally dry land, resulting from storm tide and possibly other factors. Inundation height is determined by subtracting the local elevation of land from the storm tide (using the same vertical datum for each).

Visual 40: Storm Surge: Katrina 2005

Key Points

This visual shows two pictures, taken from virtually the exact same spot, of a house about three blocks from the beach in Waveland, Mississippi, before and after Hurricane Katrina in 2005.

This house was in an evacuation zone, so the family boarded up their home and left. After Hurricane Katrina passed, they took the second picture. Their home could not withstand the storm surge that inundated their neighborhood, and they lost everything—except their lives—because they heeded the warning and evacuated.

Visual 41: Storm Surge: Ian 2022

Key Points

This visual shows a timelapse of pictures, From a remote camera in Ft. Myers Beach, Florida, in Lee County during the landfall of Hurricane Ian. The images chronical the storm surge as it moves inland and sweeps away a home. Storm Chaser Max Olson left an unmanned camera strapped to a telephone pole before the storm made landfall.

This was an evacuation zone. While some of the larger concrete buildings remained standing, keep an eye on the pink house. The first photo of Hurricane Ian’s storm surge at Fort Myers Beach is at 10:38 a.m. The street has some standing water from the ocean.

The second photo of Hurricane Ian’s storm surge at Fort Myers Beach is at 1:39 p.m. The storm surge has risen halfway up the palm trees, and you can see white caps on the water surface.

The third photo of Hurricane Ian’s storm surge at Fort Myers Beach is at 2:19 p.m. The storm surge is now covering the palm trees as well as a two-story building.

The fourth photo of Hurricane Ian’s storm surge at Fort Myers Beach is at 3:03 p.m. The storm surge is now covering the entire area with large waves on top of it.

The final photo of Hurricane Ian’s storm surge at Fort Myers Beach is at 5:03 p.m. The storm surge is starting to recede, and you can see the absence of a building that was previously there.

Visual 42: Storm Surge: Gulf Coast

Key Points

Gulf Coast These images illustrate the type of storm surge flooding that has occurred historically along the Gulf Coast.

Visual 43: Storm Surge: Southeast

Key Points

Storm surge can occur along all coastlines. It is not just a problem along the Gulf Coast or Florida. Look at these images from hurricanes that have occurred along southeast coasts.

Visual 44: Storm Surge: Mid-Atlantic

Key Points

These images are from hurricanes that have occurred along Mid-Atlantic coasts.

Instructor Note	Emphasize that storm surge can happen anywhere on the coast affected by hurricanes.

Visual 45: Storm Surge: New England

Key Points

These images are from hurricanes that have occurred along New England coasts.

Visual 46: Where Does Storm Surge Occur?

Key Points

The old rule of thumb used to be that storm surge occurs in the right-front quadrant of a hurricane. However, storm surge can occur in any area where there are onshore winds—the water goes where the wind pushes it. In this hypothetical scenario of a hurricane just off the northern Gulf coast, onshore winds would cause storm surge to occur along a large portion of the Florida Panhandle coastline. On the back side of the hurricane, northerly winds would cause storm surge to occur along portions of the coast of southeastern Louisiana. Conversely, northerly winds would push water *out* of Mobile Bay, and water levels in the bay would therefore be lower than normal. The pattern of storm surge flooding from a hurricane can be complicated depending on the geography of the area being affected.

Visual 47: Storm Surge – Knowledge Check

Which are important factors in determining how much storm surge could occur for a storm?

A. Size of the storm
B. Forward speed of the storm
C. Intensity
D. All of the above

Key Points

The correct answer is (D), all of the above. Total storm surge levels are impacted by several different storm variables. It is important to understand how changes in these variables can alter storm surge impacts, and the implications that has for planning and response operations.

Visual 48: Factors Affecting Storm Surge

- Intensity
    - Stronger storm = More storm surge
- Size (Radius of Maximum Winds, or RMW)
    - Larger storm = More storm surge
- Forward Speed
    - Slower storm = Storm surge farther inland
- Angle of approach
    - Alters focus of storm surge
- Width and Slope of Shelf (Bathymetry)
    - Gradual shelf = More storm surge

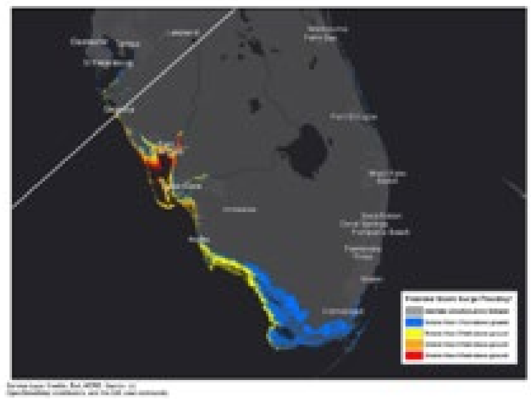
Key Points

There are several factors that contribute to the amount of surge a given storm produces at a given location. These factors work synergistically, so predicting storm surge can be difficult.

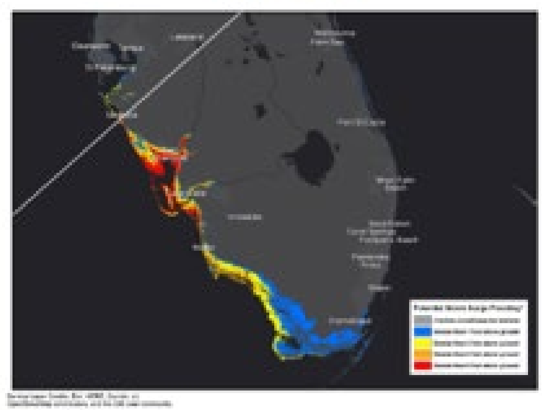
- **Storm Intensity:** Stronger winds will generally produce a higher surge; however, this is not always the case, as illustrated by the examples discussed earlier.
- **Storm Size (Radius of Maximum Wind, or RMW):** A larger storm will produce higher surge. There are two reasons for this. First, the winds in a larger storm are pushing on a larger area of the ocean. Second, the strong winds in a larger storm will tend to affect an area longer than a smaller storm. Size is a key difference between the surge generated by storms like Katrina and Charley. Think of moving your hand across a pool's surface, and how much water that can push. Now think of moving your entire arm across the pool's surface. Your arm is like a large hurricane pushing a greater amount of water toward land.
- **Storm Forward Speed:** On the open coast, a faster storm will produce a higher surge. However, in bays, sounds, and other enclosed bodies of water, a slower storm will produce a higher surge.
- **Width and Slope of Shelf (Bathymetry):** Higher storm surge occurs with wide, gently sloping continental shelves, while lower storm surge occurs with narrow, steeply sloping shelves. Areas along the Gulf Coast, especially Louisiana and Mississippi, are particularly vulnerable to storm surge because the ocean floor gradually deepens offshore. Conversely, areas such as the east coast of Florida have a steeper shelf, and storm surge is not as high.
- **Storm Angle of Approach to the Coast:** The angle at which a storm approaches a coastline can affect how much surge is generated. A storm that moves onshore perpendicular to the coast is more likely to produce a higher storm surge than a storm that moves parallel to the coast or inland at an oblique angle.
- **Central Pressure:** Lower pressure will produce a higher surge. However, central pressure is a minimal contributor compared to the other factors.

Visual 49: Effects of Storm Intensity

Category 3



Category 4

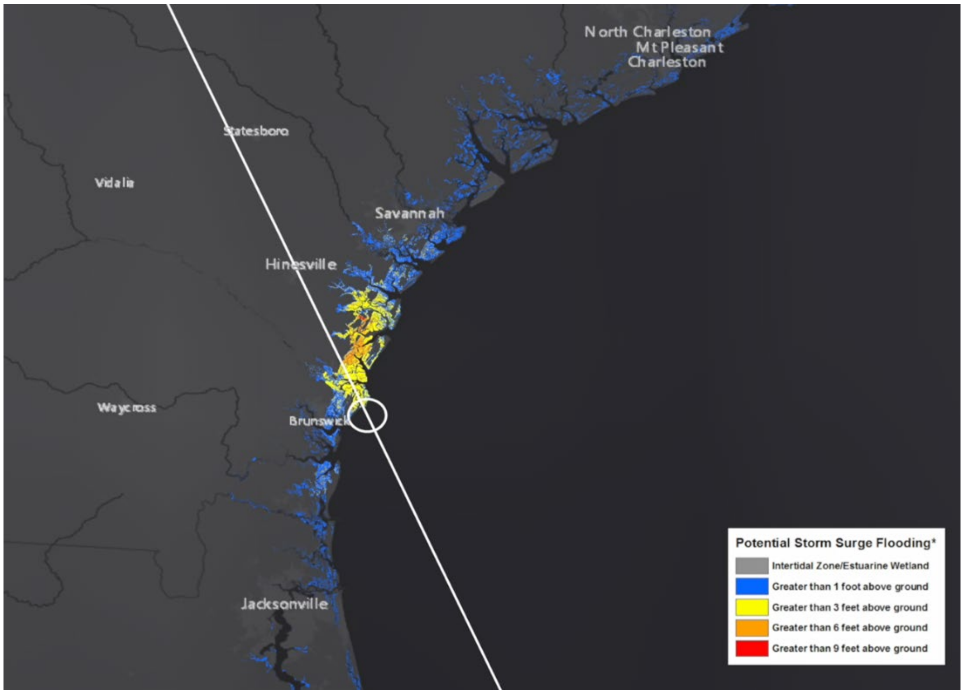


Key Points

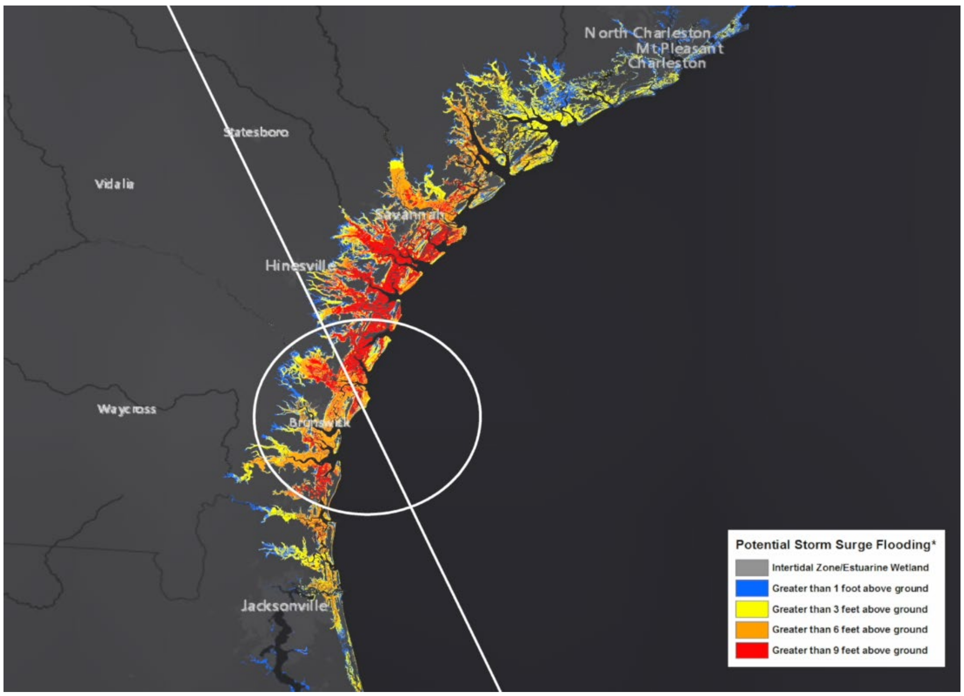
Storm surge is greater with a high-intensity storm. The image in the visual above shows the surge 15 mph stronger than in the image to the right. If all other factors are equal, a more intense storm with higher maximum sustained winds will produce more surge.

Visual 50: Effect of Storm Size

Small RMW



Large RMW

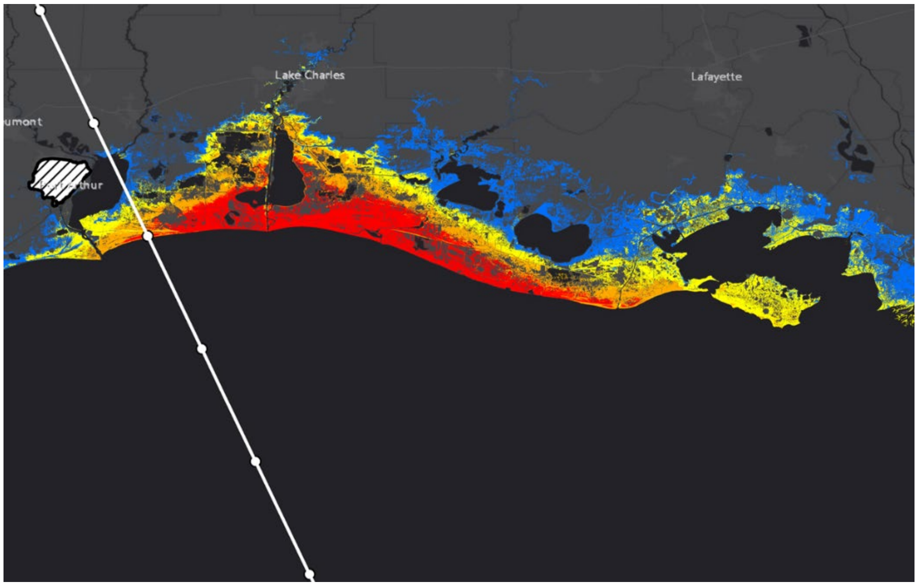


Key Points

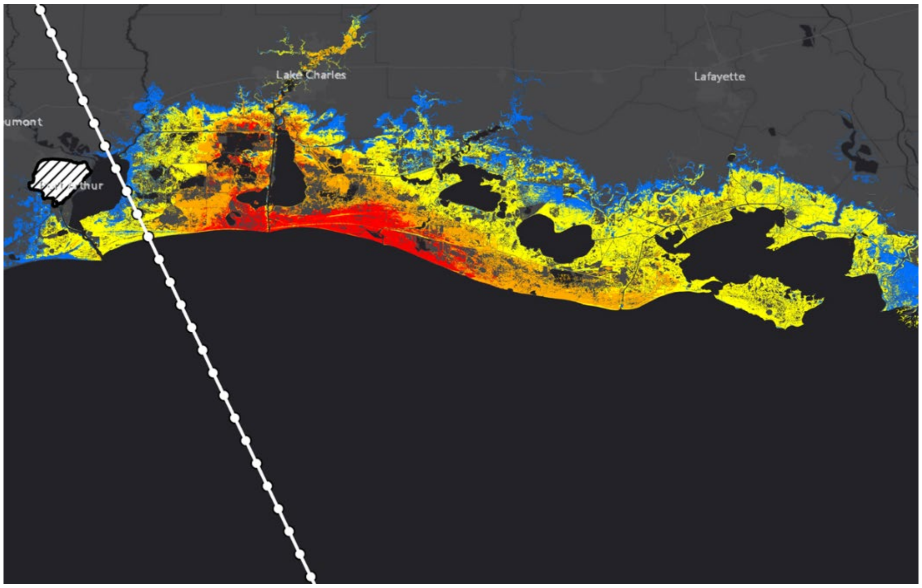
Storm Size and Radius of Max Winds (RMW): The larger the storm, the higher the storm surge will be. In this example, the radius of maximum winds increases with all other factors remaining the same. The larger the radius of maximum winds, the higher and more extensive the storm surge.

Visual 51: Effects of Forward Speed

Forward Speed 25 mph



Forward Speed 5 mph



Faster Storms:

Higher maximum at coast

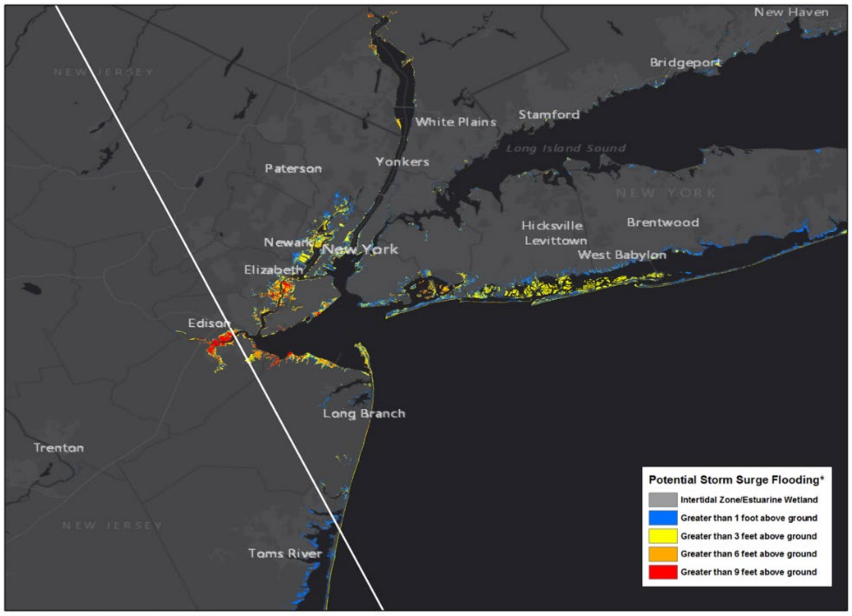
Slower Storms:

Farther inland penetration

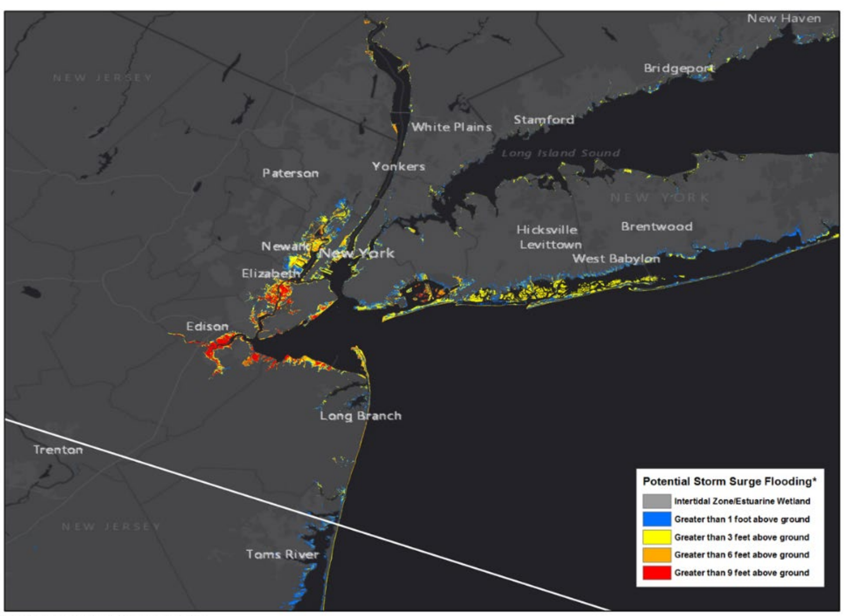
Key Points

The forward speed of the storm also affects storm surge. The surge created by a slow storm (one moving at 5 mph) will not be as high as a faster-moving storm (25 mph), but the slower storm will create surge farther inland. The visual above shows surge with the slower-moving storm and its resulting storm surge with the more rapidly moving storm.

Visual 52: Effect of Angle of Approach



Service Layer Credits: Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community



Service Layer Credits: Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community

Angle of Approach

NNW (top) vs WNW (bottom)

Key Points

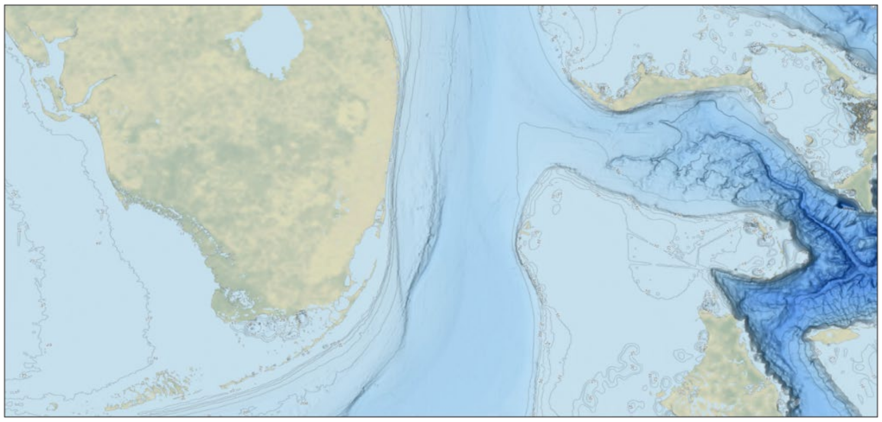
The angle of approach also has an effect on storm surge. The visual on the left shows the surge with a storm approaching from the southeast, and the visual on the right shows the surge from the same storm coming from a more easterly direction, or perpendicular to the coast.

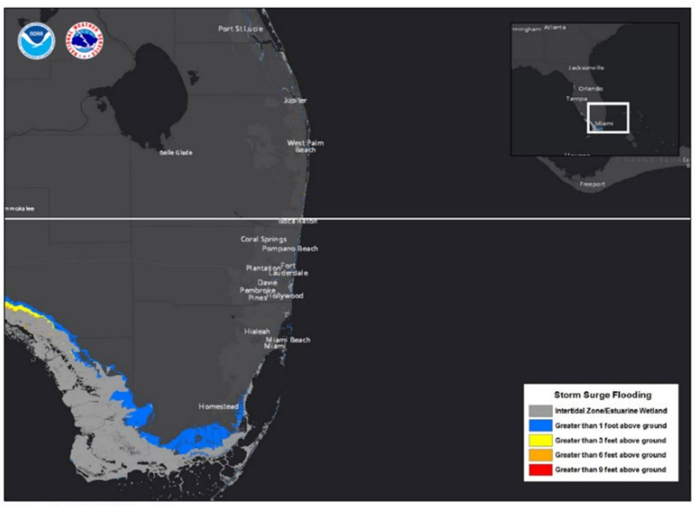
Visual 53: Effect of Width/Slope of Shelf

Key Points

The width and slope of the ocean floor is referred to as the bathymetry. As illustrated in the above visuals, a wide shelf (left) leads to a gentle slope, while a narrower shelf (right) will yield a sharper slope. A steep shelf does not allow as much water to pile up, so the storm surge in these areas will be less. A long and gradually sloping shelf will cause a high storm surge.

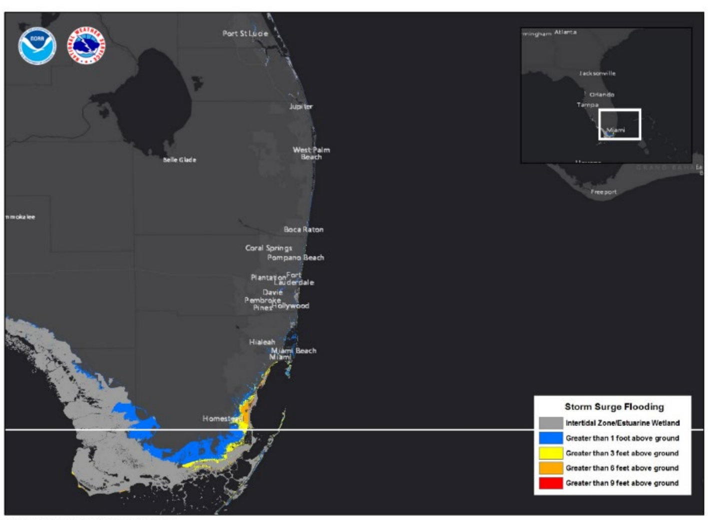
Visual 54: Effect of Width/Slope of Shelf –FL





Service Layer Credits: Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community

Steep shelf:
Palm Beach



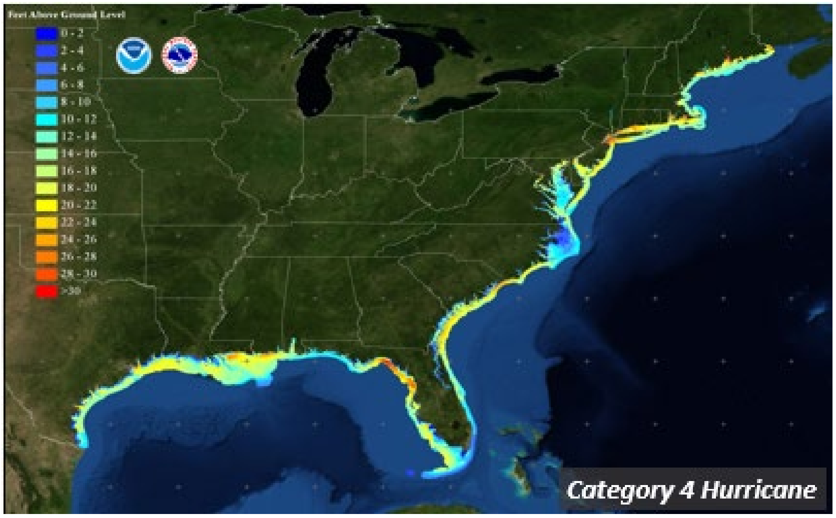
Service Layer Credits: Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community

Shallow bay:
Miami (Biscayne Bay)

Key Points

The slope of the shelf in Southwest Florida and Biscayne Bay is shallow and gentle, with the ocean floor gradually dropping off. In comparison, the East Coast of Florida has a very steep shelf, with ocean depth increasing dramatically just offshore. This makes Southwest Florida considerably more vulnerable to significant storm surge events compared to the East Coast of Florida (particularly north of Miami Beach).

Visual 55: Location, Location, Location

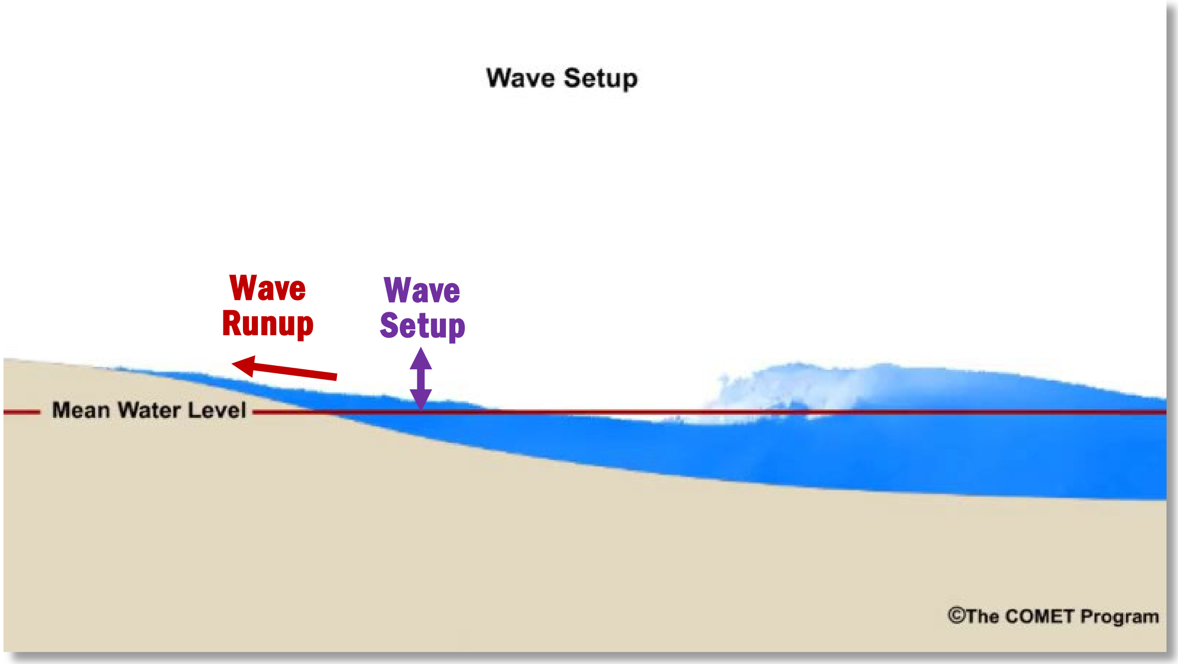


Key Points

The shape of a coastline also affects storm surge. Storm surge will be higher when a hurricane makes landfall on a concave coastline (curved inward, such as Apalachee Bay in Florida).

Finally, storm surge is highly dependent on local features and barriers that will affect water flow. A good example is the coast of North Carolina, which has the complexities of such features as barrier islands, inlets, sounds, bays, and rivers.

Visual 56: Wave Setup

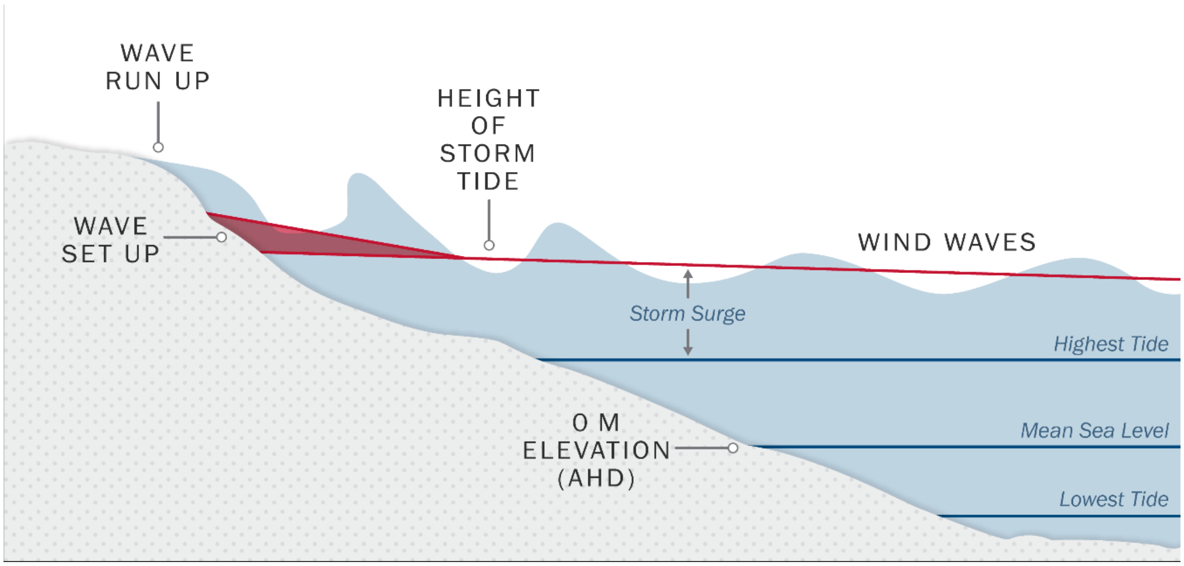


Key Points

Wave Runup and Wave Setup Breaking waves contribute to the water-level rise through wave runup and wave setup. Wave runup occurs when a wave breaks and the water is propelled onto the beach. Wave setup occurs when waves continually break onshore, and the water from the runup piles up along the coast because it can't get back out to sea. Heavy rainfall ahead of a hurricane can cause river levels to rise well inland from the coast. Once all of this water flows downriver and reaches the coast, local water levels will rise, especially near deltas and in bays.

Visual 57: Components of Total Water Level

Storm Surge + Tides + Wave Setup + Freshwater



Key Points

Total Water Level Storm surge makes up only a part of what causes water levels to rise along the coast during a hurricane. Here are the others:

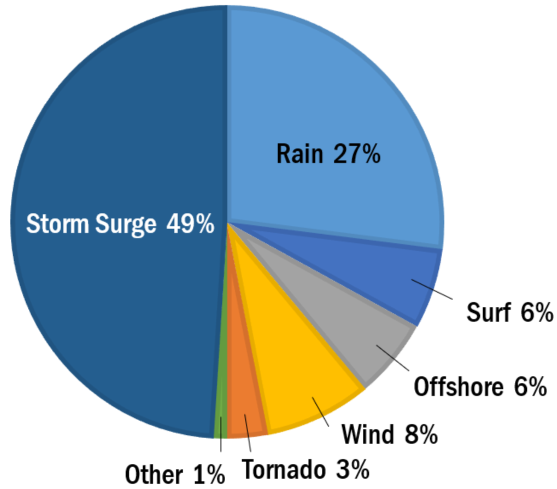
- Tides
- Waves
- Freshwater input

Water levels rise and fall along the coast every day because of the gravitational pull of the moon and sun. This is the **tide.** In general, areas along the Gulf of Mexico, except Florida, experience one high and one low tide per day (diurnal tide). Whereas the East Coast of the United States experiences two high and two low tides per day (semi-diurnal tide).

Visual 58: Atlantic Tropical Cyclone Deaths 2

U.S. tropical cyclone direct fatalities

- from 1963–2012



Key Points

Hurricane water in one of its many forms (surge, flooding, or waves) accounts for about 88% of the direct fatalities from tropical cyclones in the United States.

When this is broken down to specific causes, as shown on the pie chart, you can see that storm surge has been the deadliest hazard associated with tropical cyclones in the United States during the past 50 years. Storm surge is responsible for roughly 50% of all deaths associated with tropical cyclones.

Rainfall-induced flooding accounts for about 27% of all deaths, while wind, tornadoes, surf, and offshore flooding combined account for only 23% of deaths caused by tropical cyclones.

Visual 59: Flash Floods. Riverine Flooding.

Key Points

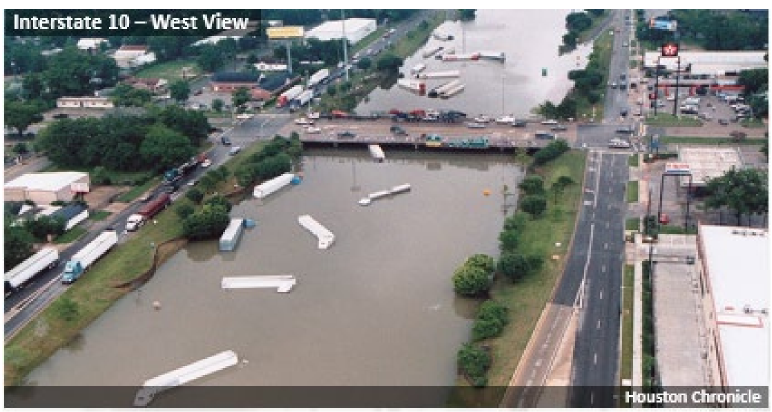
Rainfall-induced flooding is the second leading cause of death from tropical cyclones, after storm surge. About a quarter of all deaths from hurricanes occur when people drown in their vehicles, often as they attempt to abandon them.

Weaker systems, such as tropical depressions or tropical storms, can produce more rainfall and flooding than hurricanes. Flooding comes in the form of flash flooding and riverine flooding.

Heavy rains of up to 43 inches in a 24-hour period have been recorded in the United States in association with a tropical cyclone (Claudette, 1979).

Only the rooftops show after floodwaters engulfed these houses in Tarboro, North Carolina, after Hurricane Floyd in 1999. In North Carolina, inland flooding (not the wind or coastal flooding) caused the most damage during Floyd.

Visual 60: Tropical Storm Allison (2001) I-10

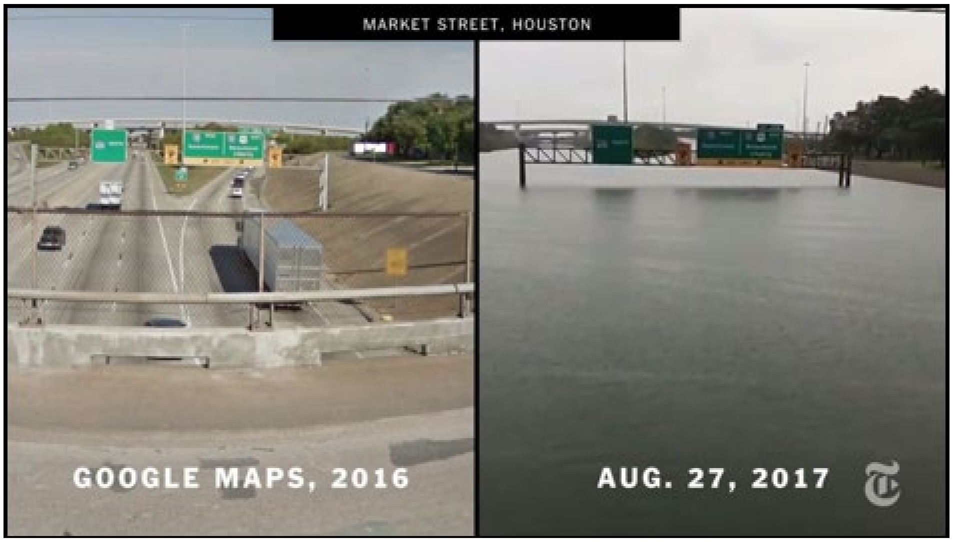


Key Points

The first photo shows what Interstate 10 in Houston, Texas (looking West), looked like in 2001 during fair conditions. The second photo is what I-10 looked like after flooding from Tropical Storm (TS) Allison. Allison was a minimal tropical storm when it made landfall, but was very slow moving, which contributed to deadly flooding. The visual below shows the exact same section of the interstate prior to the storm.

Freshwater flooding from Allison caused extensive damage in 2001. As you can see, the 10-lane interstate is completely underwater, with large semi-trucks tossed about like toys.

Visual 61: Hurricane Harvey (2017) Flooding 1



Key Points

These images show an interstate in Houston, Texas, on a good day in 2016 and after the flooding caused by Hurricane Harvey in 2017. Harvey produced more than 60 inches of rain and devastating flooding across portions of southeastern Texas. The storm is currently the second-costliest tropical cyclone to affect the United States behind Hurricane Katrina.

Visual 62: Hurricane Harvey (2017) Flooding 2

Visual 63: Hurricane Irene (2011) Flooding 1

Key Points

Tropical cyclones can cause significant rainfall and flooding well inland from the coast, including in mountainous areas. In 2011, Irene caused significant flash flooding and damage in portions of Upstate New York and Vermont when its rains were funneled through valleys.

Visual 64: Hurricane Irene (2011) Flooding 2

Visual 65: Tropical Cyclone Rainfall Factors

- **Forward Speed**
  - Slower storm = More rainfall
- **Size**
  - Larger storm = More rainfall
- **Topography and Mountains**
  - More rain on windward side
- **Fronts and Upper-Level Troughs**
  - Enhance rainfall
- **Storm Track**
  - Alters geographic focus of rainfall

Key Points

Factors Affecting Tropical Cyclone Rainfall

The **forward speed** of the storm is of critical importance. Slower storms can produce substantially more rainfall.

The **size** of the storm matters. Bigger storms tend to produce more rainfall, which of course leads to more flooding.

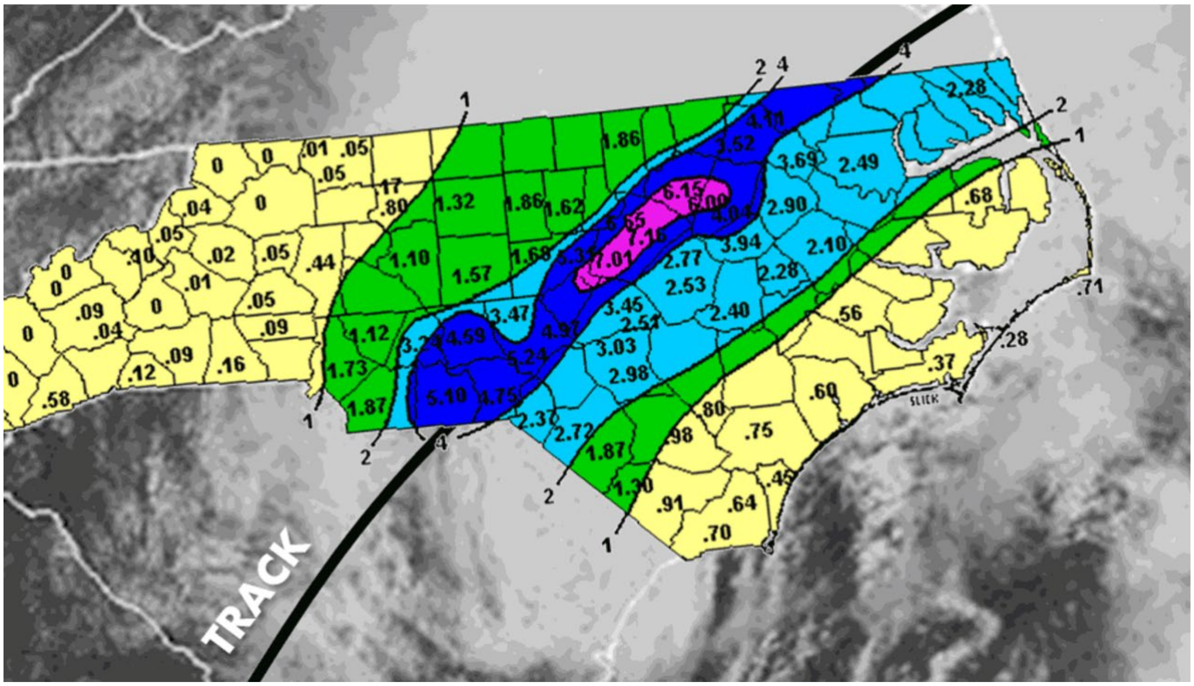
A more unstable atmosphere will enhance the overall **rain rate,** which will increase rainfall totals.

The **vertical wind shear** in the storm environment is also important. More rainfall generally occurs on the side opposite the prevailing wind shear. For example, if the prevailing wind shear is westerly, the heaviest rains would likely occur to the east of the storm track.

Topography is yet another factor. More rain falls on the windward side (or upwind side) of elevated terrain, with less rain on the leeward side (or downwind side).

The final factor is the proximity of a tropical cyclone to **frontal boundaries or** upper-level **troughs.**

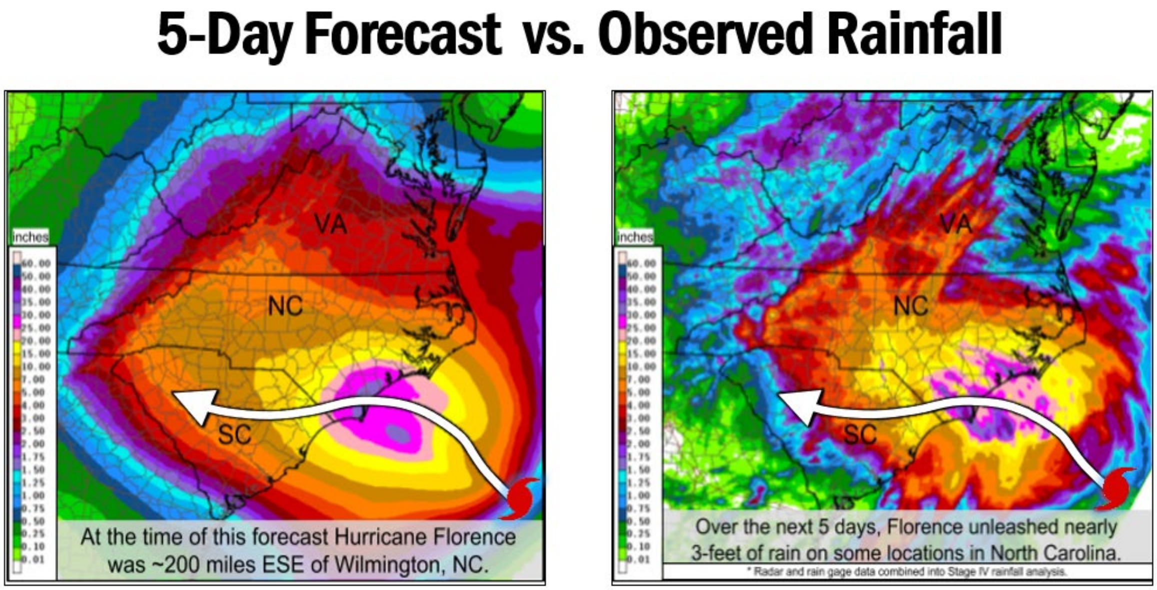
Visual 66: Tropical Storm Alberto (2006)



Key Points

Heavy rains associated with tropical cyclones can be concentrated along nearby frontal boundaries, which can be located well ahead of the storm and/or well inland from the coast. In 2006, Tropical Storm (TS) Alberto produced significant rainfall across portions of eastern and central North Carolina due to a pre-existing frontal boundary separating a warm and unstable air mass to the east and a cool and stable air mass to the west.

Visual 67: Hurricane Florence (2018)

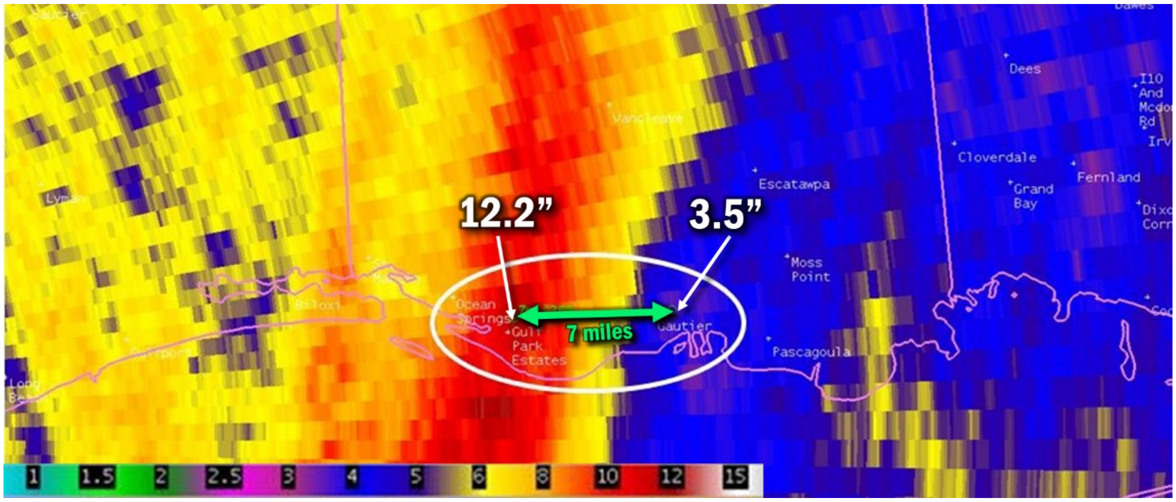


5-day Rainfall Forecast – Issued Sep 13, 2018 | 5-day Rainfall – Sep 13-18, 2018

Key Points

Tropical cyclone rainfall forecasts can generally highlight the areas at risk of heavy rains, but it's sometimes more difficult to pinpoint the specifics of where the highest amounts might occur. Five days before Hurricane Florence hit North Carolina, the Weather Prediction Center correctly forecasted the threat of significant rainfall across southeastern portions of the State (left image). The observed rainfall in the right image shows that while the general forecast was accurate, specific locations across the State and surrounding areas received higher or lower amounts.

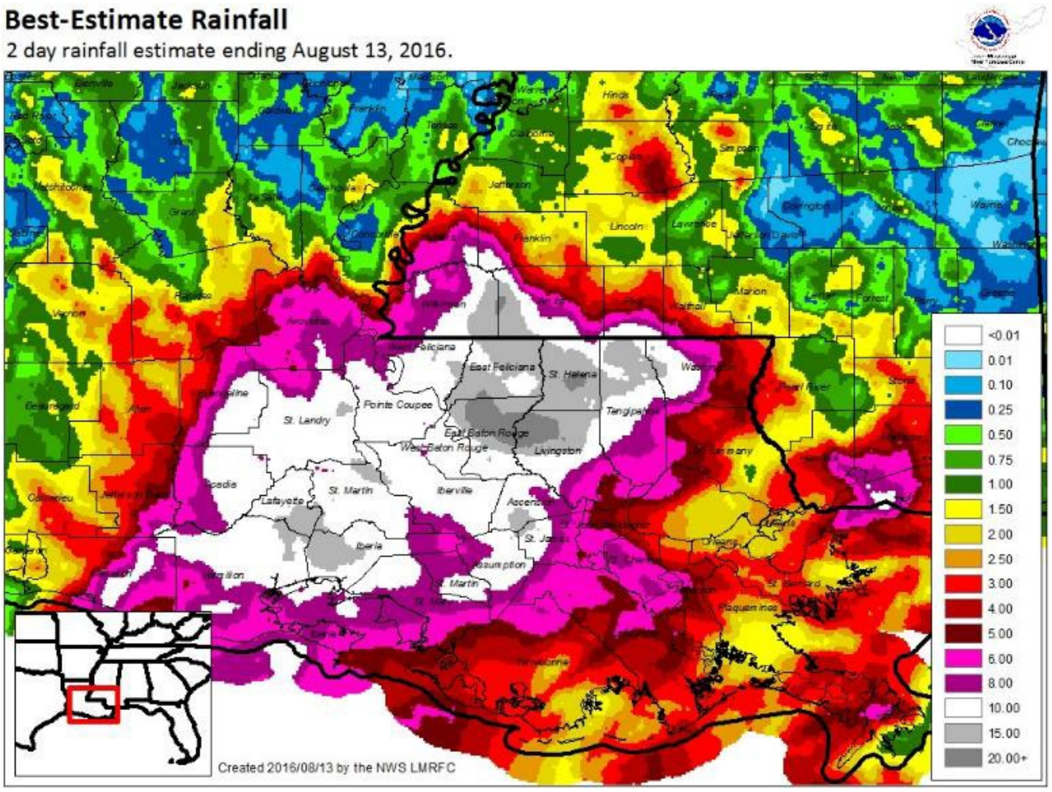
Visual 68: Tropical Storm Cindy (2017)



Key Points

Heavy rain often falls in “bands” and can mean sharp gradients in recorded rainfall. In this example from Tropical Storm (TS) Cindy in 2017, radar estimated rainfall amounts of more than 12 inches where a nearly stationary rainband set up over Mississippi. However, just 7 miles to the east, radar estimated totals of only 3.5 inches. That’s a 9-inch difference in rainfall totals over a 7-mile distance!

Visual 69: Unnamed Low (2016)



Key Points

It doesn't take a storm with a name to produce significant rainfall and flooding. In this example of an unnamed low that affected the central Gulf coast in 2016, some areas in southeastern Louisiana received more than 10 inches of rain, and totals exceeded 20 inches in a few parishes, dropping 3x the amount of rainfall that Katrina brought to the State in 2005.

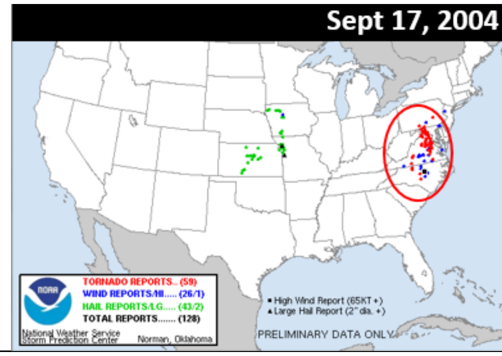
Visual 70: Tornadoes

Tornadoes

- 70% produce at least one tornado.
- 40% produce more than three tornadoes.

Tornado Outbreak:

- Hurricane Ivan (2004): 117



Key Points

One of the consequences of a hurricane dying out over land is that it creates conditions ripe for tornadoes.

Tornado production can occur for **days after landfall** when the tropical cyclone remnants maintain an identifiable low-pressure circulation.

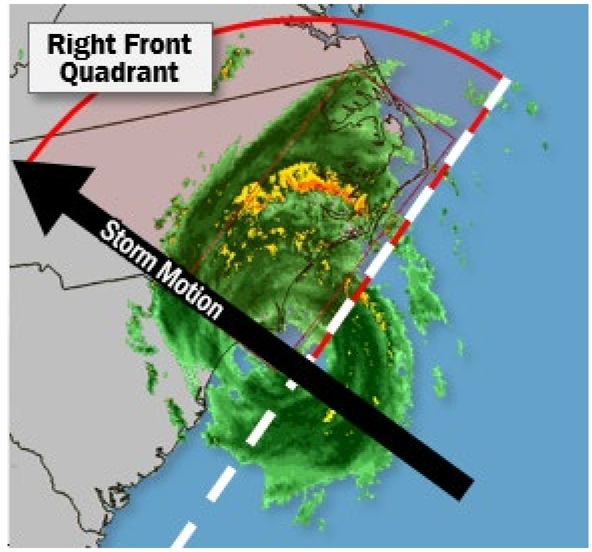
- 70% of land-falling hurricanes produce at least one tornado sometime after making landfall.
- 40% produce more than three tornadoes.
- Tropical cyclones can create favorable conditions to produce cluster outbreaks.

Tornado Outbreaks:

- Hurricane Beulah (1967): 141
- Hurricane Ivan (2004): 117
- Hurricane Frances (2004): 101
- Hurricane Camille (1969): 80
- Hurricane Katrina (2005): 43
- In 2005, there were 221 tornadoes associated with 6 tropical cyclones (Arlene, Cindy, Dennis, Katrina, Rita, and Wilma).

Visual 71: Where Do Tornadoes Form?

- Right-front quadrant: Friction over land creates favorable conditions.
- Outer rainbands: Generally form farther from the center – and the tornado potential continues after landfall.
- Smaller and short-lived: Tend to be less intense than those that occur in the Great Plains; however, some large or strong tornadoes have occurred.



Key Points

Tornado Development

Friction, as the ocean-fed storm moves over land, creates low-level wind conditions highly favorable to the development of tornadoes. The majority of tornadoes associated with tropical cyclones occur in the right-front quadrant of the cyclone, as shown on the visual, where the orientation and speed of the winds over a shallow layer in the low levels create vertical shear profiles favorable for producing tornadoes.

Tornadoes can occur for days after landfall, generally when the tropical cyclone remnants maintain an identifiable low-pressure circulation.

In general, tornadoes produced by tropical cyclones are relatively small and short lived. They are created in the storm's outer rain bands. They tend to be smaller and less intense than those that occur in the Great Plains; however, some large or strong tornadoes have occurred.

In general, the bigger or stronger the wind fields are with a tropical cyclone, the greater the potential for tornadoes. More tornadoes occur during the day.

Visual 72: Wave and Rip Current Incidents

Swells from a large hurricane can affect beaches of the entire western Atlantic.

Hurricane Lorenzo (2019)

- 8 people drowned along the U.S. East Coast in rip currents and hazardous surf.

Hurricane Delta (2020)

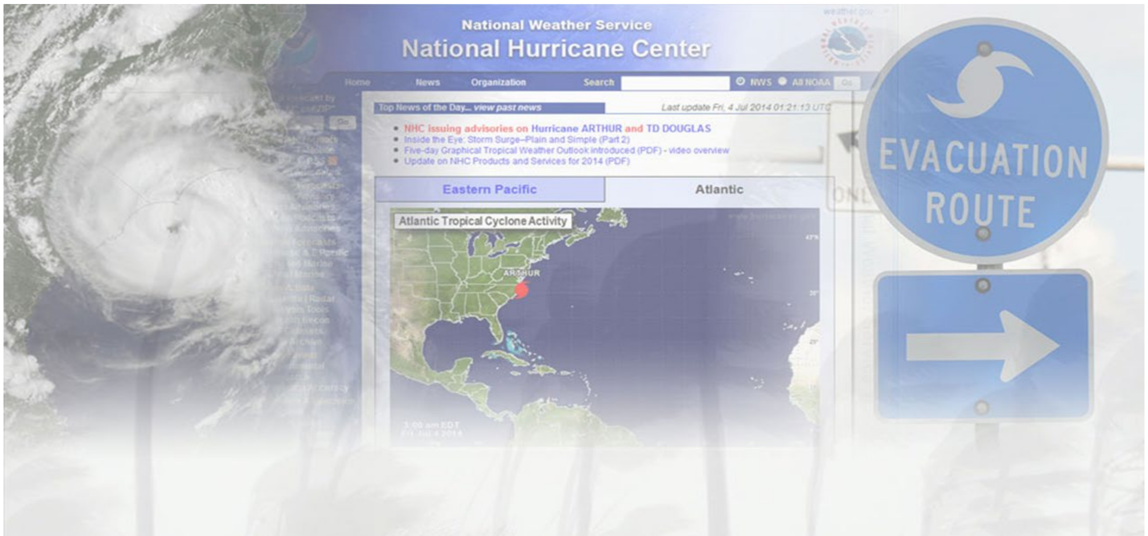
- 2 people drowned along the NW Florida coast.

Key Points

Long-period swells generated by a tropical cyclone's wind field are another not-so-obvious hazard associated with a tropical cyclone. These long-period swells can produce rough surf conditions and rip currents for swimmers in otherwise fair-weather conditions. This hazard is often overlooked because the hurricane generates these waves remotely, often hundreds of miles offshore with otherwise fair weather at the coast.

Waves and rip currents can occur when a storm is well offshore. Swells from a large hurricane can affect the beach along the entire western Atlantic seaboard.

Visual 73: Questions/Comments?



Key Points

In this unit, you learned about the characteristics and life cycle of a tropical cyclone, as well as the factors that influence its intensity. You also learned about the hazards associated with tropical cyclones, including wind, flooding, tornadoes, and—the most deadly—storm surge. Unit 2 will discuss the products available from the NHC and your local Weather Forecast Office (WFO) to help you evaluate your risk from these hazards.

Before we move on to Unit 2, are there any questions on the material covered in Unit 1?

Unit 2: National Weather Service Products

Visual 1: National Weather Service Products

Unit 2:

National Weather Service Products

Key Points

Unit 2 provides an overview of the products produced by the Weather Forecast Office (WFO) that serve to inform and advise the public about storm conditions, events, and the risks to the population.

The more you understand and can interpret these products, the more you will be able to function in your capacity.

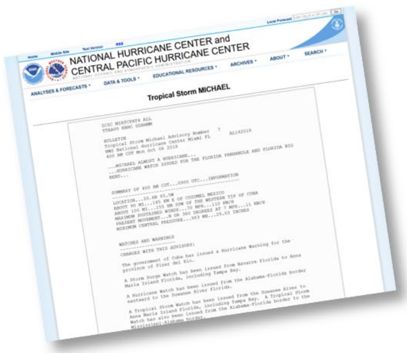
Visual 2: Unit 2 Objectives

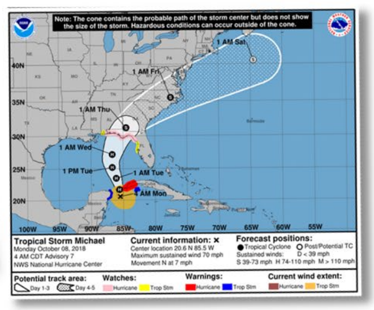
At the end of this unit, you should be able to:

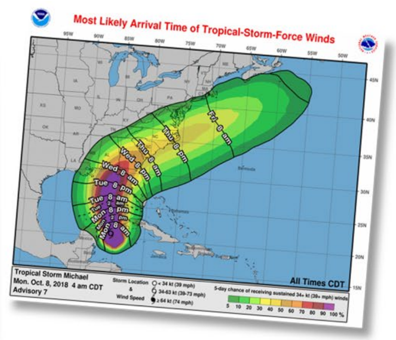
1. Use NHC text-based and graphical products.
2. Explain when NHC products are available.
3. Explain where to find critical information in NHC products to answer key questions.

Visual 3: Tropical Cyclone Products

The NWS national centers (National Hurricane Center (NHC), Weather Prediction Center (WPC), and National Water Center (NWC), etc.) provide the ‘big picture’ that complements and guides local NWS forecast office products.







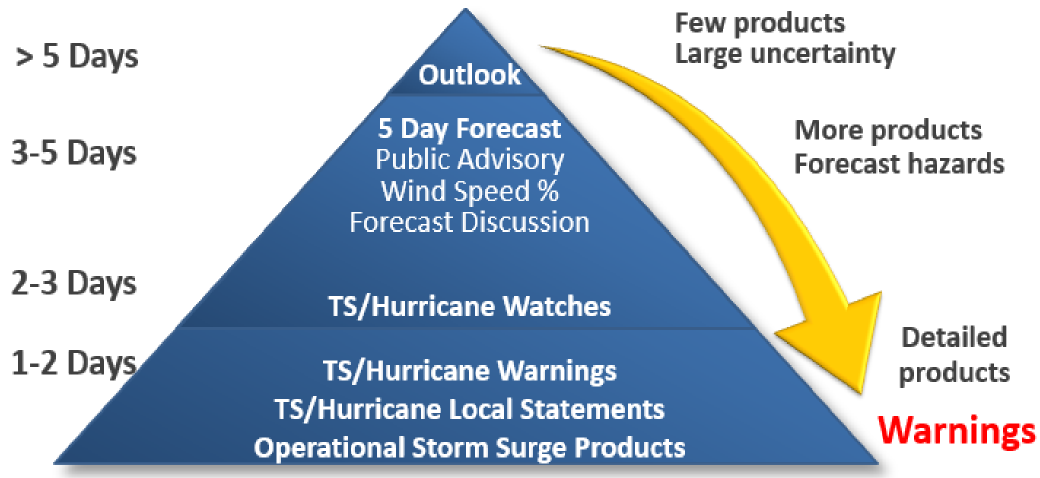
Key Points

The National Weather Service (NWS) has multiple national centers that provide a suite of products and guidance for different tropical cyclone-related phenomena. The National Water Center issues products for riverine flooding, the Weather Prediction Center is the authority for precipitation, and the National Hurricane Center provides the storm-related forecasts and analyses.

The NHC provides products and information that form the basis for forecasting and planning other entities—such as government, the news media, or the public—who are concerned with tropical cyclone events that affect populated areas.

NHC products complement and guide local National Weather Service (NWS) office forecast products and provide guidance for international partners.

Visual 4: Tropical Cyclone Products Timeframe



Key Points

The number of available products and the detail they provide increase as you get closer to an event. Typically, during the early stages, there are few products available because of the large uncertainty of forecasting a capricious storm.

If the projected date of arrival on land is greater than 5 days, generally the only product that will be available is the Outlook.

At 3–5 days before landfall, the NHC issues a 5-day forecast. This includes a Public Advisory with wind speed probability and a Forecast Discussion. Tropical Storm and Hurricane Watches, local statements, and Operational Storm Surge Products are issued about 2 days before tropical storm-force winds arrive.

Tropical Storm and Hurricane Warnings are issued about 36 hours before tropical storm-force winds arrive.

Wind-related products	**Water-related products**

• Tropical Weather Outlook
• Advisories
    ○ Public Advisory
    ○ Intermediate Advisory
    ○ Tropical Cyclone Update
• Forecast Discussion
• Forecast Error Cone
• Wind Speed Probabilities
• Wind Speed Arrival Timing
Wind-based Watches/Warnings
	• SLOSH MEOWs/MOMs
	• Rainfall forecasts
	• QPF
	• ERO
	• Hydrographs
	• Flash Flood Warnings/Emergencies
	• Flood Warnings (Mainstem)
	• Severe Weather Outlook

Visual 5: Frequently Asked Questions 1

FAQs

- What's going on in the Tropics?
- Any potential for development?
- Should we be concerned?

Tropical Weather Outlook

Key Points

All the products created by the NHC are designed to answer questions from a concerned public. This course will present NHC products based on the questions they are designed to answer. Even though the specifics will vary from storm to storm, the most frequently asked questions are constant.

Visual 6: Tropical Weather Outlook Schedule

Outlook Schedule

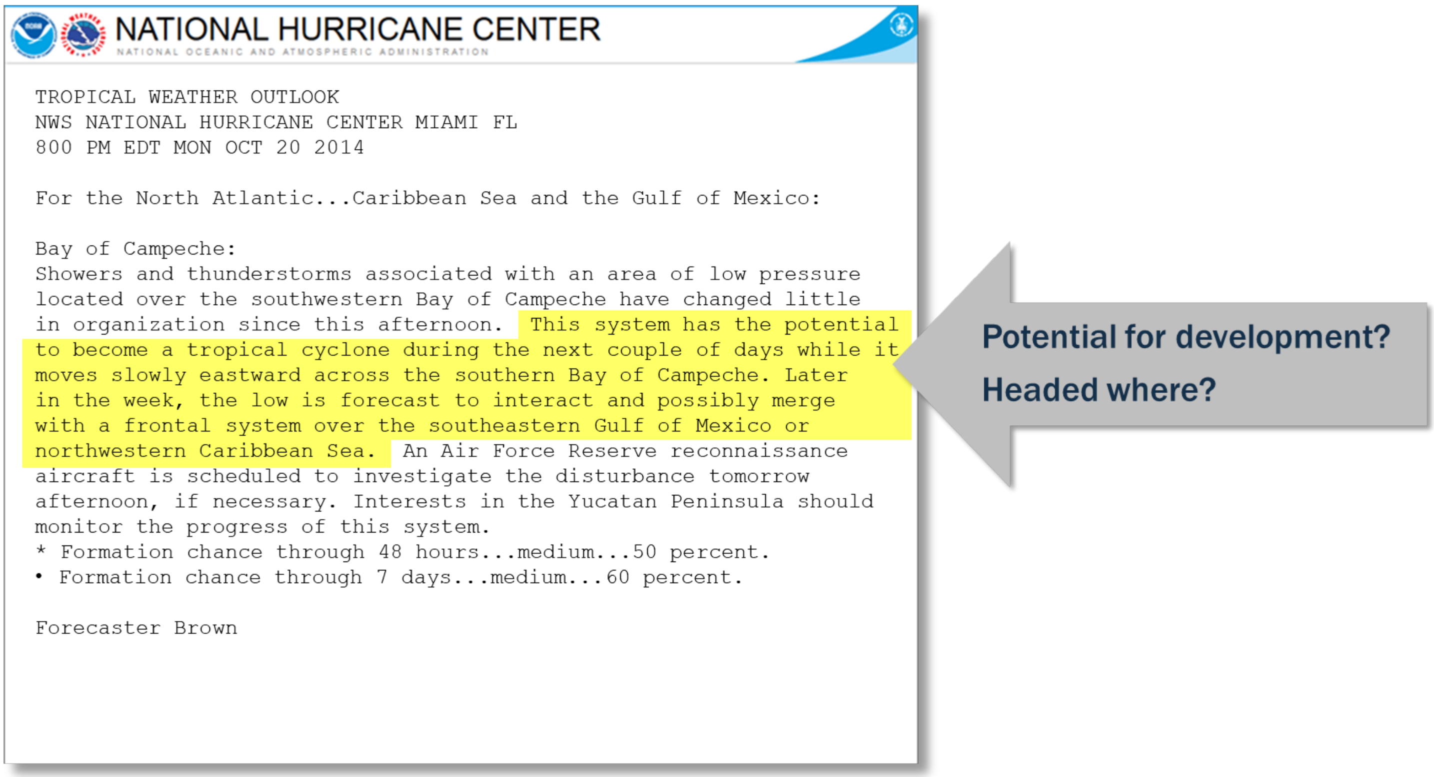
- Issued May 15 through November 30
  - 2 a.m. EDT – Tropical Outlook
  - 8 a.m. EDT – Tropical Outlook
  - 2 p.m. EDT – Tropical Outlook
  - 8 p.m. EDT – Tropical Outlook

Note: A *Special Tropical Outlook* can be issued at any time for significant or unexpected changes.

Key Points

The Tropical Weather Outlook is issued May 15th through November 30th annually. A Special Tropical Outlook can be issued at any time if something significant or unexpected occurs. Regularly scheduled updates occur at 2 a.m., 8 a.m., 2 p.m., and 8 p.m. daily. The update times are Eastern time. In the final weeks of November after Daylight Saving Time ends, the issuance times shift to 1 hour earlier (i.e., 7 a.m. EST) in coordination with turning the clocks back and keeping the Outlook issuance time at the same UTC.

Visual 7: Tropical Weather Outlook – Text 1



NATIONAL HURRICANE CENTER
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

TROPICAL WEATHER OUTLOOK
NWS NATIONAL HURRICANE CENTER MIAMI FL
800 PM EDT MON OCT 20 2014

For the North Atlantic...Caribbean Sea and the Gulf of Mexico:

Bay of Campeche:
Showers and thunderstorms associated with an area of low pressure located over the southwestern Bay of Campeche have changed little in organization since this afternoon. This system has the potential to become a tropical cyclone during the next couple of days while it moves slowly eastward across the southern Bay of Campeche. Later in the week, the low is forecast to interact and possibly merge with a frontal system over the southeastern Gulf of Mexico or northwestern Caribbean Sea. An Air Force Reserve reconnaissance aircraft is scheduled to investigate the disturbance tomorrow afternoon, if necessary. Interests in the Yucatan Peninsula should monitor the progress of this system.
* Formation chance through 48 hours...medium...50 percent.
• Formation chance through 7 days...medium...60 percent.

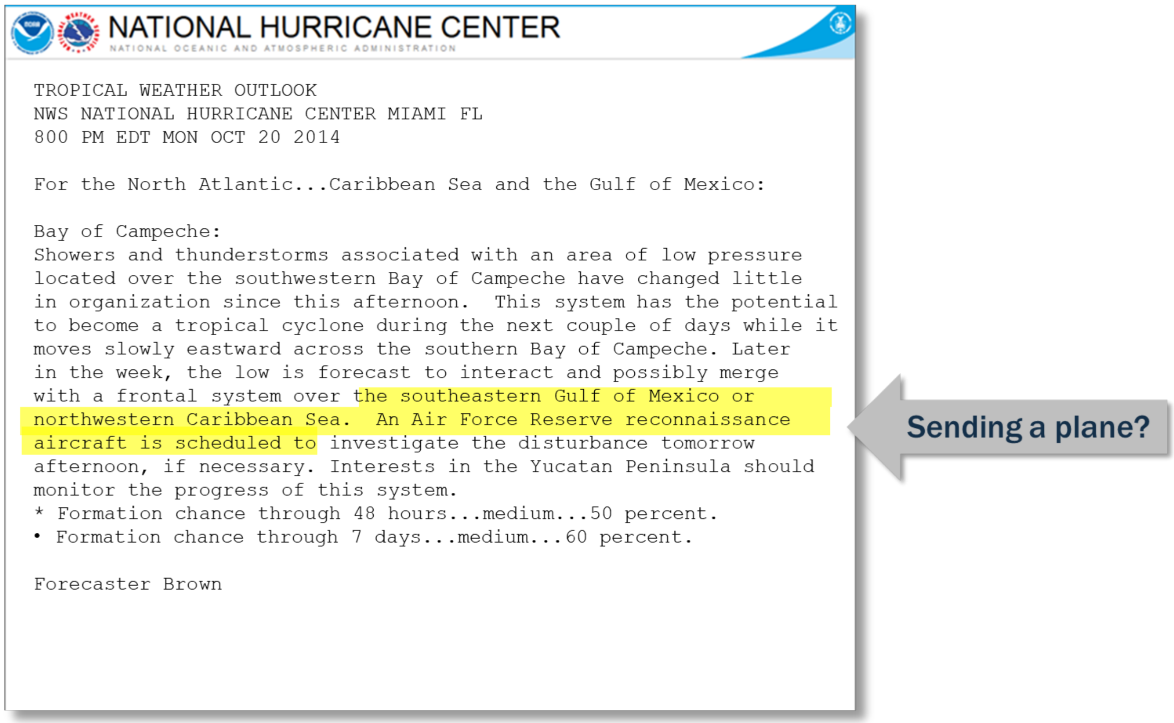
Forecaster Brown

Key Points

Tropical Weather Outlook: 7-day

The Tropical Weather Outlook is a text product that gives a 7-day assessment of tropical activity and answers several questions. The yellow highlight on this visual shows where it provides information on the disturbance, potential impacts to land areas, its movement, and the chance of formation.

Visual 8: Tropical Weather Outlook – Text 2


NATIONAL HURRICANE CENTER
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

TROPICAL WEATHER OUTLOOK
NWS NATIONAL HURRICANE CENTER MIAMI FL
800 PM EDT MON OCT 20 2014

For the North Atlantic...Caribbean Sea and the Gulf of Mexico:

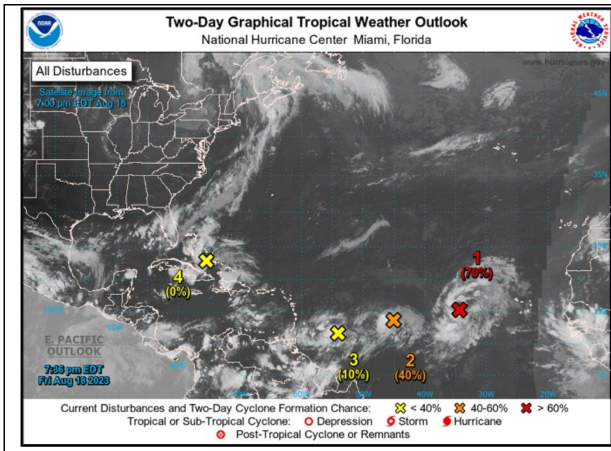
Bay of Campeche:
Showers and thunderstorms associated with an area of low pressure located over the southwestern Bay of Campeche have changed little in organization since this afternoon. This system has the potential to become a tropical cyclone during the next couple of days while it moves slowly eastward across the southern Bay of Campeche. Later in the week, the low is forecast to interact and possibly merge with a frontal system over the southeastern Gulf of Mexico or northwestern Caribbean Sea. An Air Force Reserve reconnaissance aircraft is scheduled to investigate the disturbance tomorrow afternoon, if necessary. Interests in the Yucatan Peninsula should monitor the progress of this system.
* Formation chance through 48 hours...medium...50 percent.
• Formation chance through 7 days...medium...60 percent.

Forecaster Brown

Key Points

This text highlighted in yellow on this example shows additional information that can be included in the Outlook. This includes information such as when a reconnaissance aircraft may be providing forecasters with additional information about the system.

Visual 9: 2-Day Formation Potential



Tropical Outlook

Current location of disturbances

48-hr formation chance

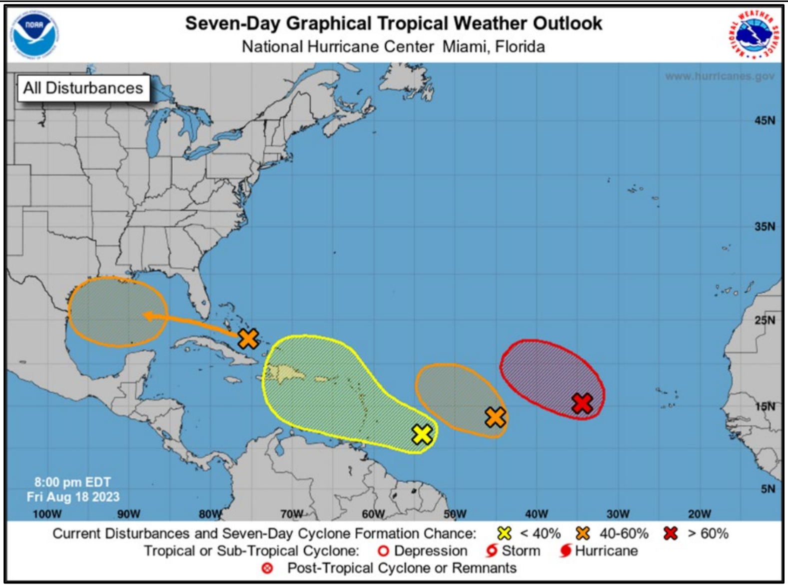
- Categorical (Low–Med–High)
- Probabilities

Key Points

The Graphical Tropical Weather Outlook gives the 2-day formation chance and identifies the current location of disturbed weather that was discussed in the textual version of the Tropical Weather Outlook.

The formation chance during the next 48 hours is given in terms of categories (low, medium, and high) and as probabilities.

Visual 10: 7-Day Formation Potential

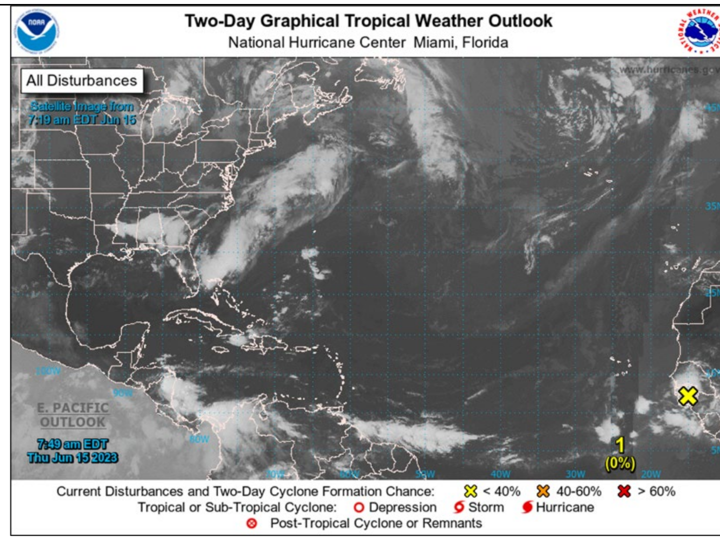
	Tropical Outlook • Initial location of disturbance (x) indicated, if it exists • Formation potential during next 7 days Shading represents the potential formation area

Key Points

Graphical Tropical Weather Outlook: 7-Day Outlook

The areas shown on the 7-day graphic depict the potential formation area during the 7-day forecast period. The X indicates the location of the disturbance if it currently exists. The shading represents the potential formation area but does not represent a true track forecast area.

Visual 11: Tropical Weather Outlook – Example 1

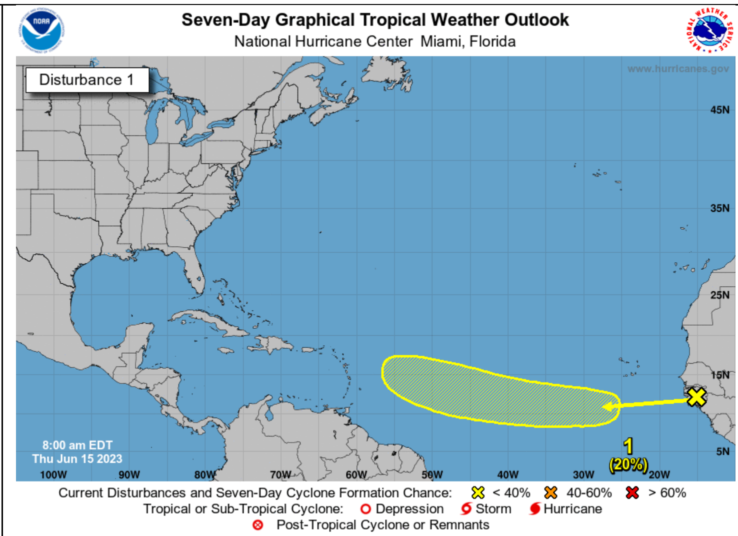
Tropical Outlook June 15 • 2 Day – 0% • 7 Day – 20%	

Key Points

Graphical Tropical Weather Outlook: 2-Day Outlook

This shows the 2-day graphical Tropical Weather Outlook issued on October 3. Note that the indicated area shows a predicted 0% chance of formation.

Visual 12: Tropical Weather Outlook – Example 2

Tropical Outlook June 15 • 2 Day – 0% • 7 Day – 20%	

Key Points

Graphical Tropical Weather Outlook: 7-Day Outlook

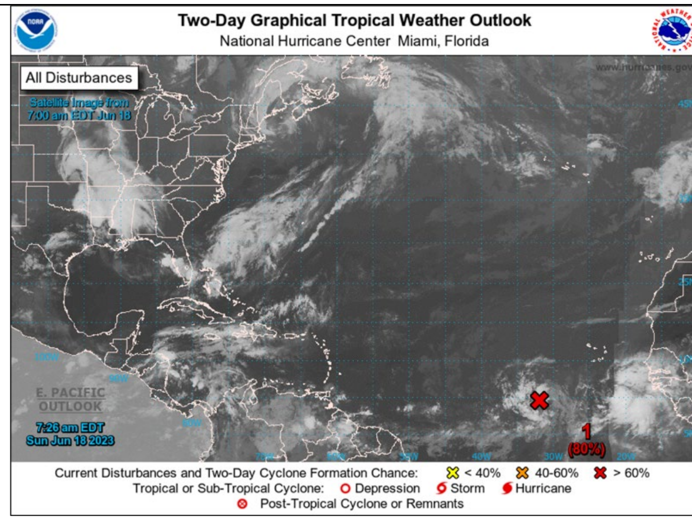
This shows the 7-day graphical Tropical Weather Outlook issued on June 15. Note that the indicated area shows a predicted 20% chance of formation. Notice the difference between the previous slide's 2-Day TWO prediction and this one.

Visual 13: Tropical Weather Outlook – Example 3

Tropical Outlook

June 18

- 2 Day – 80%
- 7 Day – 90%



Key Points

Graphical Tropical Weather Outlook: 2-Day Outlook

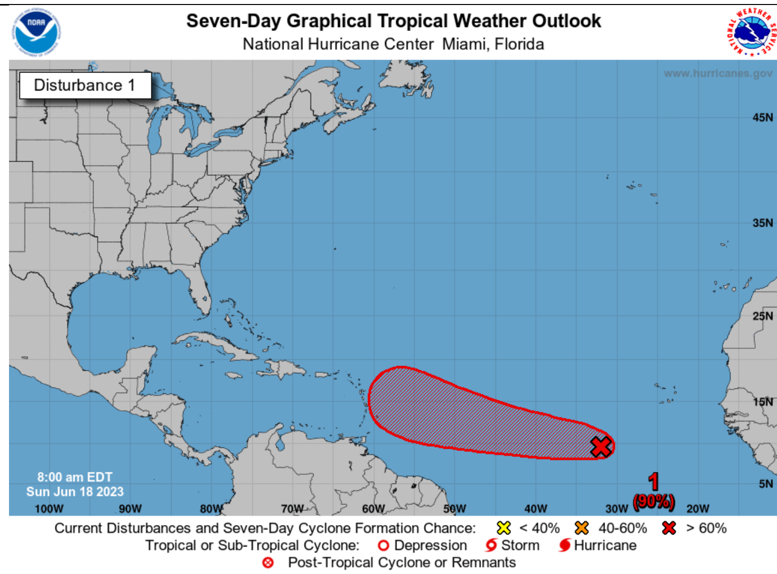
This shows the 2-day graphical Tropical Weather Outlook issued on June 18. Note that the indicated area now shows a predicted 80% chance of formation, as 48-hour development chances have steadily increased over the last few days when compared to the 2-day Outlook from June 15.

Visual 14: Tropical Weather Outlook – Example 4

Tropical Outlook

June 18

- 2 Day – 80%
- 7 Day – 90%



Key Points

Graphical Tropical Weather Outlook: 7-Day Outlook

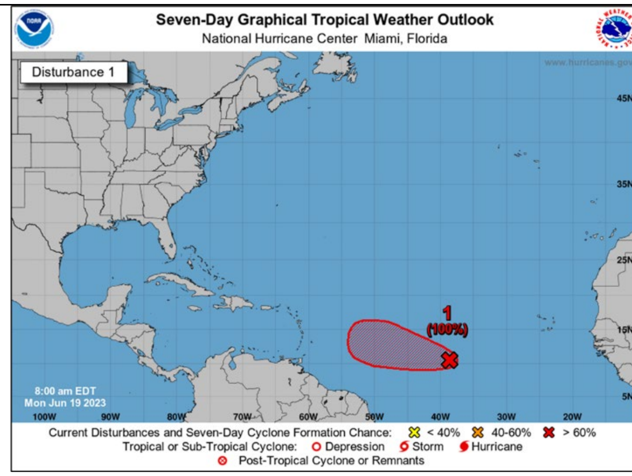
This shows the 7-day graphical Tropical Weather Outlook issued on June 18. Note that the indicated area now shows a predicted 90% chance of formation.

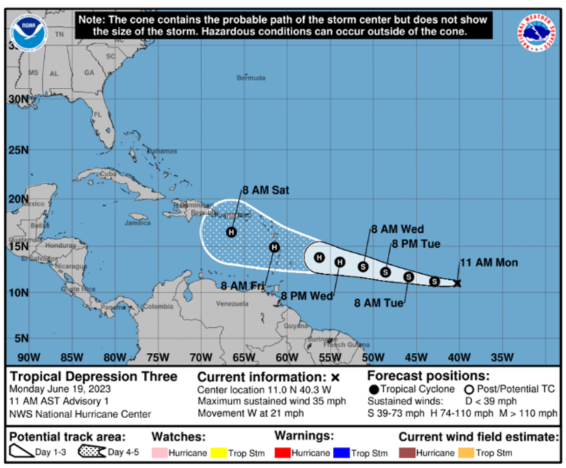
Visual 15: Tropical Weather Outlook – Example 5

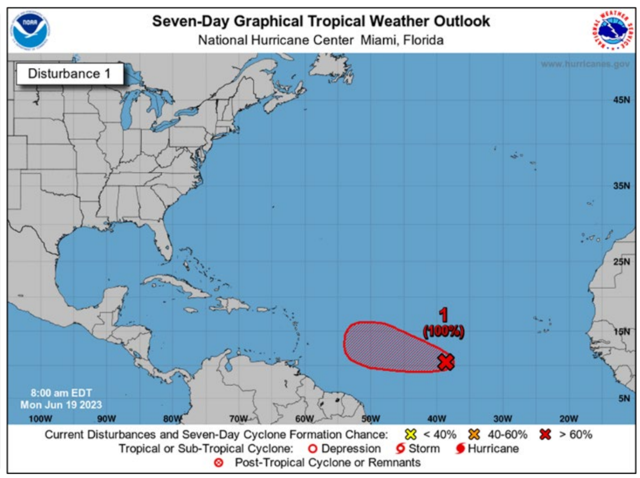
Tropical Outlook

June 19

- 2 Day – 100%
- 7 Day – 100%





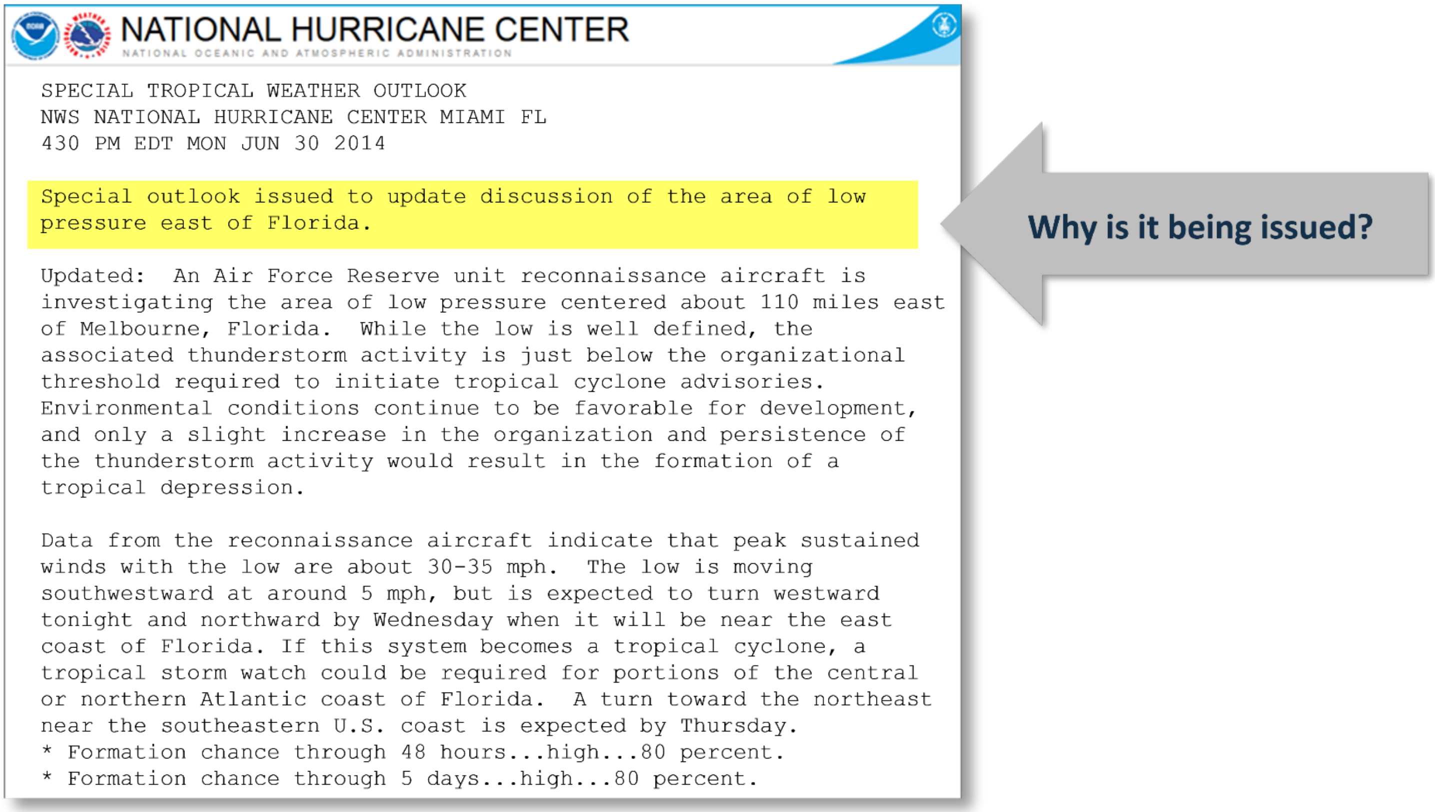


Key Points

Tropical Cyclone Advisories vs. Graphical TWO

The image on the left is the first forecast advisory on Tropical Depression Three from 11 a.m. on June 19. Consider the forecast error cone area and the predicted strength of the tropical cyclone over the next 5 days. Contrast that with the image on the right of the 7-Day Graphical TWO. How do the two complement each other? How did the shape of the Graphical TWO area change over time? What does the Graphical TWO not tell you?

Visual 16: Special Tropical Weather Outlook 1

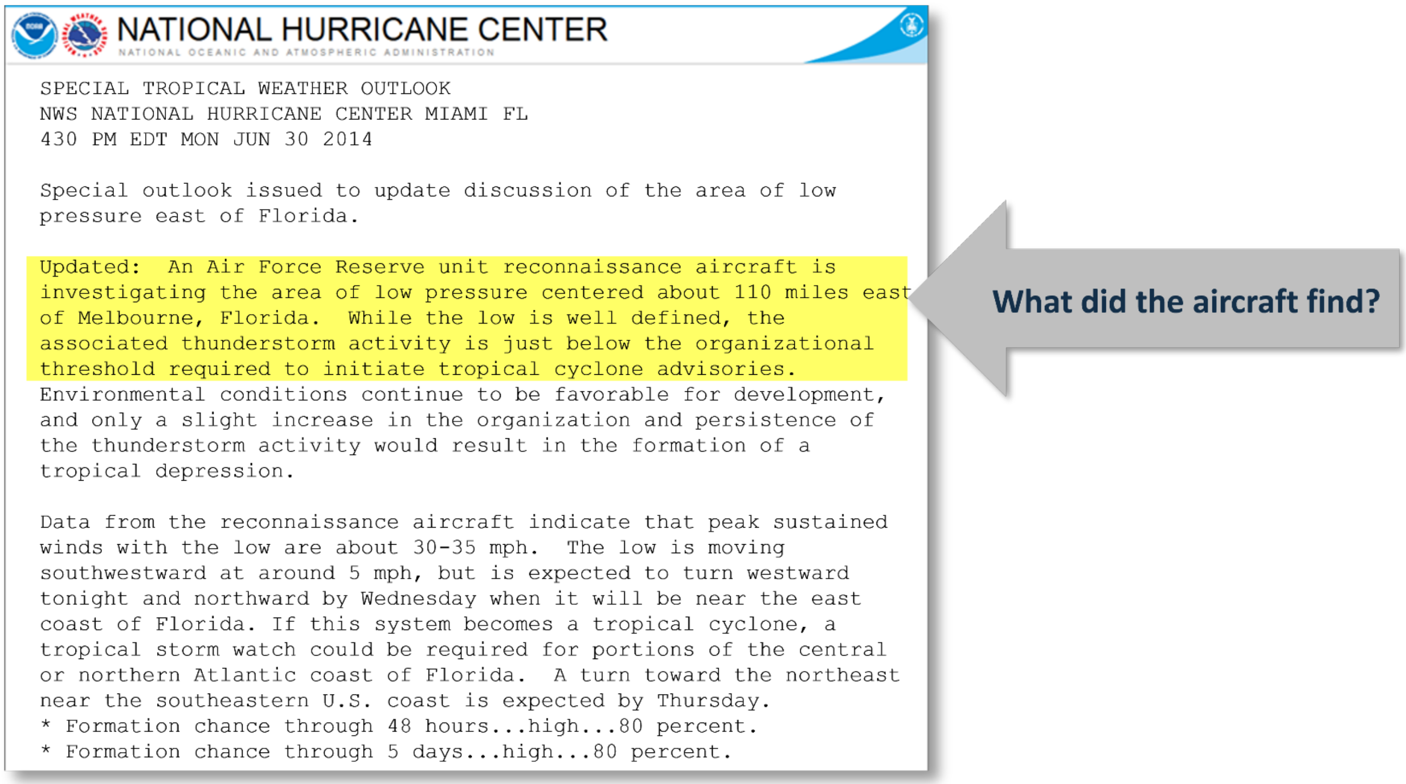



```
SPECIAL TROPICAL WEATHER OUTLOOK
NWS NATIONAL HURRICANE CENTER MIAMI FL
430 PM EDT MON JUN 30 2014

Special outlook issued to update discussion of the area of low
pressure east of Florida.

Updated:  An Air Force Reserve unit reconnaissance aircraft is
investigating the area of low pressure centered about 110 miles east
of Melbourne, Florida.  While the low is well defined, the
associated thunderstorm activity is just below the organizational
threshold required to initiate tropical cyclone advisories.
Environmental conditions continue to be favorable for development,
and only a slight increase in the organization and persistence of
the thunderstorm activity would result in the formation of a
tropical depression.

Data from the reconnaissance aircraft indicate that peak sustained
winds with the low are about 30-35 mph.  The low is moving
southwestward at around 5 mph, but is expected to turn westward
tonight and northward by Wednesday when it will be near the east
coast of Florida. If this system becomes a tropical cyclone, a
tropical storm watch could be required for portions of the central
or northern Atlantic coast of Florida.  A turn toward the northeast
near the southeastern U.S. coast is expected by Thursday.
* Formation chance through 48 hours...high...80 percent.
* Formation chance through 5 days...high...80 percent.
```

Key Points

A Special Tropical Weather Outlook is issued when significant or unexpected changes occur regarding a tropical disturbance. These can be issued at any time to provide that updated information. The reason for the update will be listed at the top of the product. See the highlighted text in yellow as an example (“Special Outlook issued to update the discussion of the area of low pressure east of Florida.”). This Special Outlook was issued in between the regular 2 p.m. and 8 p.m. ET Tropical Weather Outlooks.

Visual 17: Special Tropical Weather Outlook 2


NATIONAL HURRICANE CENTER
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

SPECIAL TROPICAL WEATHER OUTLOOK
NWS NATIONAL HURRICANE CENTER MIAMI FL
430 PM EDT MON JUN 30 2014

Special outlook issued to update discussion of the area of low pressure east of Florida.

Updated: An Air Force Reserve unit reconnaissance aircraft is investigating the area of low pressure centered about 110 miles east of Melbourne, Florida. While the low is well defined, the associated thunderstorm activity is just below the organizational threshold required to initiate tropical cyclone advisories. Environmental conditions continue to be favorable for development, and only a slight increase in the organization and persistence of the thunderstorm activity would result in the formation of a tropical depression.

Data from the reconnaissance aircraft indicate that peak sustained winds with the low are about 30-35 mph. The low is moving southwestward at around 5 mph, but is expected to turn westward tonight and northward by Wednesday when it will be near the east coast of Florida. If this system becomes a tropical cyclone, a tropical storm watch could be required for portions of the central or northern Atlantic coast of Florida. A turn toward the northeast near the southeastern U.S. coast is expected by Thursday.
* Formation chance through 48 hours...high...80 percent.
* Formation chance through 5 days...high...80 percent.

Key Points

New and Different Information

The highlighted portion of this visual shows the updated information, which in this case is a summary of recent aircraft reconnaissance findings that was not previously available.

Visual 18: Special Tropical Weather Outlook 3

NATIONAL HURRICANE CENTER
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

SPECIAL TROPICAL WEATHER OUTLOOK
NWS NATIONAL HURRICANE CENTER MIAMI FL
430 PM EDT MON JUN 30 2014

Special outlook issued to update discussion of the area of low pressure east of Florida.

Updated: An Air Force Reserve unit reconnaissance aircraft is investigating the area of low pressure centered about 110 miles east of Melbourne, Florida. While the low is well defined, the associated thunderstorm activity is just below the organizational threshold required to initiate tropical cyclone advisories. Environmental conditions continue to be favorable for development, and only a slight increase in the organization and persistence of the thunderstorm activity would result in the formation of a tropical depression.

Data from the reconnaissance aircraft indicate that peak sustained winds with the low are about 30-35 mph. The low is moving southwestward at around 5 mph, but is expected to turn westward tonight and northward by Wednesday when it will be near the east coast of Florida. If this system becomes a tropical cyclone, a tropical storm watch could be required for portions of the central or northern Atlantic coast of Florida. A turn toward the northeast near the southeastern U.S. coast is expected by Thursday.
* Formation chance through 48 hours...high...80 percent.
* Formation chance through 5 days...high...80 percent.

Watches possible?

Key Points

Tropical Storm Watch Possibility

Information about potential impacts from the disturbance are often mentioned in the Tropical Weather Outlook. In this case, the highlighted portion of this visual shows that a Tropical Storm Watch may be required.

Visual 19: Outlooks – Knowledge Check

How often do you check the Tropical Weather Outlook during hurricane season?

A. Never

B. Infrequently

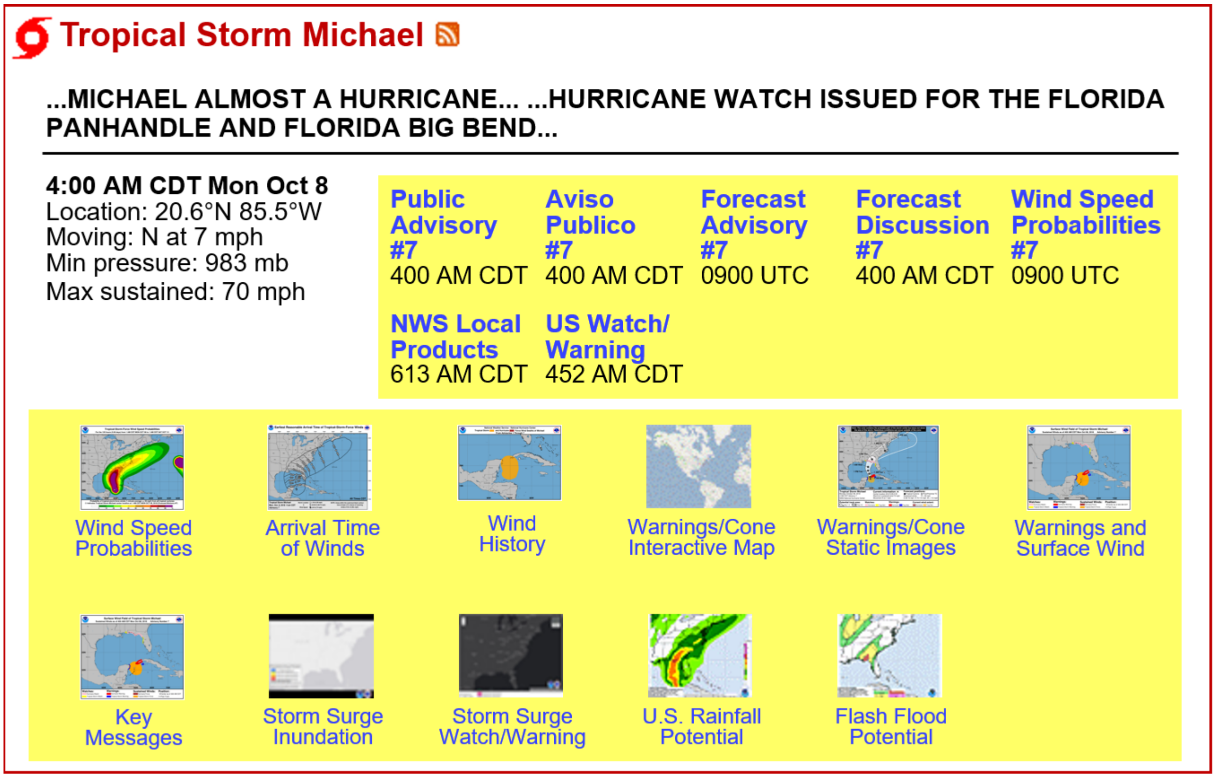
C. Once a day

D. Multiple times a day

Key Points

The Tropical Weather Outlook is updated four times a day. It is encouraged that it is checked multiple times a day during hurricane season.

Visual 20: www.hurricanes.gov



Key Points

Tropical cyclone products are available on the NHC website. This is where most people access this information. There are a variety of products to help understand where the storm is located, how strong the storm is, and where it is forecast to move. These products provide information on hazards and Watches and Warnings and can help answer many basic storm questions such as:

1. How strong is it?
2. What are the hazards?
3. Are there any associated Warnings?

The Public Advisory is the best product to use to answer these questions.

Products are available on the [National Hurricane Center website](http://www.hurricanes.gov) at [http://www.hurricanes.gov.](http://www.hurricanes.gov)

Visual 21: National Hurricane Center Advisories

Tropical Cyclones

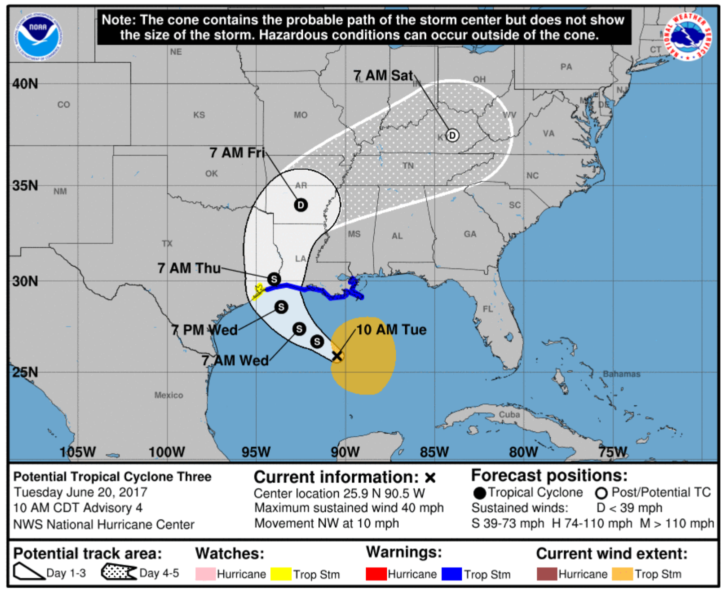
- Tropical Depressions
- Tropical Storms
- Hurricanes

Post-Tropical Cyclones

- Remains a threat to land (e.g., Sandy & Lee)

Potential Tropical Cyclones

- Systems not yet a tropical cyclone
- Threat of TS-force winds to land within 48 hours. (Introduced in 2017)



Key Points

NHC issues advisories (forecasts) on tropical cyclones but also issues them on post-tropical cyclones that pose a threat to land and on potential tropical cyclones. Potential tropical cyclones are systems that are not yet a tropical cyclone but pose the threat of bringing tropical storm conditions to land within 48 hours. The information in the advisories is helpful to Emergency Managers to learn what a system might do.

The image is of a forecast for Potential Tropical Cyclone Three (Cindy 2017).

Visual 22: Frequently Asked Questions 2

FAQs

When is new information available?
When is a good time for a conference call?
What's the battle rhythm?

NHC Advisory Timeline

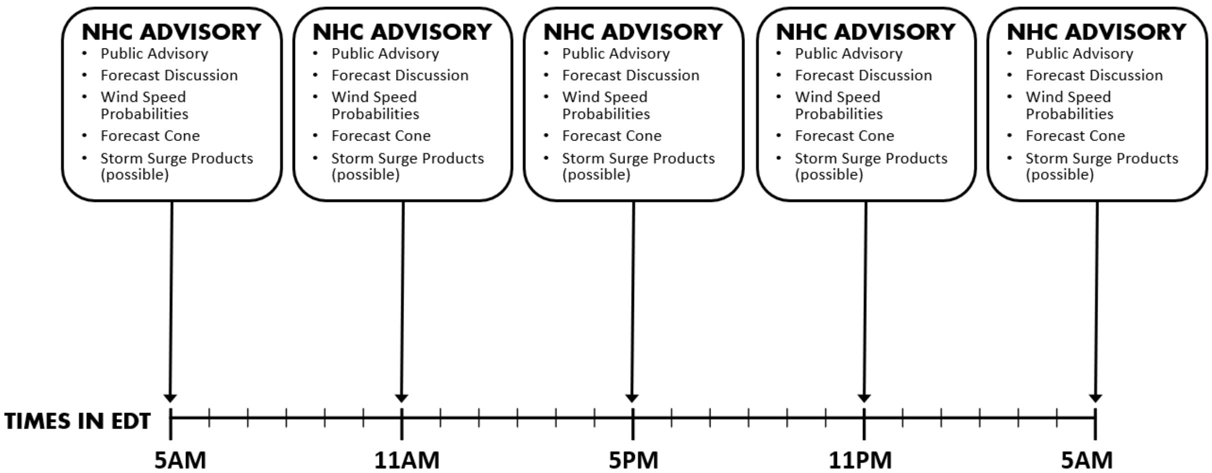
Key Points

The timeline shows when the NHC products are available and is useful when trying to locate information you need to make informed decisions.

Some of the most frequently asked questions are when new information is available from NHC and when is a good time to hold conference calls to make preparedness decisions.

Visual 23: NHC Advisory Timeline

No Watches/Warnings



Key Points

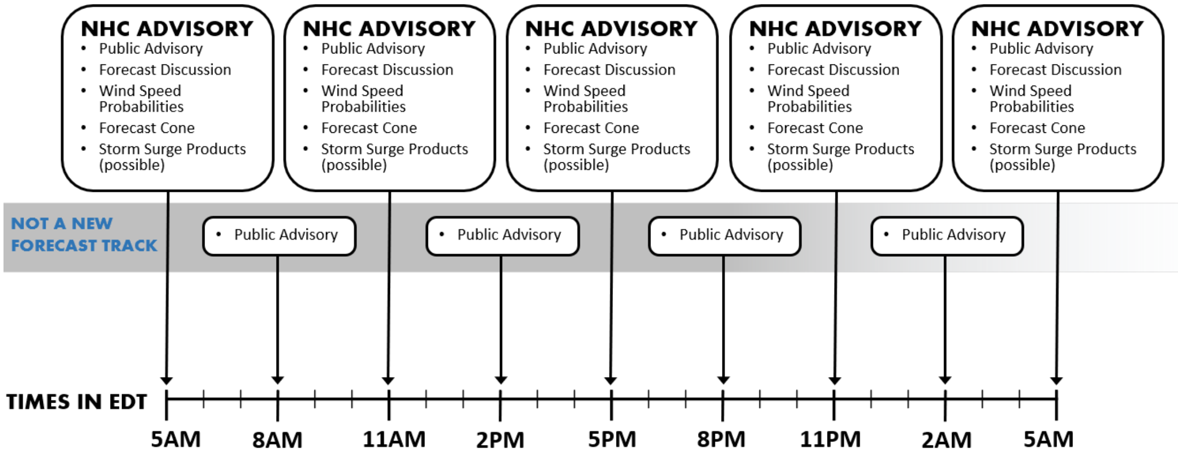
When a system is monitored, the NHC will issue an advisory package that includes:

- Public Advisory
- Forecast Discussion
- Wind Speed Probabilities
- Forecast Cone
- Storm Surge Products (possible)

The first advisory of the day is issued at 5 a.m. EDT. A second is issued at 11 a.m. EDT, then another at 5 p.m. EDT and another one at 11 p.m. EDT. The cycle continues with the new advisory package every 6 hours.

Visual 24: NHC Advisory Timeline – W/W

Watches/Warnings in effect



Key Points

When Watches and Warnings are in effect, the NHC will add information to the advisory package. The closer to the impact of the storm, the more information is available. A new public advisory is issued every 3 hours but does not contain a new forecast track.

Visual 25: Unscheduled Updates

Special Advisories

- Issued at any time whenever an unexpected significant change has occurred.
    - Aircraft or satellite estimate finds storm is stronger than forecast.
    - Storm is significantly off track.
- When U.S. Watches or Warnings are issued between regularly scheduled advisories
    - Watches or Warnings may be discontinued on intermediate Public Advisories

Key Points

While rare, Special Advisories are issued any time an unexpected significant change occurs. Aircraft or satellite may find a rapidly changing storm that is stronger than what is forecasted. These advisories are issued between the regularly scheduled advisories and contain the full suite of advisory products.

Visual 26: Frequently Asked Questions 3

FAQs

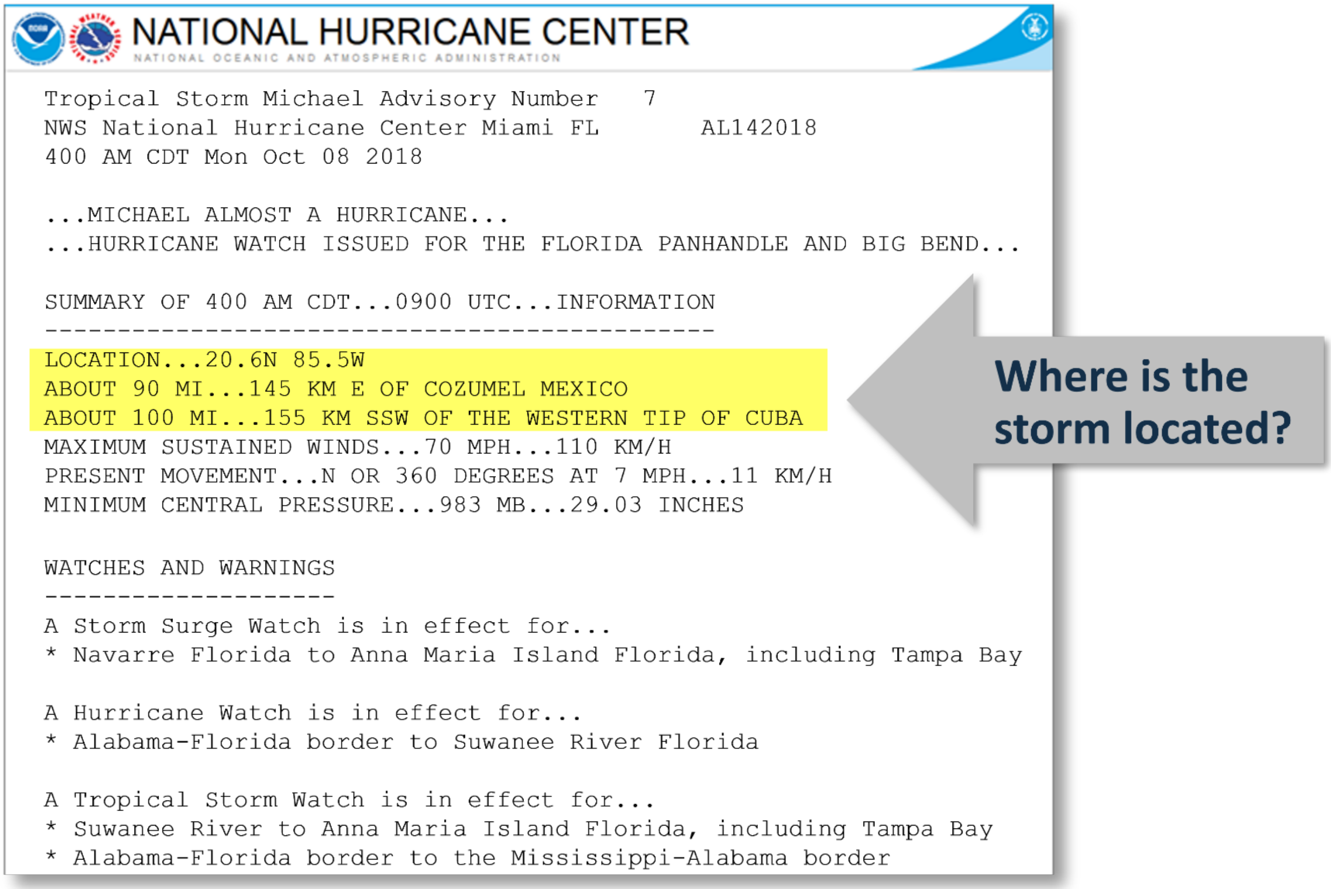
1. How strong is the storm?
2. What are the hazards?
3. Are there any Warnings?

Public Advisory

Key Points

What product can help you answer how strong is the storm, what are the hazards, and are there any Watches or Warnings in effect? The Public Advisory can help answer those questions.

Visual 27: Public Advisory – Location




```
Tropical Storm Michael Advisory Number   7
NWS National Hurricane Center Miami FL       AL142018
400 AM CDT Mon Oct 08 2018

...MICHAEL ALMOST A HURRICANE...
...HURRICANE WATCH ISSUED FOR THE FLORIDA PANHANDLE AND BIG BEND...

SUMMARY OF 400 AM CDT...0900 UTC...INFORMATION
----------------------------------------------
LOCATION...20.6N 85.5W
ABOUT 90 MI...145 KM E OF COZUMEL MEXICO
ABOUT 100 MI...155 KM SSW OF THE WESTERN TIP OF CUBA
MAXIMUM SUSTAINED WINDS...70 MPH...110 KM/H
PRESENT MOVEMENT...N OR 360 DEGREES AT 7 MPH...11 KM/H
MINIMUM CENTRAL PRESSURE...983 MB...29.03 INCHES

WATCHES AND WARNINGS
--------------------
A Storm Surge Watch is in effect for...
* Navarre Florida to Anna Maria Island Florida, including Tampa Bay

A Hurricane Watch is in effect for...
* Alabama-Florida border to Suwanee River Florida

A Tropical Storm Watch is in effect for...
* Suwanee River to Anna Maria Island Florida, including Tampa Bay
* Alabama-Florida border to the Mississippi-Alabama border
```

Key Points

Public Advisories are plain-language text products originally intended as “rip and read” stories for any television station, radio station, or other media advising the public. A Public Advisory is a concise rundown of the most important information, such as the location and strength of the tropical cyclone, the predicted hazards, and any associated Warnings.

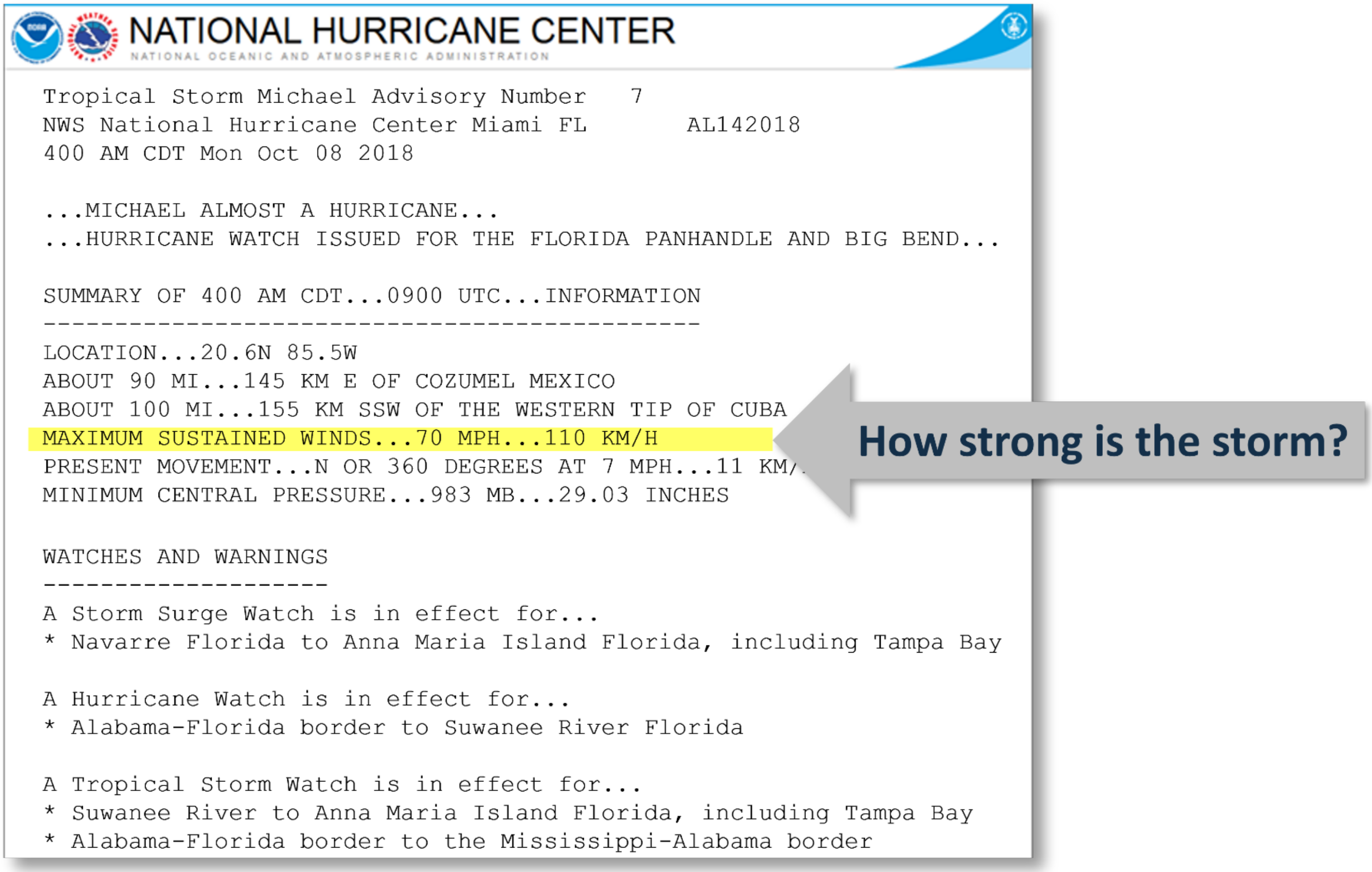
A Public Advisory includes:

1. Watches and Warnings
2. Location, motion, and forecast
3. Wind speed and forecast
4. Hazards

Location

The highlighted portion of the advisory on the visual describes where the storm is located both by latitude and longitude and by distance from a well-known geographical location.

Visual 28: Public Advisory – Strength


NATIONAL HURRICANE CENTER
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

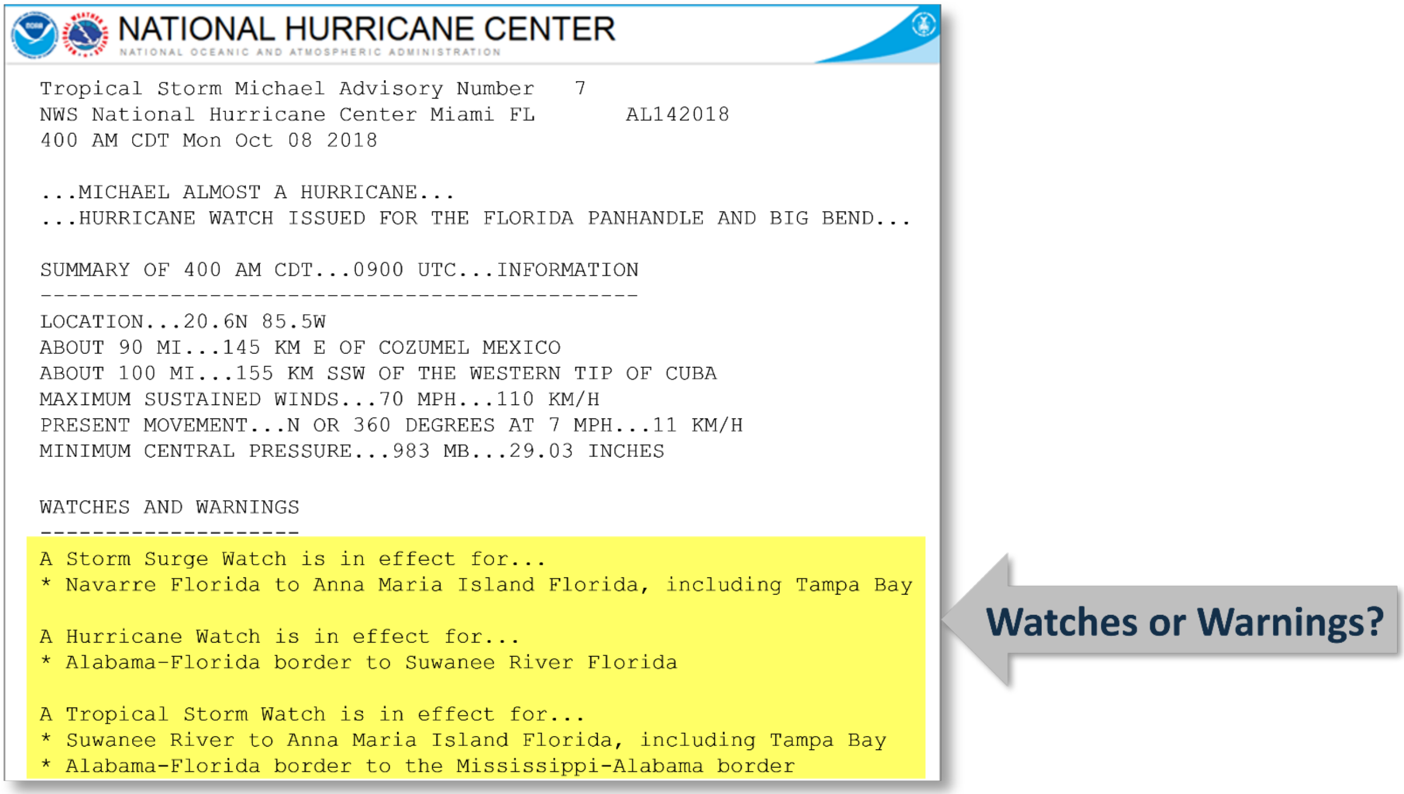
```
Tropical Storm Michael Advisory Number   7
NWS National Hurricane Center Miami FL       AL142018
400 AM CDT Mon Oct 08 2018

...MICHAEL ALMOST A HURRICANE...
...HURRICANE WATCH ISSUED FOR THE FLORIDA PANHANDLE AND BIG BEND...

SUMMARY OF 400 AM CDT...0900 UTC...INFORMATION
----------------------------------------------
LOCATION...20.6N 85.5W
ABOUT 90 MI...145 KM E OF COZUMEL MEXICO
ABOUT 100 MI...155 KM SSW OF THE WESTERN TIP OF CUBA
MAXIMUM SUSTAINED WINDS...70 MPH...110 KM/H
PRESENT MOVEMENT...N OR 360 DEGREES AT 7 MPH...11 KM/
MINIMUM CENTRAL PRESSURE...983 MB...29.03 INCHES

WATCHES AND WARNINGS
--------------------
A Storm Surge Watch is in effect for...
* Navarre Florida to Anna Maria Island Florida, including Tampa Bay

A Hurricane Watch is in effect for...
* Alabama-Florida border to Suwanee River Florida

A Tropical Storm Watch is in effect for...
* Suwanee River to Anna Maria Island Florida, including Tampa Bay
* Alabama-Florida border to the Mississippi-Alabama border
```


Key Points

Strength

The advisory also answers the question of “what is the strength of the tropical cyclone?”

Visual 29: Public Advisory – Watches/Warnings


NATIONAL HURRICANE CENTER
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

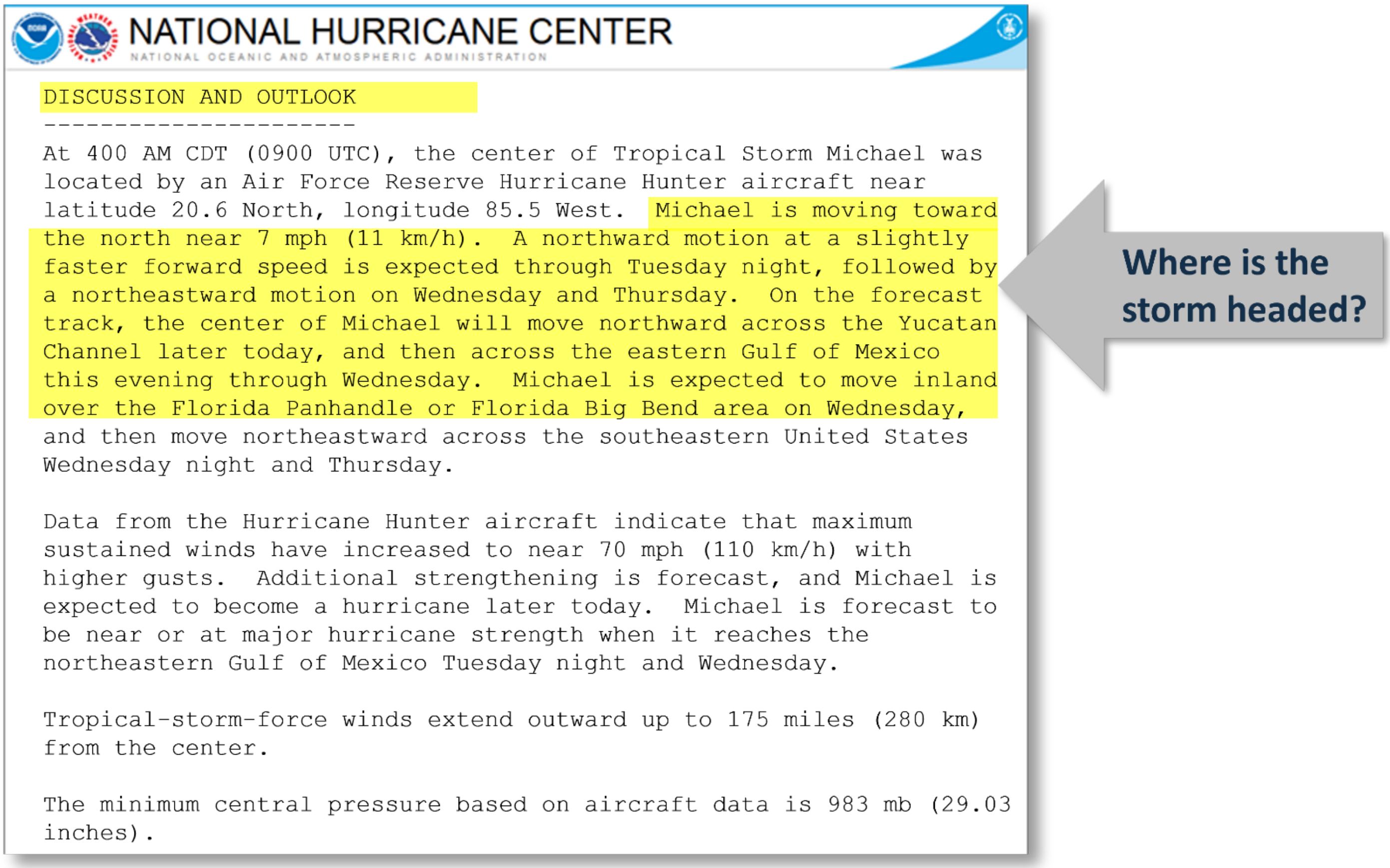
```
Tropical Storm Michael Advisory Number   7
NWS National Hurricane Center Miami FL       AL142018
400 AM CDT Mon Oct 08 2018

...MICHAEL ALMOST A HURRICANE...
...HURRICANE WATCH ISSUED FOR THE FLORIDA PANHANDLE AND BIG BEND...

SUMMARY OF 400 AM CDT...0900 UTC...INFORMATION
----------------------------------------------
LOCATION...20.6N 85.5W
ABOUT 90 MI...145 KM E OF COZUMEL MEXICO
ABOUT 100 MI...155 KM SSW OF THE WESTERN TIP OF CUBA
MAXIMUM SUSTAINED WINDS...70 MPH...110 KM/H
PRESENT MOVEMENT...N OR 360 DEGREES AT 7 MPH...11 KM/H
MINIMUM CENTRAL PRESSURE...983 MB...29.03 INCHES

WATCHES AND WARNINGS
--------------------
A Storm Surge Watch is in effect for...
* Navarre Florida to Anna Maria Island Florida, including Tampa Bay

A Hurricane Watch is in effect for...
* Alabama-Florida border to Suwanee River Florida

A Tropical Storm Watch is in effect for...
* Suwanee River to Anna Maria Island Florida, including Tampa Bay
* Alabama-Florida border to the Mississippi-Alabama border
```


Key Points

Watches and Warnings

The highlighted portion of the advisory describes whether there are any Watches and Warnings, and what the changes to Watches and Warnings have been since the previously issued advisory.

Visual 30: Public Advisory – Track Forecast



NATIONAL HURRICANE CENTER
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

```
DISCUSSION AND OUTLOOK
----------------------
At 400 AM CDT (0900 UTC), the center of Tropical Storm Michael was
located by an Air Force Reserve Hurricane Hunter aircraft near
latitude 20.6 North, longitude 85.5 West.  Michael is moving toward
the north near 7 mph (11 km/h).  A northward motion at a slightly
faster forward speed is expected through Tuesday night, followed by
a northeastward motion on Wednesday and Thursday.  On the forecast
track, the center of Michael will move northward across the Yucatan
Channel later today, and then across the eastern Gulf of Mexico
this evening through Wednesday.  Michael is expected to move inland
over the Florida Panhandle or Florida Big Bend area on Wednesday,
and then move northeastward across the southeastern United States
Wednesday night and Thursday.

Data from the Hurricane Hunter aircraft indicate that maximum
sustained winds have increased to near 70 mph (110 km/h) with
higher gusts.  Additional strengthening is forecast, and Michael is
expected to become a hurricane later today.  Michael is forecast to
be near or at major hurricane strength when it reaches the
northeastern Gulf of Mexico Tuesday night and Wednesday.

Tropical-storm-force winds extend outward up to 175 miles (280 km)
from the center.

The minimum central pressure based on aircraft data is 983 mb (29.03
inches).
```

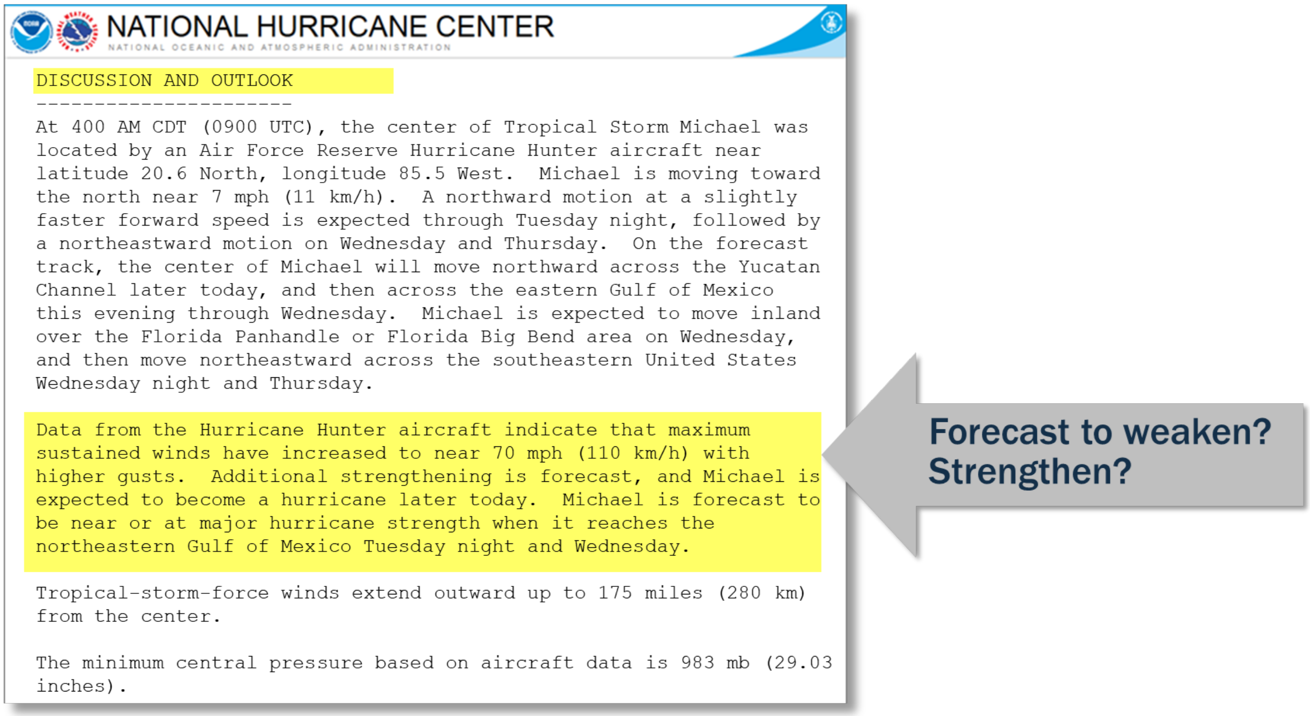

Key Points

Track Forecast

The highlighted portion of the advisory describes where the storm is located, its current motion, and where it is expected to go during the next 2 days.

This area of the advisory is a great resource to pull text out for crafting announcements.

Visual 31: Public Advisory – Intensity Forecast



DISCUSSION AND OUTLOOK

At 400 AM CDT (0900 UTC), the center of Tropical Storm Michael was located by an Air Force Reserve Hurricane Hunter aircraft near latitude 20.6 North, longitude 85.5 West. Michael is moving toward the north near 7 mph (11 km/h). A northward motion at a slightly faster forward speed is expected through Tuesday night, followed by a northeastward motion on Wednesday and Thursday. On the forecast track, the center of Michael will move northward across the Yucatan Channel later today, and then across the eastern Gulf of Mexico this evening through Wednesday. Michael is expected to move inland over the Florida Panhandle or Florida Big Bend area on Wednesday, and then move northeastward across the southeastern United States Wednesday night and Thursday.

Data from the Hurricane Hunter aircraft indicate that maximum sustained winds have increased to near 70 mph (110 km/h) with higher gusts. Additional strengthening is forecast, and Michael is expected to become a hurricane later today. Michael is forecast to be near or at major hurricane strength when it reaches the northeastern Gulf of Mexico Tuesday night and Wednesday.

Tropical-storm-force winds extend outward up to 175 miles (280 km) from the center.

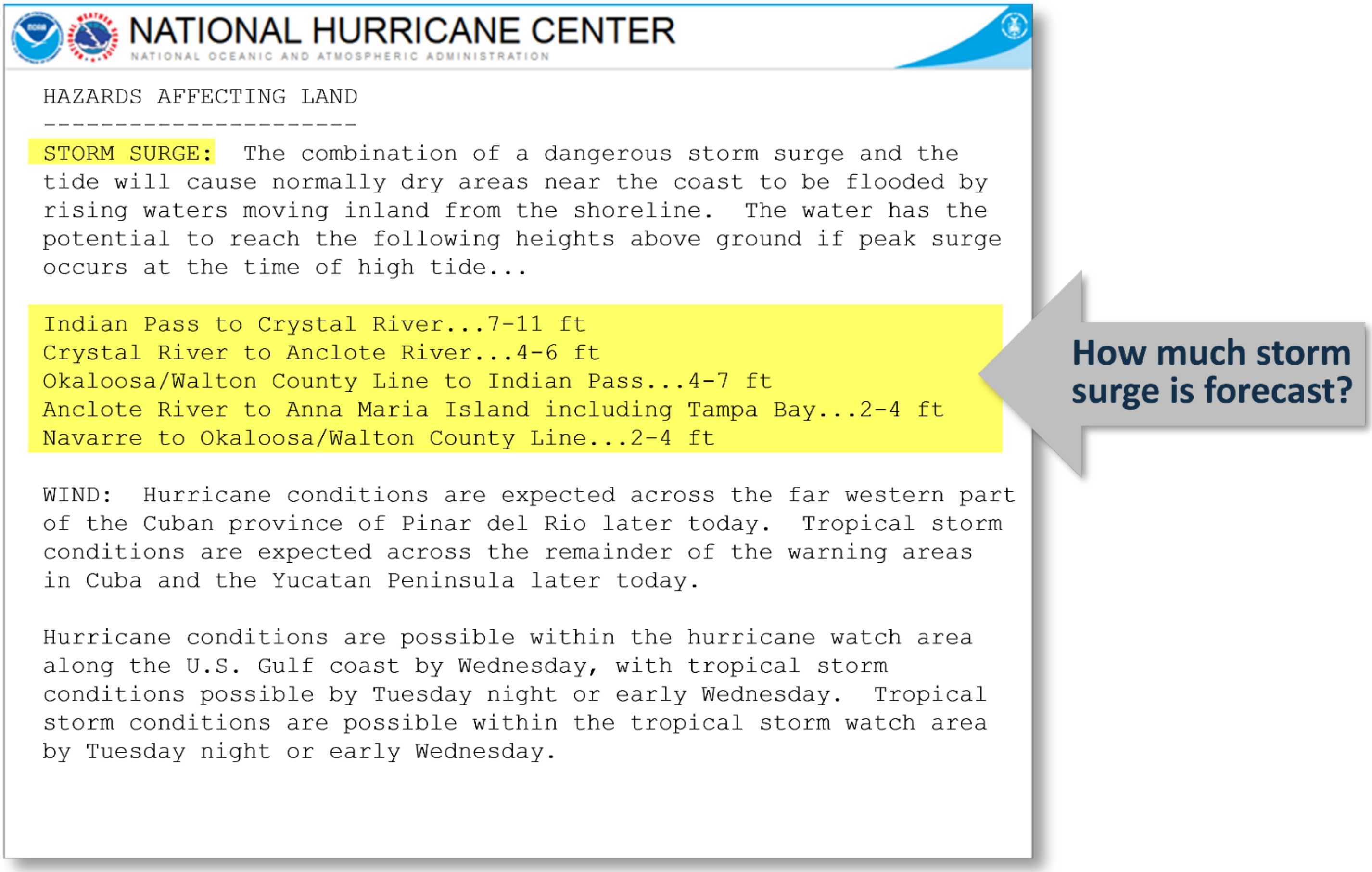
The minimum central pressure based on aircraft data is 983 mb (29.03 inches).

Key Points

Intensity Forecast

The highlighted portion of the advisory describes the tropical cyclone’s current intensity and whether it is predicted to strengthen or weaken during the next 3 days.

Visual 32: Public Advisory – Surge Forecast


NATIONAL HURRICANE CENTER

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

HAZARDS AFFECTING LAND

STORM SURGE: The combination of a dangerous storm surge and the tide will cause normally dry areas near the coast to be flooded by rising waters moving inland from the shoreline. The water has the potential to reach the following heights above ground if peak surge occurs at the time of high tide...

Indian Pass to Crystal River...7-11 ft
Crystal River to Anclote River...4-6 ft
Okaloosa/Walton County Line to Indian Pass...4-7 ft
Anclote River to Anna Maria Island including Tampa Bay...2-4 ft
Navarre to Okaloosa/Walton County Line...2-4 ft

WIND: Hurricane conditions are expected across the far western part of the Cuban province of Pinar del Rio later today. Tropical storm conditions are expected across the remainder of the warning areas in Cuba and the Yucatan Peninsula later today.

Hurricane conditions are possible within the hurricane watch area along the U.S. Gulf coast by Wednesday, with tropical storm conditions possible by Tuesday night or early Wednesday. Tropical storm conditions are possible within the tropical storm watch area by Tuesday night or early Wednesday.

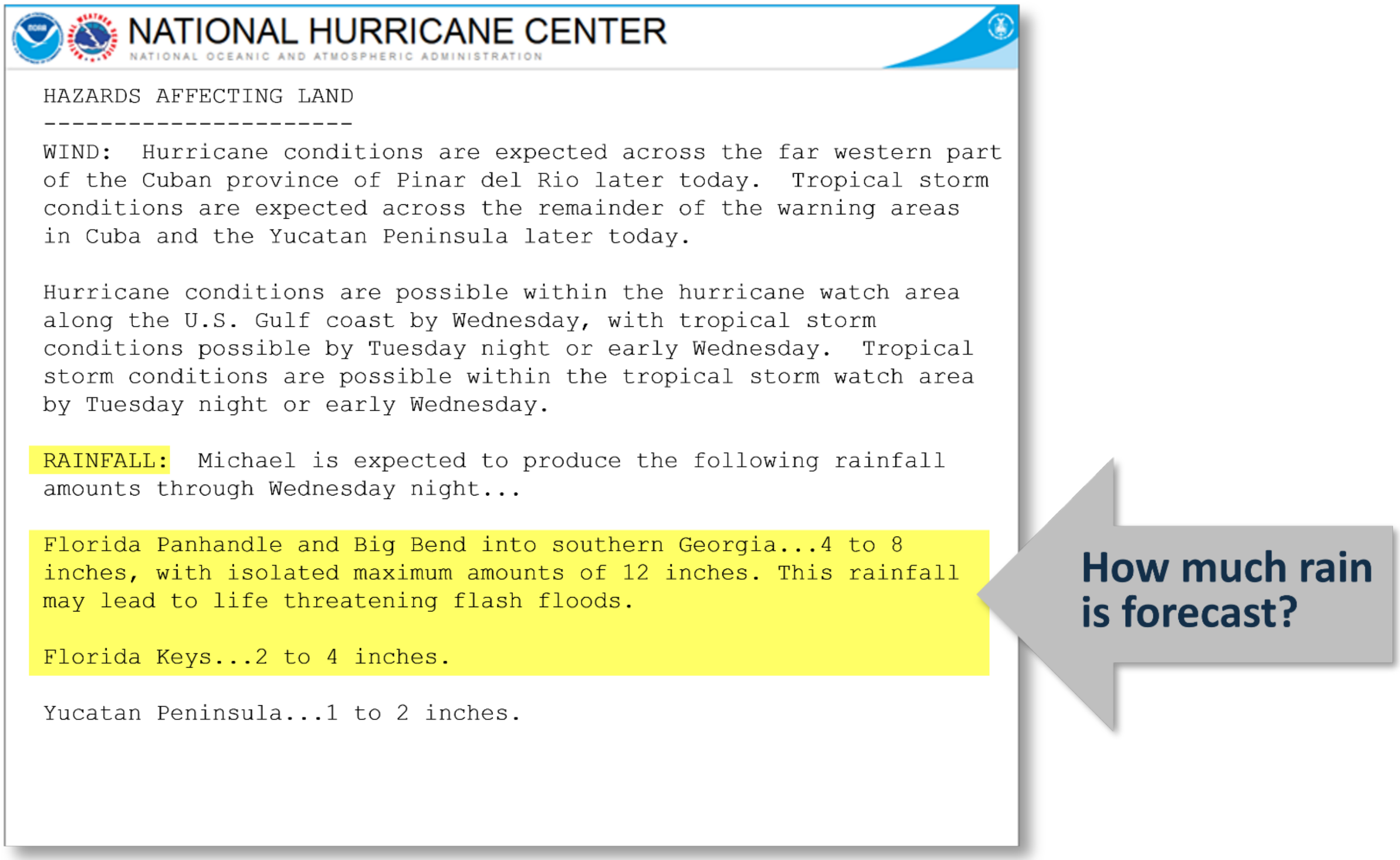
Key Points

Surge Forecast

The highlighted portion of the advisory is the beginning of the hazard section. This section describes any hazards (storm surge, wind, rainfall, tornadoes, or high surf). The hazards are typically arranged by their expected impact, with the most significant hazard listed first.

This section shows how storm surge is described in the Public Advisory. Ranges of possible storm surge inundation (above ground) are given for segments of the coast.

Visual 33: Public Advisory – Rain Forecast


NATIONAL HURRICANE CENTER
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

HAZARDS AFFECTING LAND

WIND: Hurricane conditions are expected across the far western part of the Cuban province of Pinar del Rio later today. Tropical storm conditions are expected across the remainder of the warning areas in Cuba and the Yucatan Peninsula later today.

Hurricane conditions are possible within the hurricane watch area along the U.S. Gulf coast by Wednesday, with tropical storm conditions possible by Tuesday night or early Wednesday. Tropical storm conditions are possible within the tropical storm watch area by Tuesday night or early Wednesday.

RAINFALL: Michael is expected to produce the following rainfall amounts through Wednesday night...

Florida Panhandle and Big Bend into southern Georgia...4 to 8 inches, with isolated maximum amounts of 12 inches. This rainfall may lead to life threatening flash floods.

Florida Keys...2 to 4 inches.

Yucatan Peninsula...1 to 2 inches.

Key Points

Rain Forecast

The hazard section of the Public Advisory also provides the predicted storm total rainfall amounts associated with the tropical cyclone.

Visual 34: Frequently Asked Questions 4

FAQs

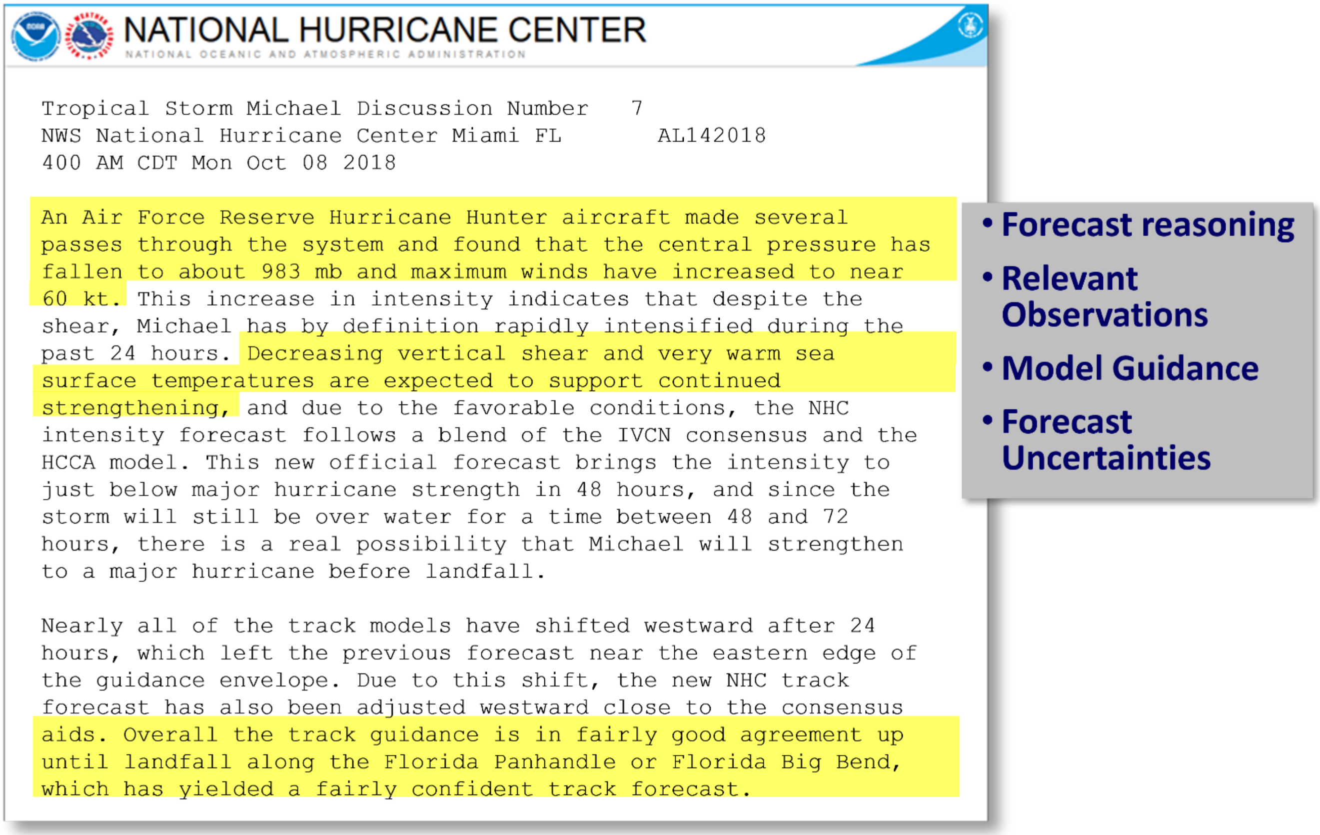
- How confident are the forecasters?
- Forecast reasoning?
- What are the key messages?

Forecast Discussion

Key Points

Another common question is how confident are the forecasters with the forecast and the key messages they relay to the public? The Forecast Discussion is also a good place to pull out key information to share with the public. It is available in the advisory package every six hours.

Visual 35: Forecast Discussion



Tropical Storm Michael Discussion Number 7
NWS National Hurricane Center Miami FL AL142018
400 AM CDT Mon Oct 08 2018

An Air Force Reserve Hurricane Hunter aircraft made several passes through the system and found that the central pressure has fallen to about 983 mb and maximum winds have increased to near 60 kt. This increase in intensity indicates that despite the shear, Michael has by definition rapidly intensified during the past 24 hours. Decreasing vertical shear and very warm sea surface temperatures are expected to support continued strengthening, and due to the favorable conditions, the NHC intensity forecast follows a blend of the IVCN consensus and the HCCA model. This new official forecast brings the intensity to just below major hurricane strength in 48 hours, and since the storm will still be over water for a time between 48 and 72 hours, there is a real possibility that Michael will strengthen to a major hurricane before landfall.

Nearly all of the track models have shifted westward after 24 hours, which left the previous forecast near the eastern edge of the guidance envelope. Due to this shift, the new NHC track forecast has also been adjusted westward close to the consensus aids. Overall the track guidance is in fairly good agreement up until landfall along the Florida Panhandle or Florida Big Bend, which has yielded a fairly confident track forecast.

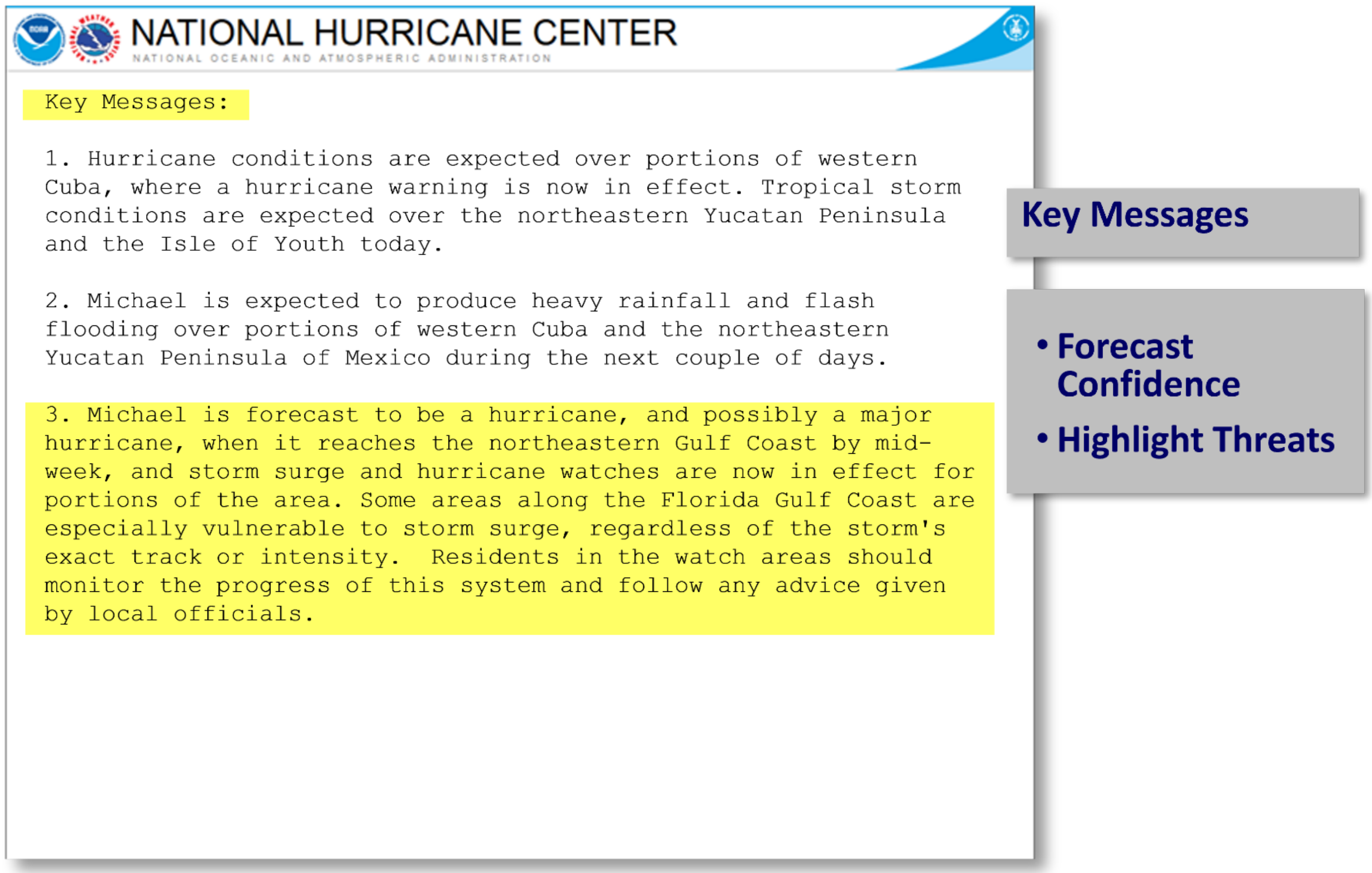
Key Points

Forecast Reasoning

The Tropical Cyclone Discussion provides the reasoning behind forecasts and Warnings, as well as a discussion of relevant observations, model guidance, and forecast uncertainties. It includes a table of forecast positions and intensities in knots and miles per hour. It may also describe the forecaster’s degree of confidence in the official forecast, discuss possible alternate scenarios, and highlight unusual hazards.

The Tropical Cyclone Discussion is issued for active cyclones every 6 hours with the Forecast Advisories.

Visual 36: Forecast Discussion - Key Messages



Key Points

You can use the Key Messages to provide information to the public through public information statements. The NHC uses this area to highlight questions or issues with the forecast. The Key Messages are listed on the Forecast Discussion, after the actual discussion.

Visual 37: Key Messages

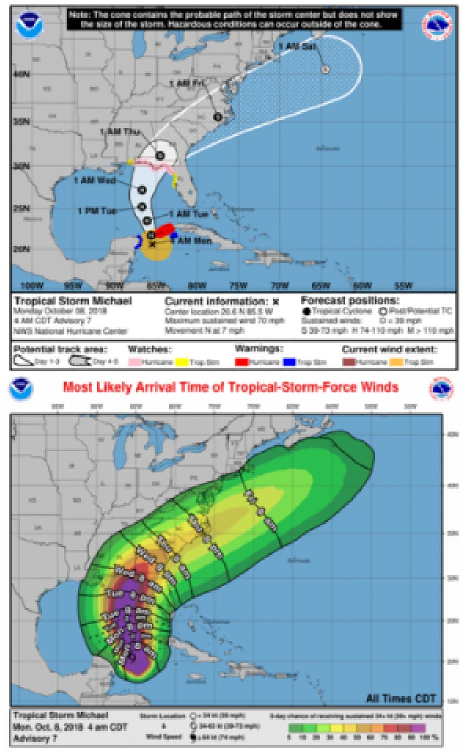
Key Messages for Tropical Storm Michael

Advisory 7: 4:00 AM CDT Mon Oct 08, 2018

1. Hurricane conditions are expected over portions of western Cuba, where a hurricane warning is now in effect. Tropical storm conditions are expected over the northeastern Yucatan Peninsula and the Isle of Youth today.

2. Michael is expected to produce heavy rainfall and flash flooding over portions of western Cuba and the northeastern Yucatan Peninsula of Mexico during the next couple of days.

3. Michael is forecast to be a hurricane, and possibly a major hurricane, when it reaches the northeastern Gulf Coast by mid-week, and storm surge and hurricane watches are now in effect for portions of the area. Some areas along the Florida Gulf Coast are especially vulnerable to storm surge, regardless of the storm's exact track or intensity. Residents in the watch areas should monitor the progress of this system and follow any advice given by local officials.

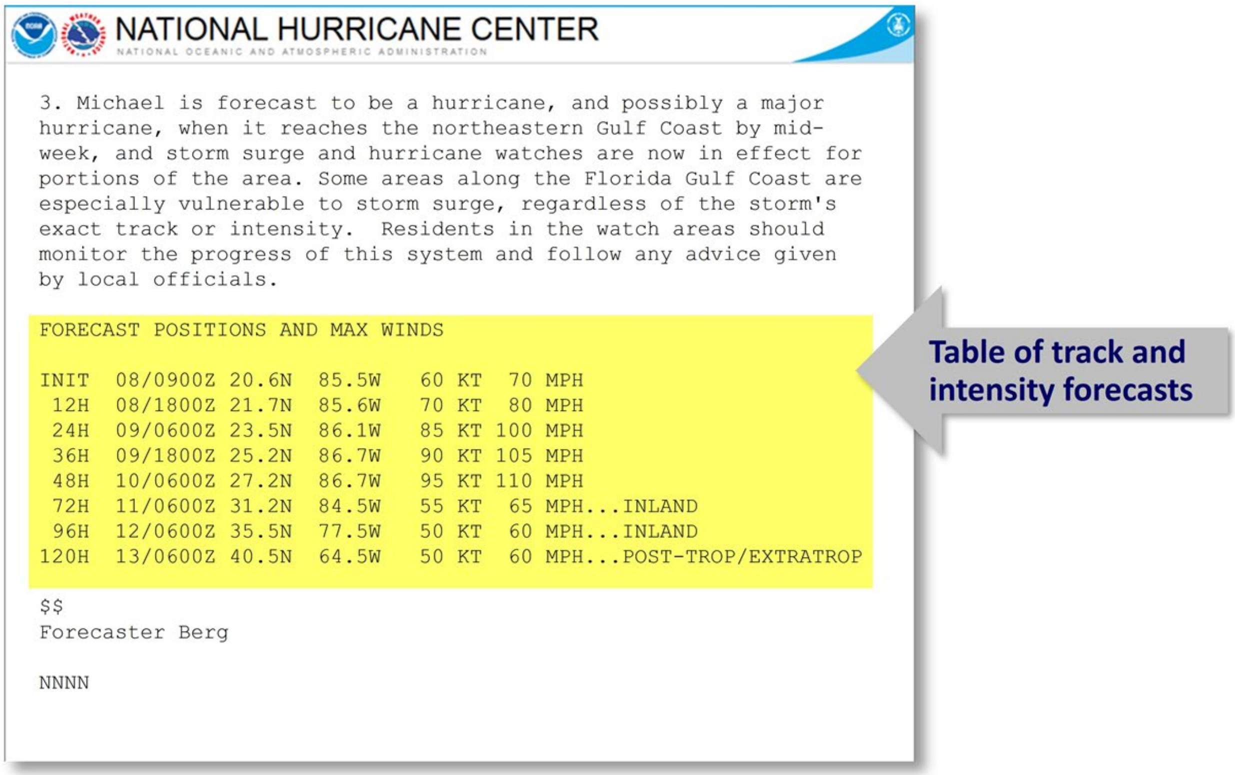


For more information go to hurricanes.gov

Key Points

The NHC provides an infographic along with the text product. This is an example of that graphic product.

Visual 38: Forecast Discussion –Intensity



3. Michael is forecast to be a hurricane, and possibly a major hurricane, when it reaches the northeastern Gulf Coast by mid-week, and storm surge and hurricane watches are now in effect for portions of the area. Some areas along the Florida Gulf Coast are especially vulnerable to storm surge, regardless of the storm's exact track or intensity. Residents in the watch areas should monitor the progress of this system and follow any advice given by local officials.

```
FORECAST POSITIONS AND MAX WINDS

INIT  08/0900Z 20.6N  85.5W   60 KT  70 MPH
 12H  08/1800Z 21.7N  85.6W   70 KT  80 MPH
 24H  09/0600Z 23.5N  86.1W   85 KT 100 MPH
 36H  09/1800Z 25.2N  86.7W   90 KT 105 MPH
 48H  10/0600Z 27.2N  86.7W   95 KT 110 MPH
 72H  11/0600Z 31.2N  84.5W   55 KT  65 MPH...INLAND
 96H  12/0600Z 35.5N  77.5W   50 KT  60 MPH...INLAND
120H  13/0600Z 40.5N  64.5W   50 KT  60 MPH...POST-TROP/EXTRATROP
```

$$
Forecaster Berg

NNNN

Key Points

This table highlights the track and intensity forecasts all in one location. You can use this if you need a quick reference. This is included at the very bottom of the Forecast Discussion.

Visual 39: Frequently Asked Questions 5

FAQs

- How large is the storm?
- Where is the storm headed?
- What are the forecast maximum winds?

Forecast Advisory

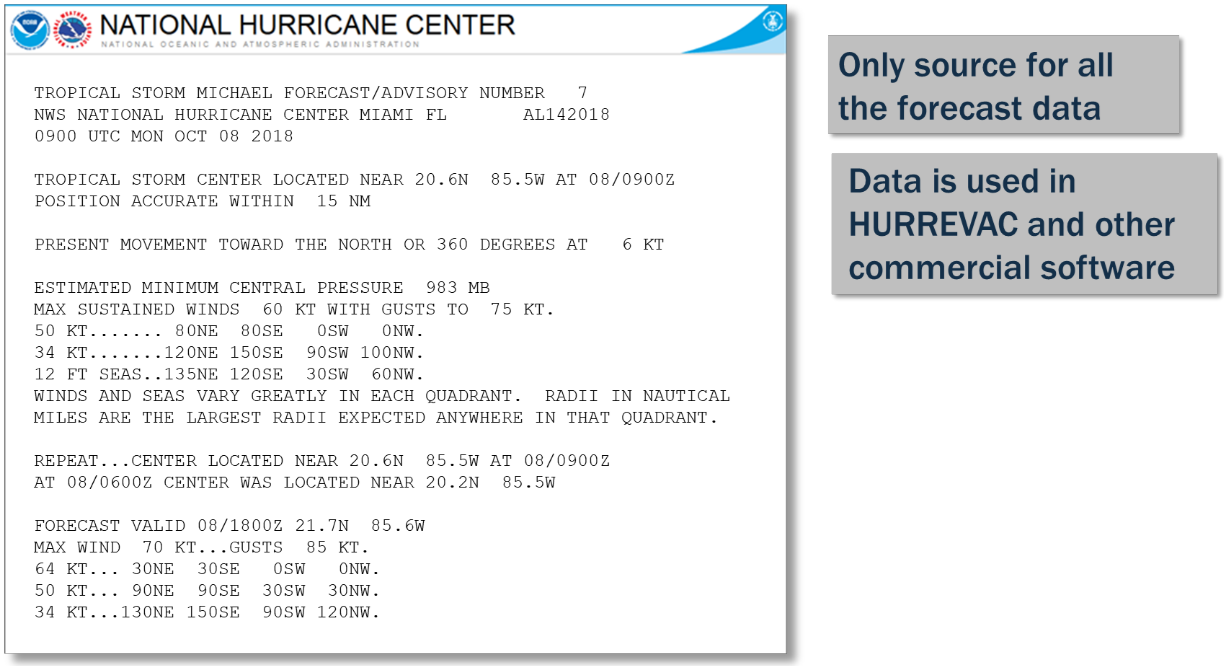
Key Points

The Forecast Advisory is the product most useful to answer questions such as:

- How large is the storm?
- Where is the storm headed?
- What are the forecast maximum winds?

It is the source of all data that others use to pull information. It is the only source of all data.

Visual 40: Forecast Advisory




```
TROPICAL STORM MICHAEL FORECAST/ADVISORY NUMBER   7
NWS NATIONAL HURRICANE CENTER MIAMI FL       AL142018
0900 UTC MON OCT 08 2018

TROPICAL STORM CENTER LOCATED NEAR 20.6N  85.5W AT 08/0900Z
POSITION ACCURATE WITHIN  15 NM

PRESENT MOVEMENT TOWARD THE NORTH OR 360 DEGREES AT   6 KT

ESTIMATED MINIMUM CENTRAL PRESSURE  983 MB
MAX SUSTAINED WINDS  60 KT WITH GUSTS TO  75 KT.
50 KT....... 80NE  80SE   0SW   0NW.
34 KT.......120NE 150SE  90SW 100NW.
12 FT SEAS..135NE 120SE  30SW  60NW.
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 20.6N  85.5W AT 08/0900Z
AT 08/0600Z CENTER WAS LOCATED NEAR 20.2N  85.5W

FORECAST VALID 08/1800Z 21.7N  85.6W
MAX WIND  70 KT...GUSTS  85 KT.
64 KT... 30NE  30SE   0SW   0NW.
50 KT... 90NE  90SE  30SW  30NW.
34 KT...130NE 150SE  90SW 120NW.
```

Key Points

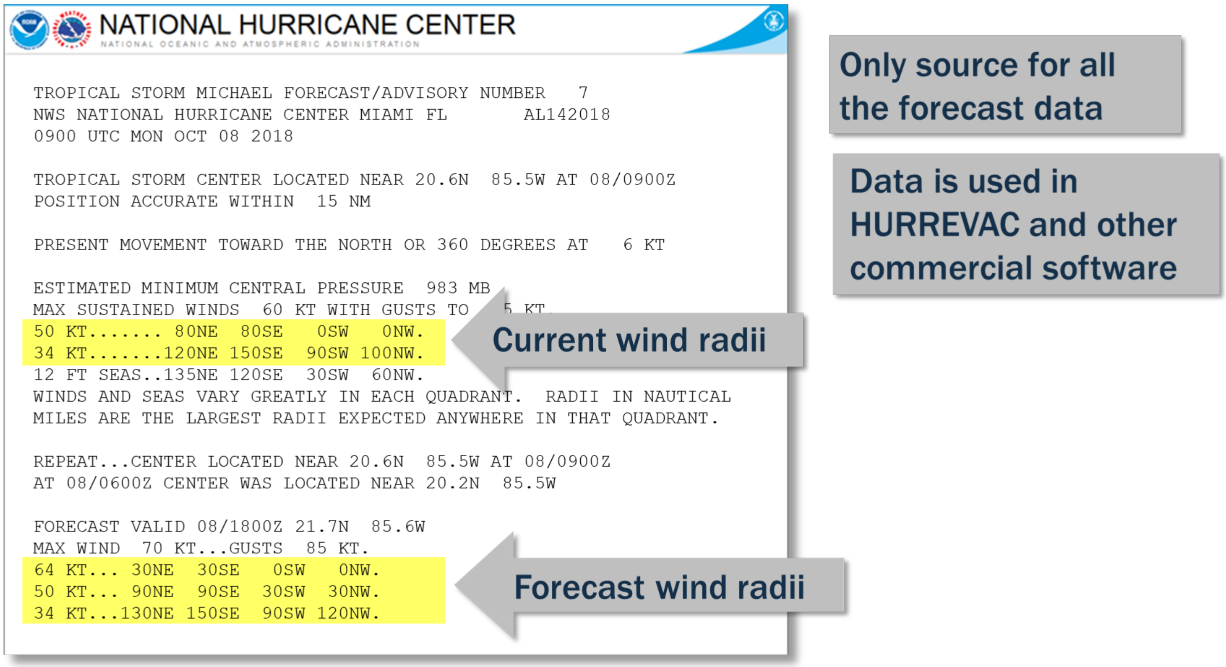
Overview

The Forecast Advisory provides information about the position (latitude and longitude coordinates), size in wind radii, and intensity. It also contains a list of all the Watches and Warnings that are in effect.

It is the only source of all the forecast data, which is then used in HURREVAC and other commercial tracking software.

Forecast Advisories are issued every 6 hours.

Visual 41: Forecast Advisory – Wind Radii 1

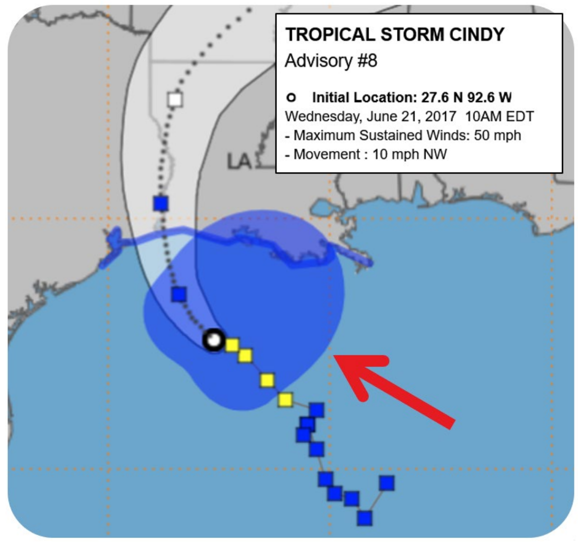



```
TROPICAL STORM MICHAEL FORECAST/ADVISORY NUMBER   7
NWS NATIONAL HURRICANE CENTER MIAMI FL       AL142018
0900 UTC MON OCT 08 2018

TROPICAL STORM CENTER LOCATED NEAR 20.6N  85.5W AT 08/0900Z
POSITION ACCURATE WITHIN  15 NM

PRESENT MOVEMENT TOWARD THE NORTH OR 360 DEGREES AT   6 KT

ESTIMATED MINIMUM CENTRAL PRESSURE  983 MB
MAX SUSTAINED WINDS  60 KT WITH GUSTS TO  [illegible]5 KT.
50 KT....... 80NE  80SE   0SW   0NW.
34 KT.......120NE 150SE  90SW 100NW.
12 FT SEAS..135NE 120SE  30SW  60NW.
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 20.6N  85.5W AT 08/0900Z
AT 08/0600Z CENTER WAS LOCATED NEAR 20.2N  85.5W

FORECAST VALID 08/1800Z 21.7N  85.6W
MAX WIND  70 KT...GUSTS  85 KT.
64 KT... 30NE  30SE   0SW   0NW.
50 KT... 90NE  90SE  30SW  30NW.
34 KT...130NE 150SE  90SW 120NW.
```

Key Points

The highlighted portion of this Forecast Advisory shows the analyzed storm size and its forecast size.

Visual 42: Wind Radii – Knowledge Check

What does the blue area around the center of Cindy represent? A. Tropical storm winds are occurring everywhere in the blue area. B. Area with a two-thirds chance of experiencing tropical storm-force winds. C. Maximum extent of tropical storm winds. D. Area where hurricane winds are occurring.	

Key Points

Tropical storm-force winds may not be occurring everywhere within the area, but it is the maximum extent from the center at which they are occurring. This graphic is made based on the four quadrants wind radii forecast from the advisory package.

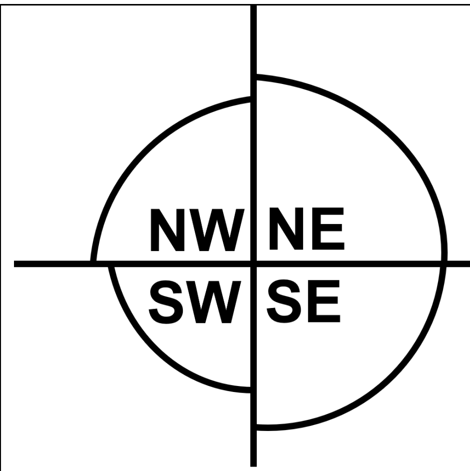
Visual 43: Forecast Advisory - Wind Radii 2

NHC forecasts cyclone size via wind radii in four quadrants.

- Radii are the largest distance from the center in a quadrant.
- An over-estimate, especially near land.

Forecast wind radii:

64 KT....... 30NE 40SE 0SW 0NW
50 KT....... 80NE 70SE 40SW 40NW
34 KT.......150NE 150SE 140SW 100NW



Key Points

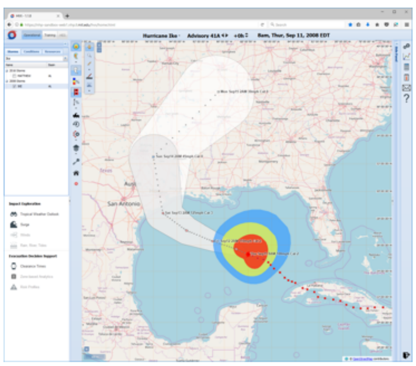
The NHC estimates and forecasts cyclone size via wind radii in four quadrants. Radii represent the largest distance from the center of a quadrant.

It gives you a feel for how big the storm is and the maximum extent of where the winds are going.

Visual 44: Wind Radii

Wind Radii

- **NHC forecasts cyclone size via wind radii in four quadrants**

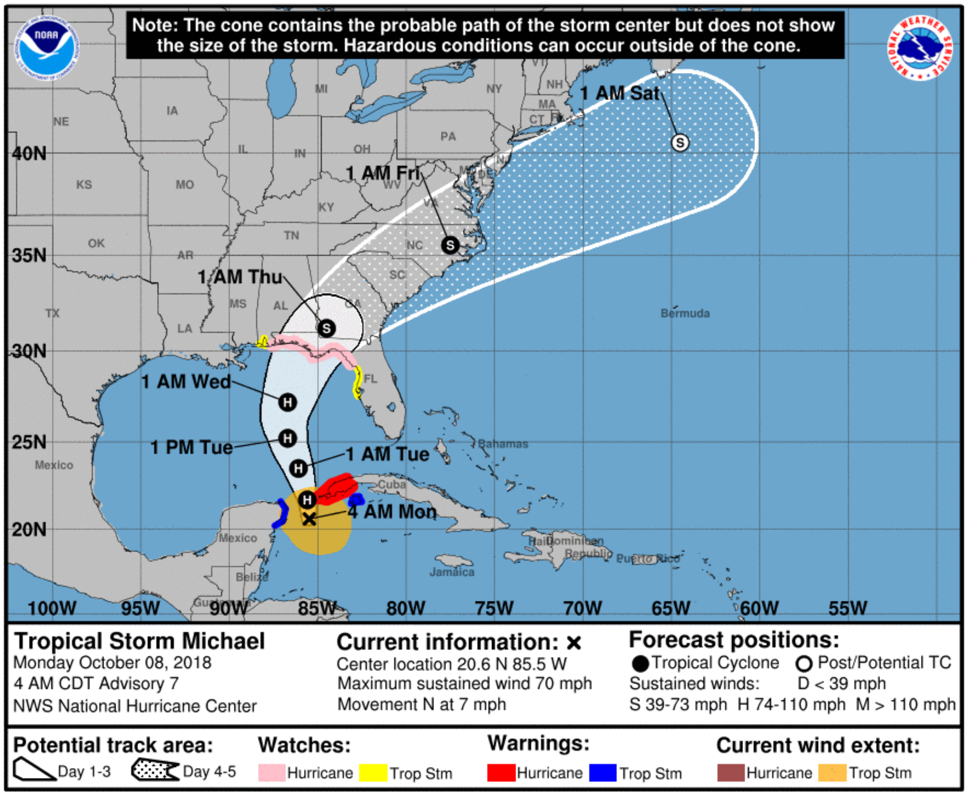


	34 kt (Blue)	50 kt (Yellow)	64 kt (Red)
12 hr	Yes	Yes	Yes
24 hr	Yes	Yes	Yes
36 hr	Yes	Yes	Yes
48 hr	Yes	Yes	Yes
60 hr	Yes	Yes	N/A
72 hr	Yes	Yes	N/A
96 hr	N/A	N/A	N/A
120 hr	N/A	N/A	N/A

Key Points

At 60 and 72 hours, the forecast for hurricane-force winds drops off, but they will continue to forecast tropical storm-force winds. The wind radii forecast is not possible beyond 72 hours.

Visual 45: Forecast Error Cone



Key Points

This is an example of the graphic product the complements that Forecast Advisory text product.

Visual 46: Forecast Error Cone – Knowledge Check

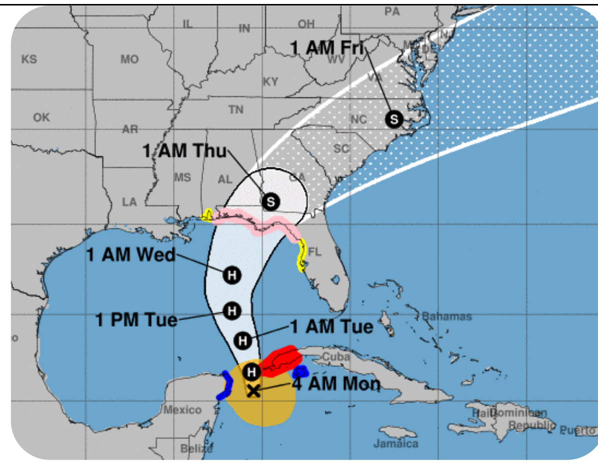
What is used to construct the size of the NHC forecast error cone?

A. Possible impact areas

B. Size of the wind field

C. Model spread

D. Past 5 years of track forecast error



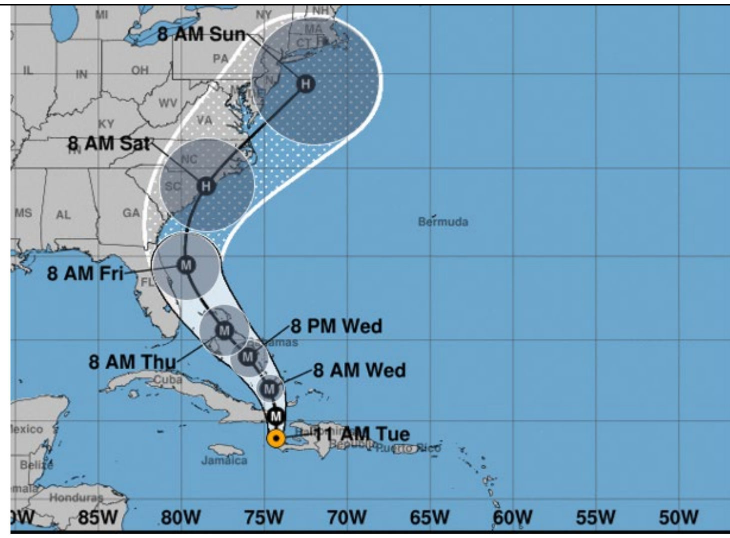
Key Points

The cone doesn't know anything about how extensive the model spread is and doesn't tell us anything about impact areas.

Visual 47: Forecast Error Cone Explained

Error Cone

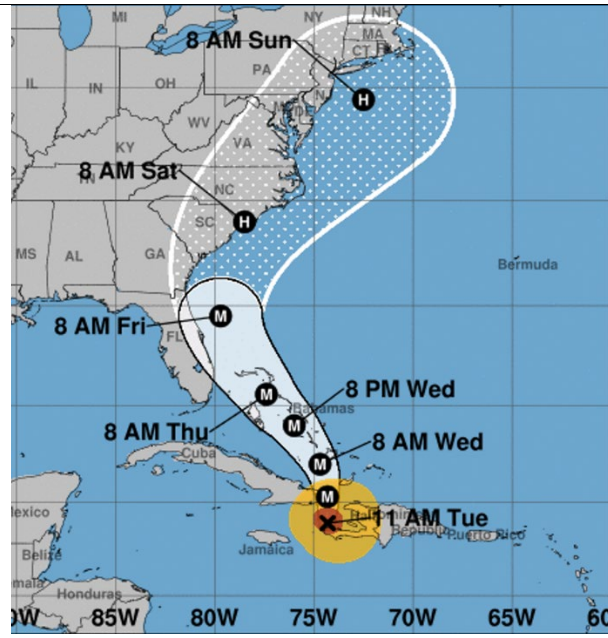
- Probable track of the center of the tropical cyclone.
- Formed by connecting circles centered on each forecast point.
- Each circle uses NHC historical (5-year) track errors.
- Actual storm position will be within the circle 67% of the time.



Key Points

The cone represents the probable track. The cone itself represents the 2/3 chance of the track falling inside the cone. The cone is helpful to explain uncertainty. The center of the storm will be outside the cone 1/3 of the time.

Visual 48: Not in The Cone: No Worries?

ERROR CONE **Situational awareness tool** **Only displays information about historical track uncertainty.** • Doesn't communicate information about specific hurricane hazards. **Impacts can occur well outside the area enclosed by the cone.** • On average, the center is outside the cone 1/3 of the time.	

Key Points

Forecast Cone

Many people might assume that if they are outside of the cone, they have no need to worry because they will not feel the storm's impact. This is not an accurate understanding of the cone.

- The cone only displays information about historical track uncertainty.
- It contains no information about specific hazards.
- Tropical cyclone impacts can occur well outside the area enclosed by the cone.
- The tropical cyclone center is expected to move outside the cone about one-third of the time.

Keep in mind that a tropical cyclone is not a point. Its effects can span hundreds of miles from the center. The area experiencing hurricane-force winds and tropical storm-force winds can extend well beyond the white areas shown, which enclose the center's most likely track area.

Visual 49: Frequently Asked Questions 6

FAQs

- Chance for some effects?
- Are staging areas at risk?

When is the earliest TS winds could begin?

Wind Speed Probabilities and Arrival Times

Key Points

The Tropical Cyclone Surface Wind Speed Probability product is a tabular text product that provides probabilistic information (i.e., the likelihood of an event, expressed as a percentage) on the likelihood of sustained winds meeting or exceeding specific thresholds at particular locations.

The thresholds are:

- Tropical storm force (39 miles per hour [mph])
- 58 mph
- Hurricane force (74 mph)

Wind speed probabilities are based on the track, intensity, and wind radii (size) forecasts as well as the typical uncertainties of the NHC forecasts.

Visual 50: Wind Speed Probabilities – Text 1

NATIONAL HURRICANE CENTER
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

```
TROPICAL STORM MICHAEL WIND SPEED PROBABILITIES NUMBER   7
NWS NATIONAL HURRICANE CENTER MIAMI FL       AL142018
0900 UTC MON OCT 08 2018

  - - - - WIND SPEED PROBABILITIES FOR SELECTED LOCATIONS - - - -

               FROM     FROM     FROM     FROM     FROM     FROM     FROM
  TIME       06Z MON  18Z MON  06Z TUE  18Z TUE  06Z WED  06Z THU  06Z FRI
PERIODS        TO       TO       TO       TO       TO       TO       TO
             18Z MON  06Z TUE  18Z TUE  06Z WED  06Z THU  06Z FRI  06Z SAT

FORECAST HOUR    (12)     (24)     (36)     (48)     (72)     (96)    (120)
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
LOCATION       KT

TALLAHASSEE FL 34  X    X( X)    1( 1)    6( 7)   68(75)    6(81)    X(81)
TALLAHASSEE FL 50  X    X( X)    X( X)    1( 1)   41(42)    6(48)    X(48)
TALLAHASSEE FL 64  X    X( X)    X( X)    X( X)   20(20)    4(24)    X(24)

APALACHICOLA   34  X    X( X)    5( 5)   29(34)   57(91)    1(92)    X(92)
APALACHICOLA   50  X    X( X)    X( X)    6( 6)   59(65)    2(67)    X(67)
APALACHICOLA   64  X    X( X)    X( X)    1( 1)   39(40)    1(41)    X(41)

PANAMA CITY FL 34  X    X( X)    4( 4)   26(30)   60(90)    1(91)    X(91)
PANAMA CITY FL 50  X    X( X)    X( X)    6( 6)   57(63)    1(64)    X(64)
PANAMA CITY FL 64  X    X( X)    X( X)    1( 1)   37(38)    X(38)    X(38)
```

Location-Specific Probabilities

- Tropical-Storm-Force
- 58 mph
- Hurricane-Force

Key Points

Location-Specific Probabilities

The highlighted portion here shows individual period and cumulative chance of tropical storm-force winds occurring at Tallahassee, Florida.

Visual 51: Wind Speed Probabilities – Text 2

NATIONAL HURRICANE CENTER
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

```
TROPICAL STORM MICHAEL WIND SPEED PROBABILITIES NUMBER   7
NWS NATIONAL HURRICANE CENTER MIAMI FL       AL142018
0900 UTC MON OCT 08 2018

  - - - - WIND SPEED PROBABILITIES FOR SELECTED LOCATIONS - - - -

               FROM     FROM     FROM     FROM     FROM     FROM     FROM
  TIME       06Z MON 18Z MON 06Z TUE 18Z TUE 06Z WED 06Z THU 06Z FRI
PERIODS        TO       TO       TO       TO       TO       TO       TO
             18Z MON 06Z TUE 18Z TUE 06Z WED 06Z THU 06Z FRI 06Z SAT

FORECAST HOUR    (12)    (24)     (36)     (48)     (72)     (96)    (120)
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
LOCATION       KT

TALLAHASSEE FL 34  X    X( X)    1( 1)    6( 7)   68(75)    6(81)    X(81)
TALLAHASSEE FL 50  X    X( X)    X( X)    1( 1)   41(42)    6(48)    X(48)
TALLAHASSEE FL 64  X    X( X)    X( X)    X( X)   20(20)    4(24)    X(24)

APALACHICOLA   34  X    X( X)    5( 5)   29(34)   57(91)    1(92)    X(92)
APALACHICOLA   50  X    X( X)    X( X)    6( 6)   59(65)    2(67)    X(67)
APALACHICOLA   64  X    X( X)    X( X)    1( 1)   39(40)    1(41)    X(41)

PANAMA CITY FL 34  X    X( X)    4( 4)   26(30)   60(90)    1(91)    X(91)
PANAMA CITY FL 50  X    X( X)    X( X)    6( 6)   57(63)    1(64)    X(64)
PANAMA CITY FL 64  X    X( X)    X( X)    1( 1)   37(38)    X(38)    X(38)
```

Location-Specific Probabilities

- Tropical-Storm-Force
- 58 mph
- Hurricane-Force

Key Points

Example: Tropical Storm-Force Winds

This shows the same information as the previous slide, but for 58-mph winds.

Visual 52: Wind Speed Probabilities – Text 3

NATIONAL HURRICANE CENTER
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

```
TROPICAL STORM MICHAEL WIND SPEED PROBABILITIES NUMBER   7
NWS NATIONAL HURRICANE CENTER MIAMI FL       AL142018
0900 UTC MON OCT 08 2018

 - - - - WIND SPEED PROBABILITIES FOR SELECTED LOCATIONS - - - -

               FROM    FROM    FROM    FROM    FROM    FROM    FROM
  TIME       06Z MON 18Z MON 06Z TUE 18Z TUE 06Z WED 06Z THU 06Z FRI
PERIODS        TO      TO      TO      TO      TO      TO      TO
             18Z MON 06Z TUE 18Z TUE 06Z WED 06Z THU 06Z FRI 06Z SAT

FORECAST HOUR    (12)   (24)    (36)    (48)    (72)    (96)   (120)
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
LOCATION       KT

TALLAHASSEE FL 34  X   X( X)   1( 1)   6( 7)  68(75)   6(81)   X(81)
TALLAHASSEE FL 50  X   X( X)   X( X)   1( 1)  41(42)   6(48)   X(48)
TALLAHASSEE FL 64  X   X( X)   X( X)   X( X)  20(20)   4(24)   X(24)

APALACHICOLA   34  X   X( X)   5( 5)  29(34)  57(91)   1(92)   X(92)
APALACHICOLA   50  X   X( X)   X( X)   6( 6)  59(65)   2(67)   X(67)
APALACHICOLA   64  X   X( X)   X( X)   1( 1)  39(40)   1(41)   X(41)

PANAMA CITY FL 34  X   X( X)   4( 4)  26(30)  60(90)   1(91)   X(91)
PANAMA CITY FL 50  X   X( X)   X( X)   6( 6)  57(63)   1(64)   X(64)
PANAMA CITY FL 64  X   X( X)   X( X)   1( 1)  37(38)   X(38)   X(38)
```

Location-Specific Probabilities

- Tropical-Storm-Force
- 58 mph
- Hurricane-Force

Key Points

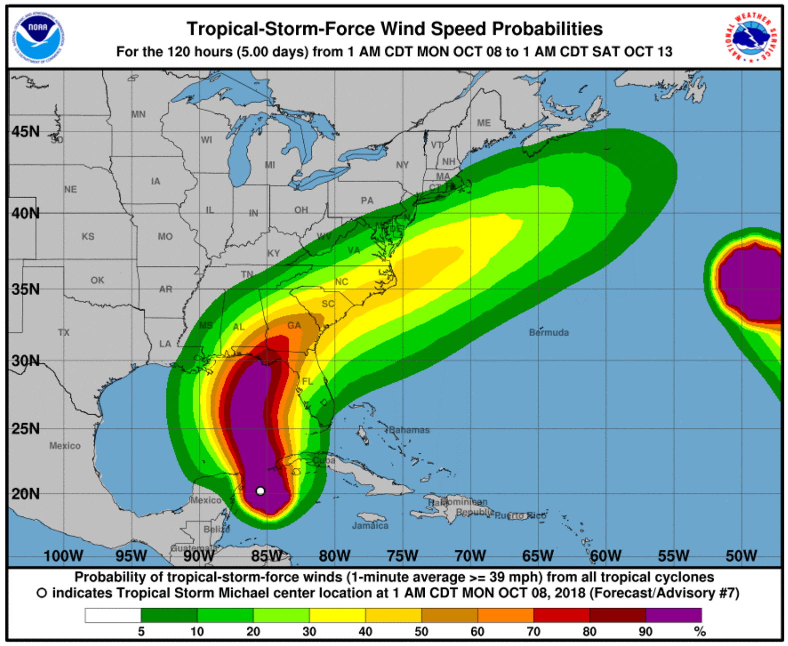
Example: Hurricane-Force Winds

This shows the same, but for hurricane-force winds.

Visual 53: 5-Day Cumulative Graphic: TS-Force

Location-specific Probabilities

- **Tropical Storm-Force**
- 58 mph ("Strong" Trop Storm)
- Hurricane-Force



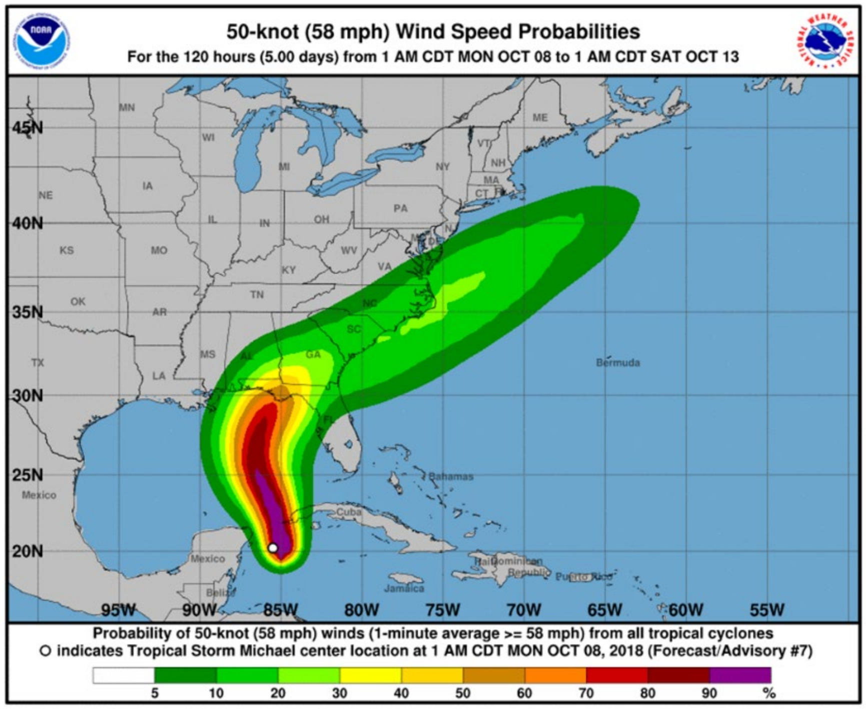
Key Points

This is the graphic product for the same information as the previous text products, displaying the cumulative probabilities over the 5-day forecast.

Visual 54: 5-Day Cumulative Graphic: 58-mph

Location-specific Probabilities

- Tropical Storm-Force
- **58 mph (“Strong” Trop Storm)**
- Hurricane-Force



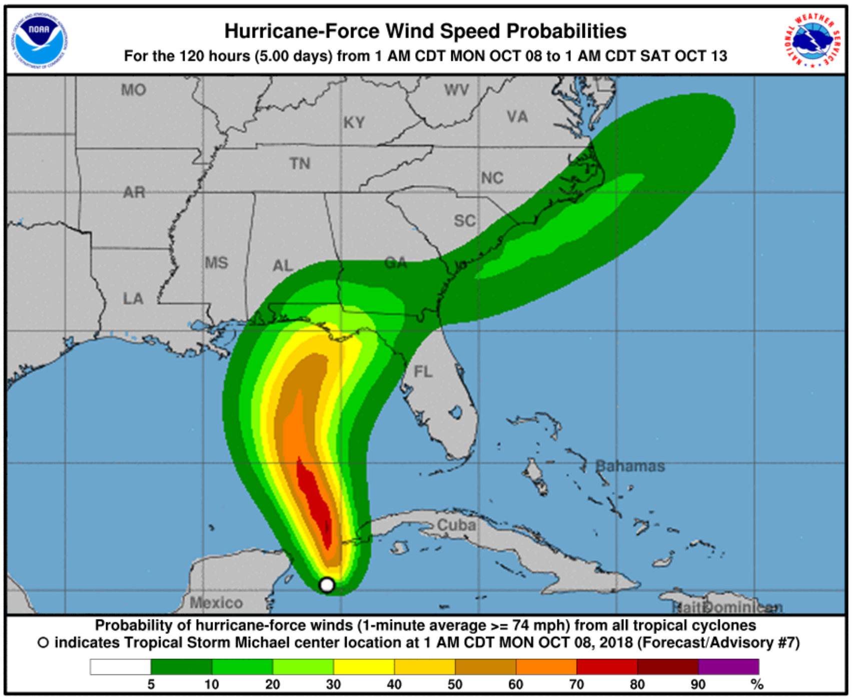
Key Points

The graphic product is a companion to the text product.

Visual 55: 5-Day Cumulative Graphic: Hurricane

<table>
<tr>
<td>
Location-specific Probabilities

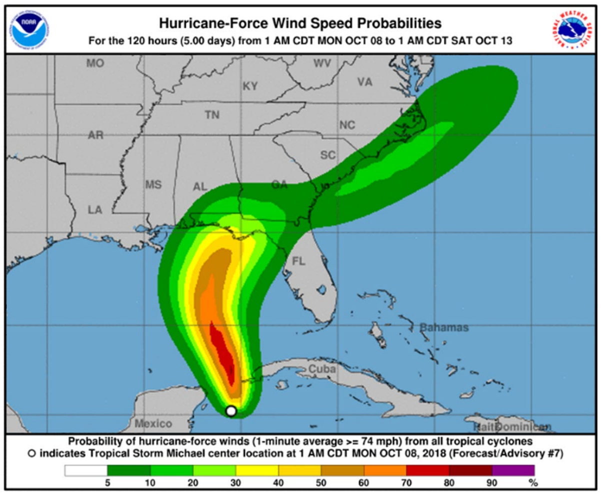
Tropical Storm-Force
58 mph (“Strong” Trop Storm)
Hurricane-Force

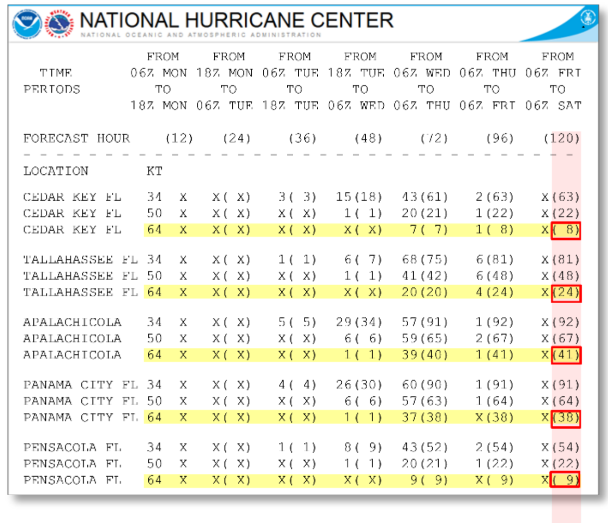
</td>
<td>
</td>
</tr>
</table>

Key Points

The graphic product is a companion to the text product.

Visual 56: Location-Specific Probabilities 1





NATIONAL HURRICANE CENTER
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

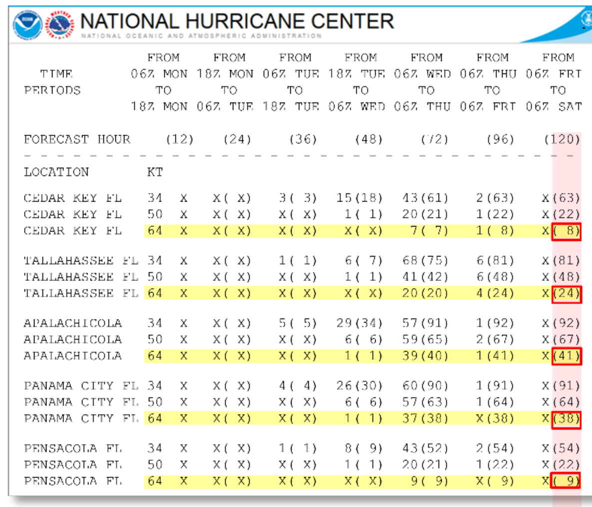
TIME PERIODS		FROM 06Z MON TO 18Z MON	FROM 18Z MON TO 06Z TUE	FROM 06Z TUE TO 18Z TUE	FROM 18Z TUE TO 06Z WED	FROM 06Z WED TO 06Z THU	FROM 06Z THU TO 06Z FRI	FROM 06Z FRI TO 06Z SAT
FORECAST HOUR		(12)	(24)	(36)	(48)	(72)	(96)	(120)
LOCATION	KT							
CEDAR KEY FL	34	X	X(X)	3(3)	15(18)	43(61)	2(63)	X(63)
CEDAR KEY FL	50	X	X(X)	X(X)	1(1)	20(21)	1(22)	X(22)
CEDAR KEY FL	64	X	X(X)	X(X)	X(X)	7(7)	1(8)	X(8)
TALLAHASSEE FL	34	X	X(X)	1(1)	6(7)	68(75)	6(81)	X(81)
TALLAHASSEE FL	50	X	X(X)	X(X)	1(1)	41(42)	6(48)	X(48)
TALLAHASSEE FL	64	X	X(X)	X(X)	X(X)	20(20)	4(24)	X(24)
APALACHICOLA	34	X	X(X)	5(5)	29(34)	57(91)	1(92)	X(92)
APALACHICOLA	50	X	X(X)	X(X)	6(6)	59(65)	2(67)	X(67)
APALACHICOLA	64	X	X(X)	X(X)	1(1)	39(40)	1(41)	X(41)
PANAMA CITY FL	34	X	X(X)	4(4)	26(30)	60(90)	1(91)	X(91)
PANAMA CITY FL	50	X	X(X)	X(X)	6(6)	57(63)	1(64)	X(64)
PANAMA CITY FL	64	X	X(X)	X(X)	1(1)	37(38)	X(38)	X(38)
PENSACOLA FL	34	X	X(X)	1(1)	8(9)	43(52)	2(54)	X(54)
PENSACOLA FL	50	X	X(X)	X(X)	1(1)	20(21)	1(22)	X(22)
PENSACOLA FL	64	X	X(X)	X(X)	X(X)	9(9)	X(9)	X(9)

Key Points

An X indicates a 0% chance of hurricane-force winds occurring for that location at that time. The number in the parentheses is the cumulative number. The last column is where you'll most likely look for information.

The text product information is translated to a graphic product show here.

Visual 57: Location-Specific Probabilities 2


NATIONAL HURRICANE CENTER

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

TIME PERIODS		FROM 06Z MON TO 18Z MON	FROM 18Z MON TO 06Z TUE	FROM 06Z TUE TO 18Z TUE	FROM 18Z TUE TO 06Z WED	FROM 06Z WED TO 06Z THU	FROM 06Z THU TO 06Z FRI	FROM 06Z FRI TO 06Z SAT
FORECAST HOUR		(12)	(24)	(36)	(48)	(72)	(96)	(120)
LOCATION	KT							
CEDAR KEY FL	34	X	X(X)	3(3)	15(18)	43(61)	2(63)	X(63)
CEDAR KEY FL	50	X	X(X)	X(X)	1(1)	20(21)	1(22)	X(22)
CEDAR KEY FL	64	X	X(X)	X(X)	X(X)	7(7)	1(8)	X(8)
TALLAHASSEE FL	34	X	X(X)	1(1)	6(7)	68(75)	6(81)	X(81)
TALLAHASSEE FL	50	X	X(X)	X(X)	1(1)	41(42)	6(48)	X(48)
TALLAHASSEE FL	64	X	X(X)	X(X)	X(X)	20(20)	4(24)	X(24)
APALACHICOLA	34	X	X(X)	5(5)	29(34)	57(91)	1(92)	X(92)
APALACHICOLA	50	X	X(X)	X(X)	6(6)	59(65)	2(67)	X(67)
APALACHICOLA	64	X	X(X)	X(X)	1(1)	39(40)	1(41)	X(41)
PANAMA CITY FL	34	X	X(X)	4(4)	26(30)	60(90)	1(91)	X(91)
PANAMA CITY FL	50	X	X(X)	X(X)	6(6)	57(63)	1(64)	X(64)
PANAMA CITY FL	64	X	X(X)	X(X)	1(1)	37(38)	X(38)	X(38)
PENSACOLA FL	34	X	X(X)	1(1)	8(9)	43(52)	2(54)	X(54)
PENSACOLA FL	50	X	X(X)	X(X)	1(1)	20(21)	1(22)	X(22)
PENSACOLA FL	64	X	X(X)	X(X)	X(X)	9(9)	X(9)	X(9)

Key Points

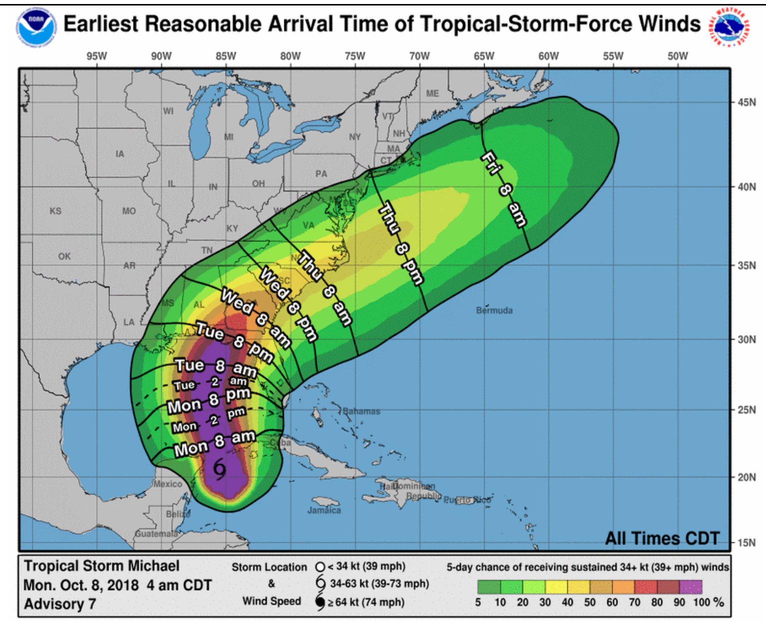
The text product information is translated to a graphic product shown here.

Visual 58: Earliest Reasonable Onset

Earliest Reasonable

- 10% chance of onset (Most conservative timing)
- Black Contours: Arrival time of TS winds

Color fill: 5-day cumulative TS probabilities



Key Points

There are two types of graphics that are great for planning and based on wind speed probability data. The first is Earliest Reasonable that gives the most conservative estimate of arrival with a 10% chance of onset. The black contours show the arrival time of tropical storm-force winds. The colored areas show the 5-day cumulative of the tropical storm-force winds probabilities.

Visual 59: Most Likely Onset

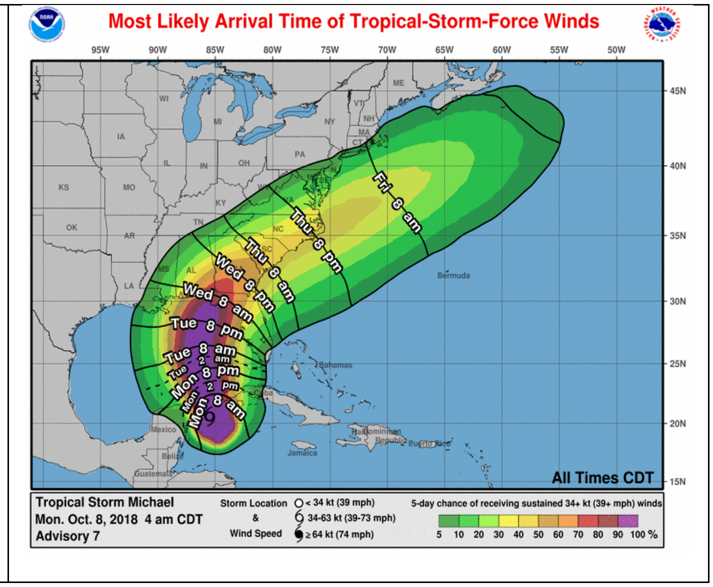
Most Likely

- 50% chance of onset

(Equally likely to occur before as after)

- Black Contours: Arrival time of TS winds

Color fill: 5-day cumulative TS probabilities



Key Points

The second type of graphic is the Most Likely. This graphic shows that the tropical storm-force winds are equally likely to occur before as after the time. There is a 50% chance of the onset of the winds. The black contour shows the arrival of tropical storm-force winds. The color fill shows the 5-day cumulative tropical storm-force winds probabilities.

Visual 60: Frequently Asked Questions 7

FAQs

- What hazards are a threat?
- Where is the greatest concern?
- When will hurricane hazards begin?

Watches and Warnings

Key Points

NHC-issued Watches and Warnings are the products that answer questions like:

- What hazards are a threat?
- Where is the greatest concern?
- When will hurricane hazards begin?

There are several types of Watches and Warnings.

Visual 61: Storm Surge Watches/Warnings

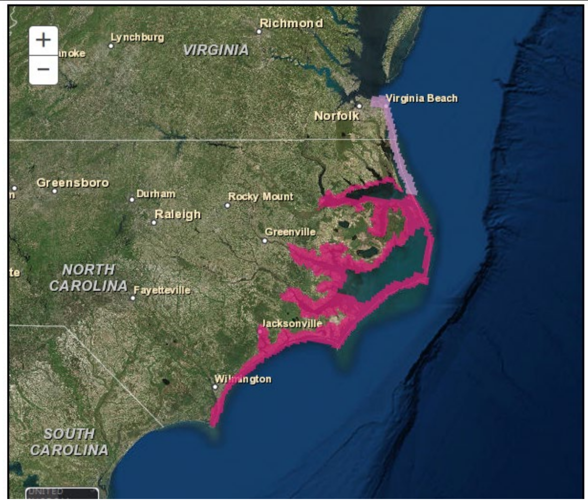
Storm Surge Watch

- There is the **possibility** of life-threatening inundation, generally **within 48 hours.**

Storm Surge Warning

- There is a **danger** of life-threatening inundation, generally **within 36 hours.**

Activates WEA.



Key Points

The lead times of Tropical Storm and Hurricane Watches and Warnings are tied to the anticipated arrival time of tropical storm-force winds. Watches are issued 48 hours prior to arrival of tropical storm winds, and Warnings are issued 36 hours prior to arrival of tropical storm winds.

Visual 62: Hurricane Watches/Warnings

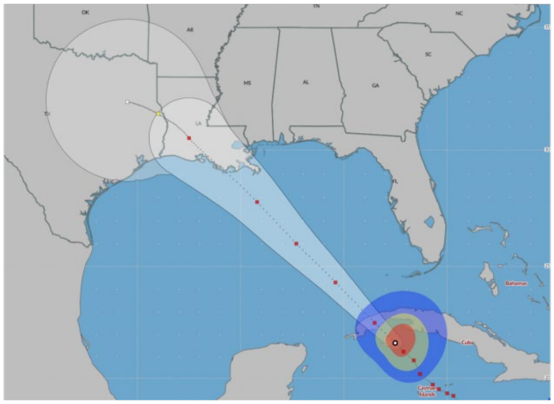
Hurricane Watch • Hurricane conditions are **possible** within the Watch area, generally **within 48 hours.** **Hurricane Warning** • Hurricane conditions are **expected** within the Warning area, generally **within 36 hours.** • **Activates WEA.**	

Note: The lead time for Hurricane Watches and Warnings is tied to the anticipated **arrival time of tropical storm-force winds.**

Key Points

The lead times of Tropical Storm and Hurricane Watches and Warnings are tied to the anticipated arrival time of tropical storm-force winds. Watches are issued 48 hours prior to arrival of tropical storm winds, and Warnings are issued 36 hours prior to arrival of tropical storm winds.

Visual 63: Take What Action, Where, & When?



Key Points

In this scenario, a hurricane is currently located near western Cuba and is forecast to track northwest into the Gulf of Mexico. This hurricane is forecast to be approaching the coast of Louisiana in around 48 hours. Warnings are issued 36 hours prior to the arrival of tropical storm-force winds. Based on this forecast, where would you issue the Hurricane Warning? Remember to take into account forecast error and the forecast cone, not just the deterministic forecast down the middle of the cone.

If the storm takes a track on the right or left side of the forecast cone, where would the wind radii for hurricane-force winds be? Watches and Warnings are issued to take into account forecast error and uncertainty.

Visual 64: NHC Forecast – Knowledge Check

How often is a new NHC track and intensity forecast routinely issued?

A. Every 3 hours

B. Every 6 hours

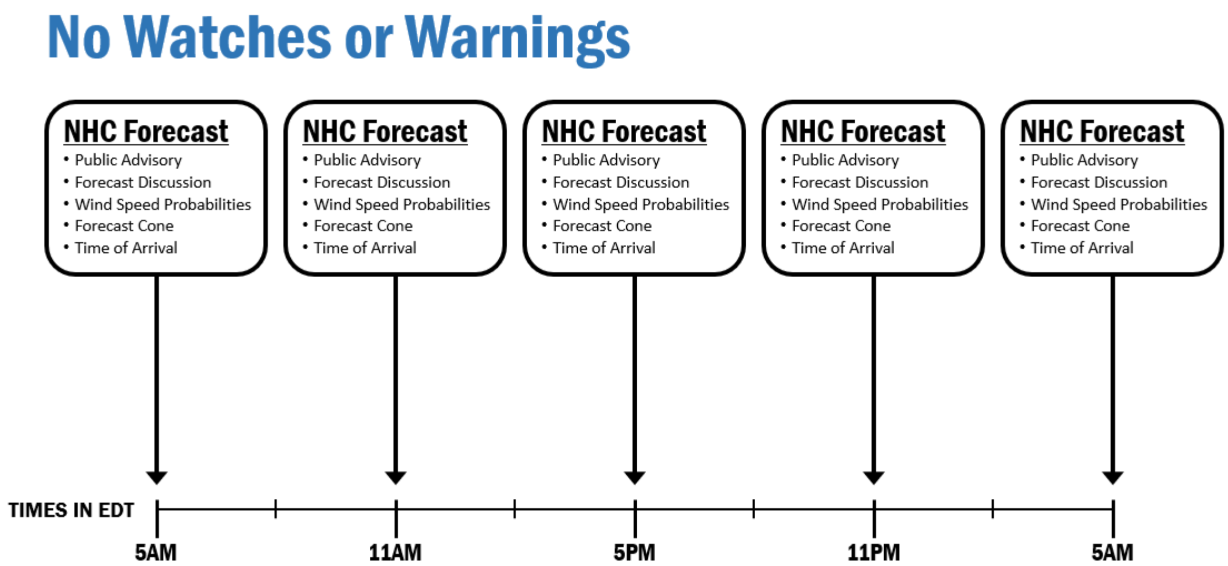
C. Every 8 hours

D. Only when there is a change in the models

Key Points

Remember that the NHC routinely issues a new track and intensity forecast every 6 hours.

Visual 65: NHC Advisory Timeline 2



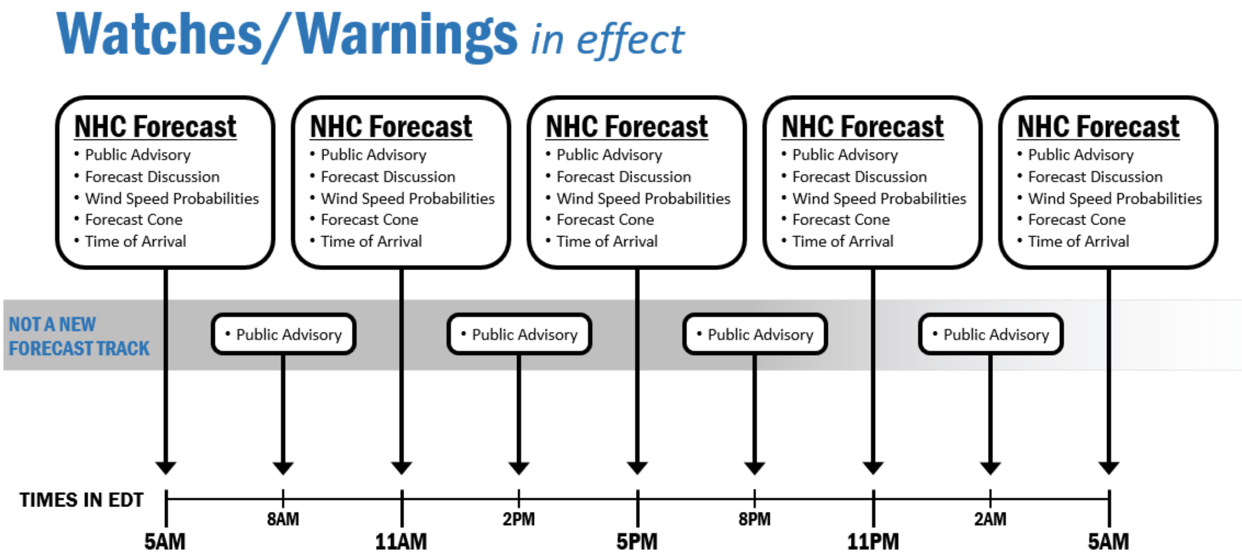
Key Points

Scheduled Updates (No Watches or Warnings)

With no Watches or Warnings in effect, updates are issued at the following times (EDT):

- 5 a.m. - Advisory
- 11 a.m. - Advisory
- 5 p.m. - Advisory
- 11 p.m. - Advisory

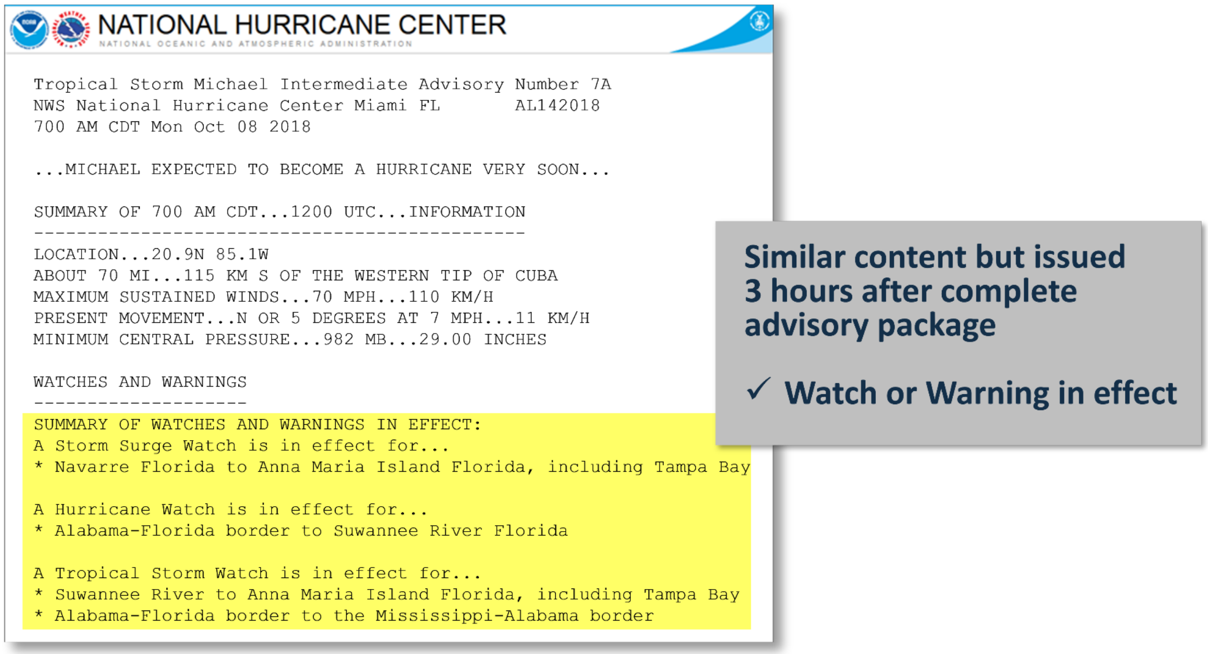
Visual 66: NHC Advisory Timeline – W/W 2



Key Points

Closer to the incident means more information and products are available. Note that the issuance of a Public Advisory does not include a new forecast track. Once Watches or Warnings have been issued by NHC, intermediate Public Advisories will begin.

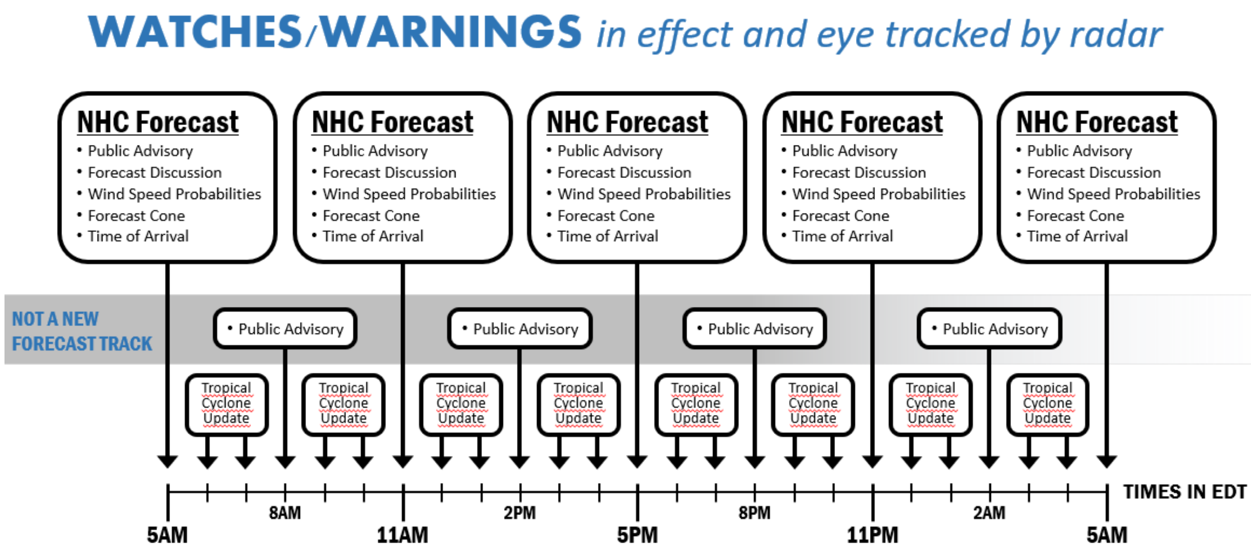
Visual 67: Immediate Public Advisory



Key Points

Public Advisories are normally issued every 6 hours, but whenever Watches or Warnings are in effect, Intermediate Advisories are issued every 3 hours between the main advisories. Intermediate Advisories are not used to issue Watches or Warnings for the United States, but they can be used to issue international Watches or Warnings. The content is similar to routine Public Advisories.

Visual 68: NHC Advisory Timeline – Eye



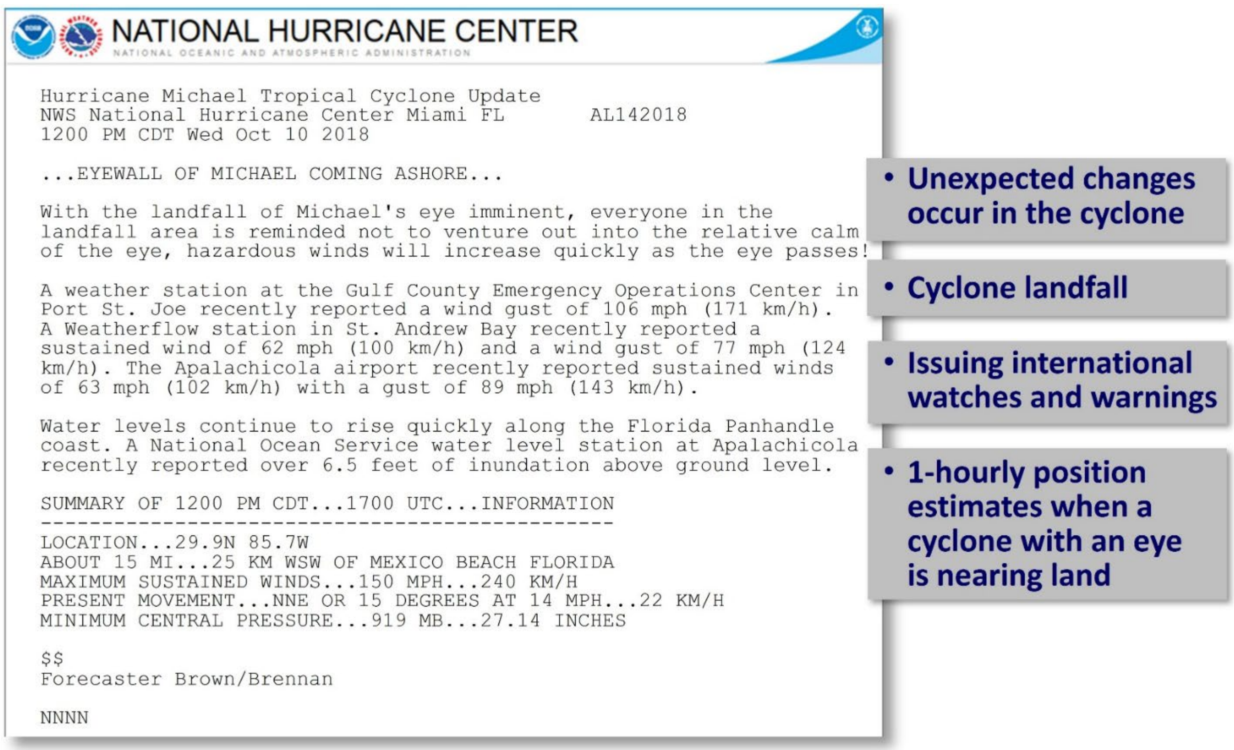
Key Points

The Tropical Cyclone Update provides more information as the storm is closer to the coast and tracked with radar. These updates come every hour from the NHC.

The hourly updates include:

- Status of the storm
- Strength
- Location

Visual 69: Tropical Cyclone Update


NATIONAL HURRICANE CENTER
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

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Hurricane Michael Tropical Cyclone Update
NWS National Hurricane Center Miami FL       AL142018
1200 PM CDT Wed Oct 10 2018

...EYEWALL OF MICHAEL COMING ASHORE...

With the landfall of Michael's eye imminent, everyone in the
landfall area is reminded not to venture out into the relative calm
of the eye, hazardous winds will increase quickly as the eye passes!

A weather station at the Gulf County Emergency Operations Center in
Port St. Joe recently reported a wind gust of 106 mph (171 km/h).
A Weatherflow station in St. Andrew Bay recently reported a
sustained wind of 62 mph (100 km/h) and a wind gust of 77 mph (124
km/h). The Apalachicola airport recently reported sustained winds
of 63 mph (102 km/h) with a gust of 89 mph (143 km/h).

Water levels continue to rise quickly along the Florida Panhandle
coast. A National Ocean Service water level station at Apalachicola
recently reported over 6.5 feet of inundation above ground level.

SUMMARY OF 1200 PM CDT...1700 UTC...INFORMATION
-----------------------------------------------
LOCATION...29.9N 85.7W
ABOUT 15 MI...25 KM WSW OF MEXICO BEACH FLORIDA
MAXIMUM SUSTAINED WINDS...150 MPH...240 KM/H
PRESENT MOVEMENT...NNE OR 15 DEGREES AT 14 MPH...22 KM/H
MINIMUM CENTRAL PRESSURE...919 MB...27.14 INCHES

$$
Forecaster Brown/Brennan

NNNN
```


Key Points

A Tropical Cyclone Update is issued between regularly scheduled Public Advisories to inform users of significant changes in a tropical cyclone.

This product is issued when:

- Unexpected changes occur in the cyclone.
- A cyclone makes landfall.
- Issuing international Watches and Warnings
- A cyclone with an easily trackable center (by radar) is nearing land (hourly position estimates are provided in this instance).

Visual 70: Frequently Asked Questions 8

FAQs

- What areas could flood?
- How high could the water get?
- Reasonable worst-case scenario?

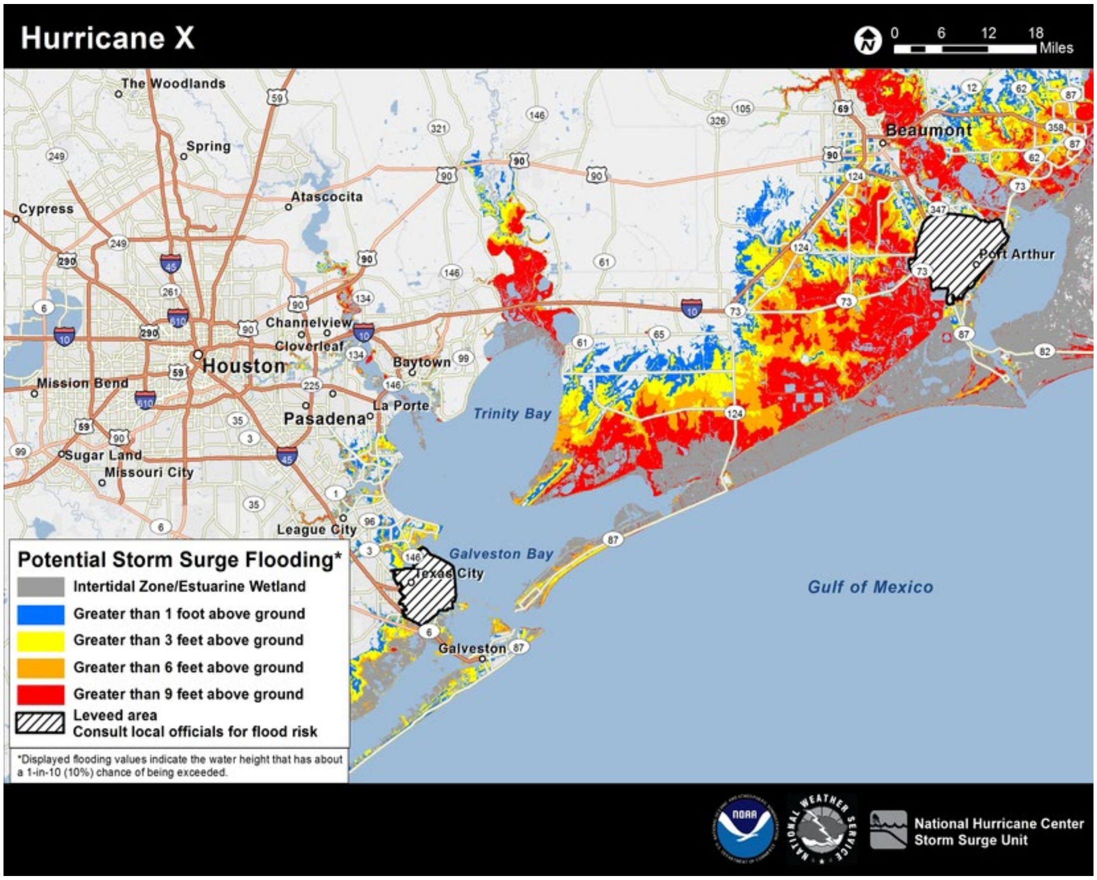
Storm Surge Products

Key Points

You can use storm surge products to answer questions such as:

- What areas could flood?
- How high could the water get?
- What’s the reasonable worst-case scenario for storm surge inundation?

Visual 71: Potential Storm Surge Flooding 1



Key Points

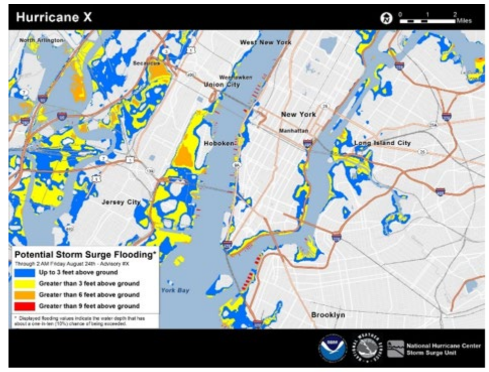
The Potential Storm Surge Flooding Map shows geographical areas where inundation from storm surge could occur and how high above ground the water could reach in those areas. The map is based on the latest forecast track and intensity of the tropical cyclone and considers likely forecast errors. The shading represents inundation levels that have a 10% chance of being exceeded, which can therefore be thought of as representing a reasonable worst-case scenario for any location. The first map will usually be issued at the same time as the initial Hurricane Watch or, in some cases, with a Tropical Storm Watch.

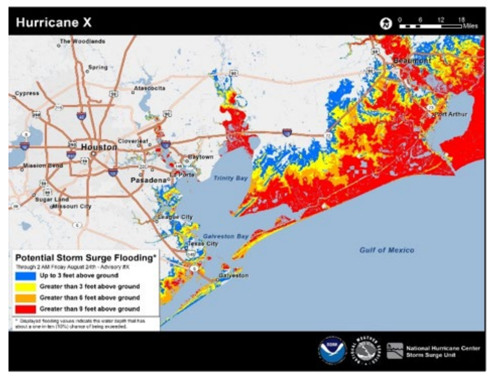
Visual 72: Potential Storm Surge Flooding 2

Inundation Map

- Height above ground that the water could reach.
    - Reasonable worst-case scenario for any individual location.
    - Values have a 10% chance of being exceeded.
- Issued up to 72 hours before a potential storm surge threat.

Available 60+ minutes after the advisory release.

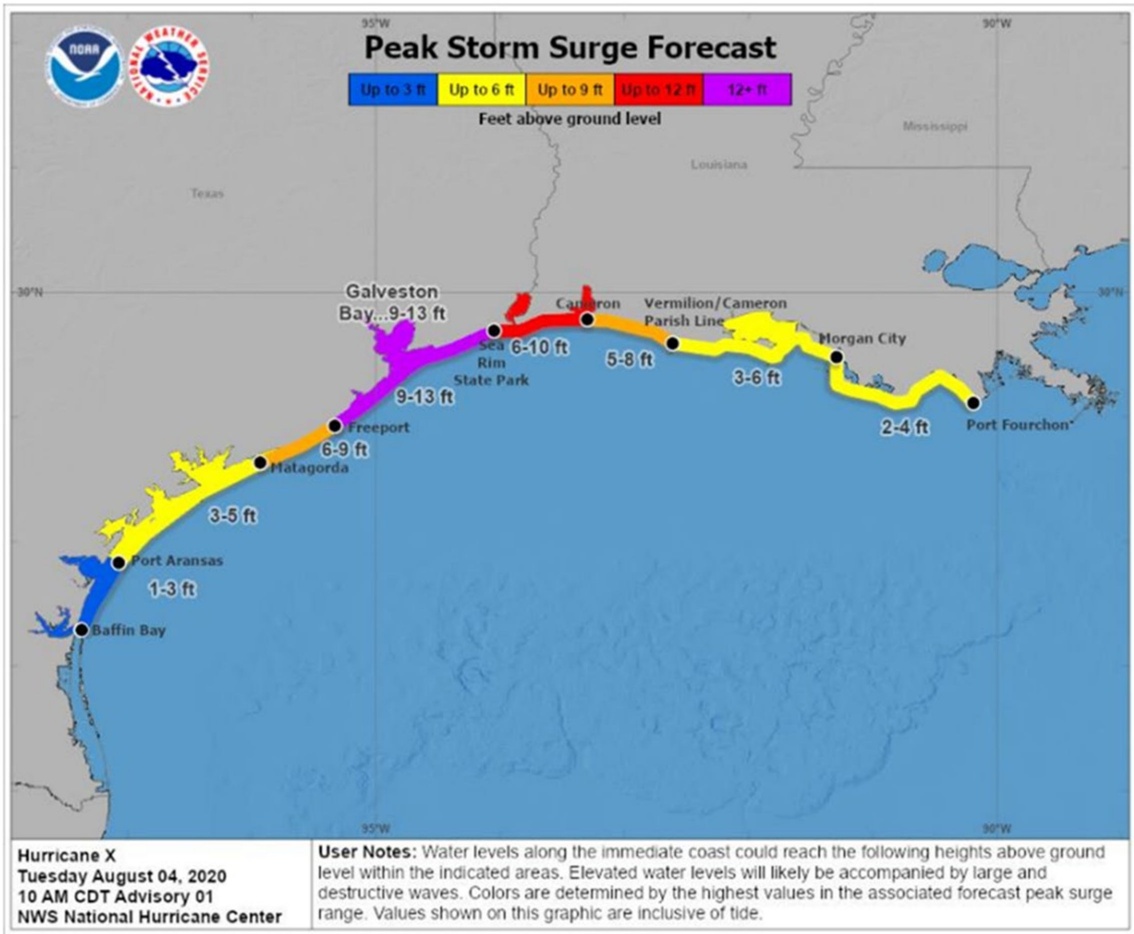




Key Points

The inundation map is calculated using official forecast information. It is released after the advisory, usually around an hour after the advisory release.

Visual 73: Peak Storm Surge Forecast Graphic



Key Points

This graphic is intended for use at a state or regional level to show peak values that could occur along the immediate coast. The colors denote ranges of the peak storm surge forecast. This graphic was first experimental in the 2020 season and became operational in 2023. This graphic is “big picture” and shows that the maximum storm surge could be within a stretch of coastline. It does not show specific areas that could be inundated.

Visual 74: Frequently Asked Questions 9

FAQs

- How much rain is forecast?
- What areas could see flash flooding?
- Which day has the greatest risk?

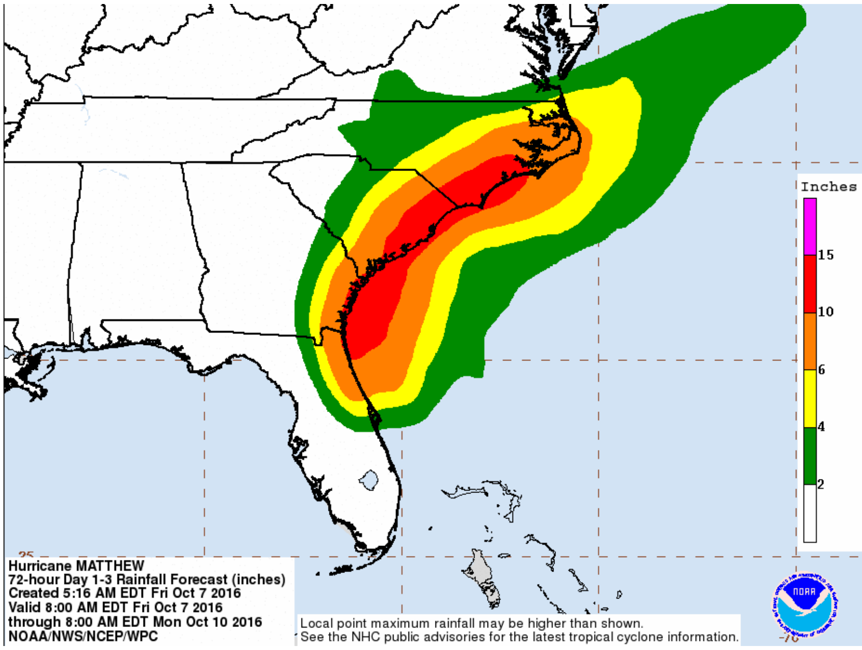
Rainfall Products

Key Points

Rainfall products answer questions such as:

- What areas will flood?
- How much rain is forecast?

Visual 75: Rainfall Forecast

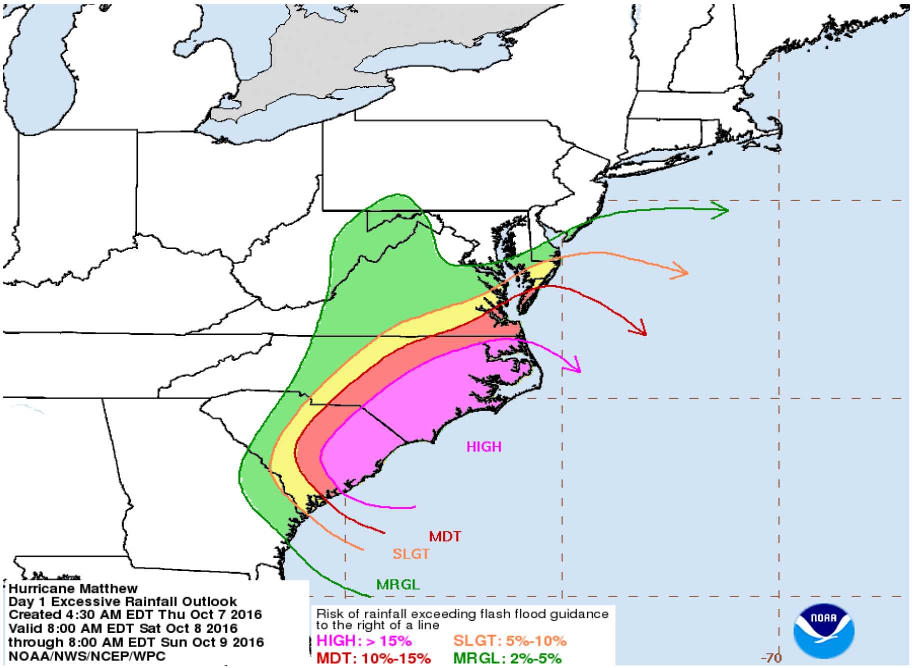


Key Points

The NHC coordinates with The Weather Prediction Center on rainfall information. This is an example of a product produced outside of the Public Advisory. It shows data of how much rain is expected to fall in that area from a *specific storm.*

This is a storm-specific graphic and doesn't include PREs and post-storm rain that could be relevant for an EM.

Visual 76: Excessive Rainfall Outlook (ERO) 1



Key Points

The Excessive Rainfall Outlook is available on a daily basis on the Weather Prediction Center's website and is updated generally twice a day. It shows areas that are at risk of flash flooding. The Excessive Rainfall Outlook is available on the Weather Prediction Center (WPC) website.

When a tropical cyclone threatens land within the next 2–3 days, these graphics are published on the National Hurricane Center website as a part of the forecast package. The graphic may include a Days 1–3 combined outlook with each day then broken down on a side panel.

The ERO is a situational awareness and planning tool that "gets your head in the game." It is NOT an explicit forecast of flash flooding at a specific location and does NOT account for longer-term flooding on mainstem rivers.

The ERO accounts for uncertainty in placement, timing of intense rainfall, and summarizes the larger-scale risk factors.

Visual 77: Excessive Rainfall Outlook (ERO) 2

High Risk Days

- About 4% of days (Includes tropical and non-tropical events).

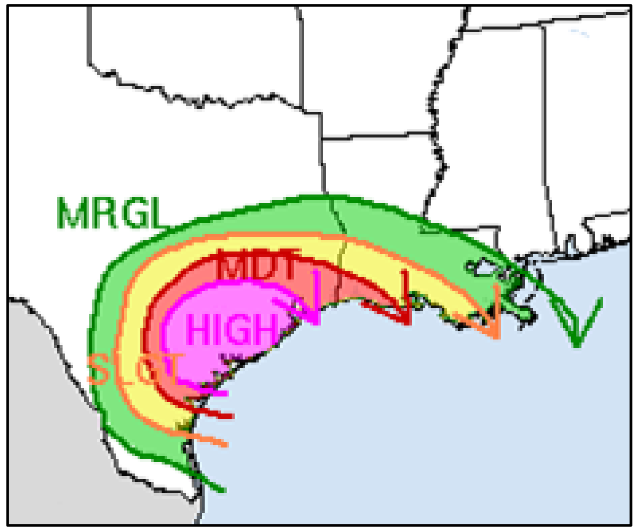
What happens during High-Risk days?

- 46% have at least 1 fatality or injury.
- 62% have at least $1 million in damages.

High Risk Accounts for:

- 39% of Flood Fatalities
- 83% of Flood Damages

Stats from 2010 to 2020



Key Points

Roughly 4% of days are High Risk Days (including tropical and non-tropical events).

About half the time a High Risk is issued, there is a flood-related casualty, and about two out of every three times, there is more than $1 million in damage. (Based on statistics from 2010–2020)

Close to half of flood-related fatalities occur on High-Risk days. 90 percent of flood-related damages in the Lower 48 states in the past 5 years have occurred on High-Risk days. (Based on statistics from 2010–2018).

Visual 78: Frequently Asked Questions 10

FAQs

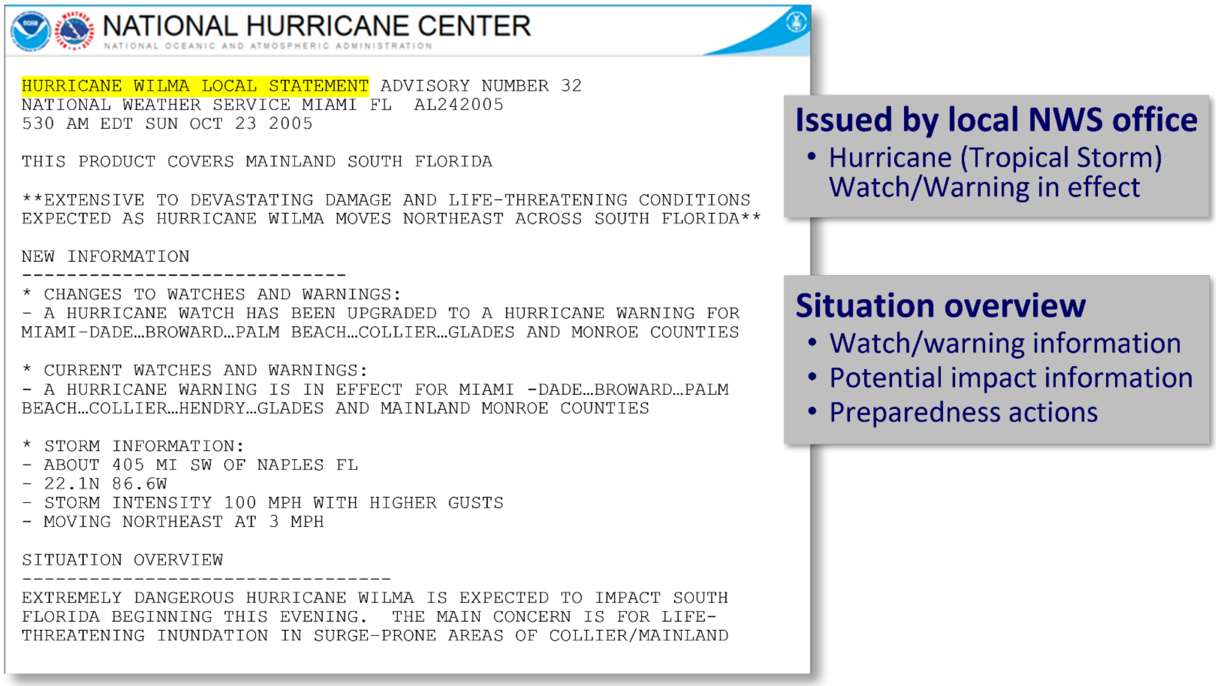
- Local impacts?
- Localized forecast information?
- Inland Watches and Warnings?

Local NWS Weather Forecast Offices

Key Points

Local NWS Weather Forecast Offices provide information to answer these questions. The information is similar to a Public Advisory but is focused on a specific area.

Visual 79: Hurricane Local Statements 1


NATIONAL HURRICANE CENTER
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

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HURRICANE WILMA LOCAL STATEMENT ADVISORY NUMBER 32
NATIONAL WEATHER SERVICE MIAMI FL  AL242005
530 AM EDT SUN OCT 23 2005

THIS PRODUCT COVERS MAINLAND SOUTH FLORIDA

**EXTENSIVE TO DEVASTATING DAMAGE AND LIFE-THREATENING CONDITIONS
EXPECTED AS HURRICANE WILMA MOVES NORTHEAST ACROSS SOUTH FLORIDA**

NEW INFORMATION
-----------------------------
* CHANGES TO WATCHES AND WARNINGS:
- A HURRICANE WATCH HAS BEEN UPGRADED TO A HURRICANE WARNING FOR
MIAMI-DADE…BROWARD…PALM BEACH…COLLIER…GLADES AND MONROE COUNTIES

* CURRENT WATCHES AND WARNINGS:
- A HURRICANE WARNING IS IN EFFECT FOR MIAMI -DADE…BROWARD…PALM
BEACH…COLLIER…HENDRY…GLADES AND MAINLAND MONROE COUNTIES

* STORM INFORMATION:
- ABOUT 405 MI SW OF NAPLES FL
- 22.1N 86.6W
- STORM INTENSITY 100 MPH WITH HIGHER GUSTS
- MOVING NORTHEAST AT 3 MPH

SITUATION OVERVIEW
---------------------------------
EXTREMELY DANGEROUS HURRICANE WILMA IS EXPECTED TO IMPACT SOUTH
FLORIDA BEGINNING THIS EVENING.  THE MAIN CONCERN IS FOR LIFE-
THREATENING INUNDATION IN SURGE-PRONE AREAS OF COLLIER/MAINLAND
```
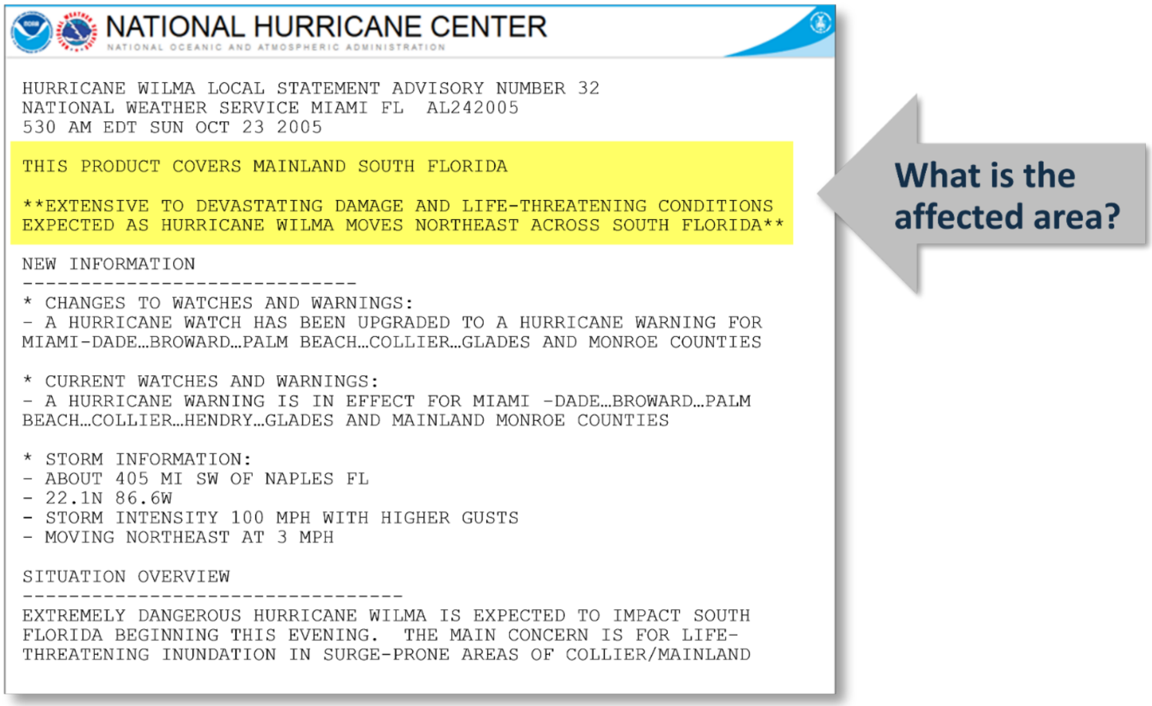


Key Points

This text product provides information on potential hurricane impacts at the local level. Local NWS Forecast Offices issue it whenever a Tropical Storm or Hurricane Watch or Warning is in effect for a portion of their area of responsibility. The information contained within it is based on the NHC forecast, but it provides more localized information about storm surge, wind, rainfall, and tornado hazards.

Visual 80: Hurricane Local Statements 2



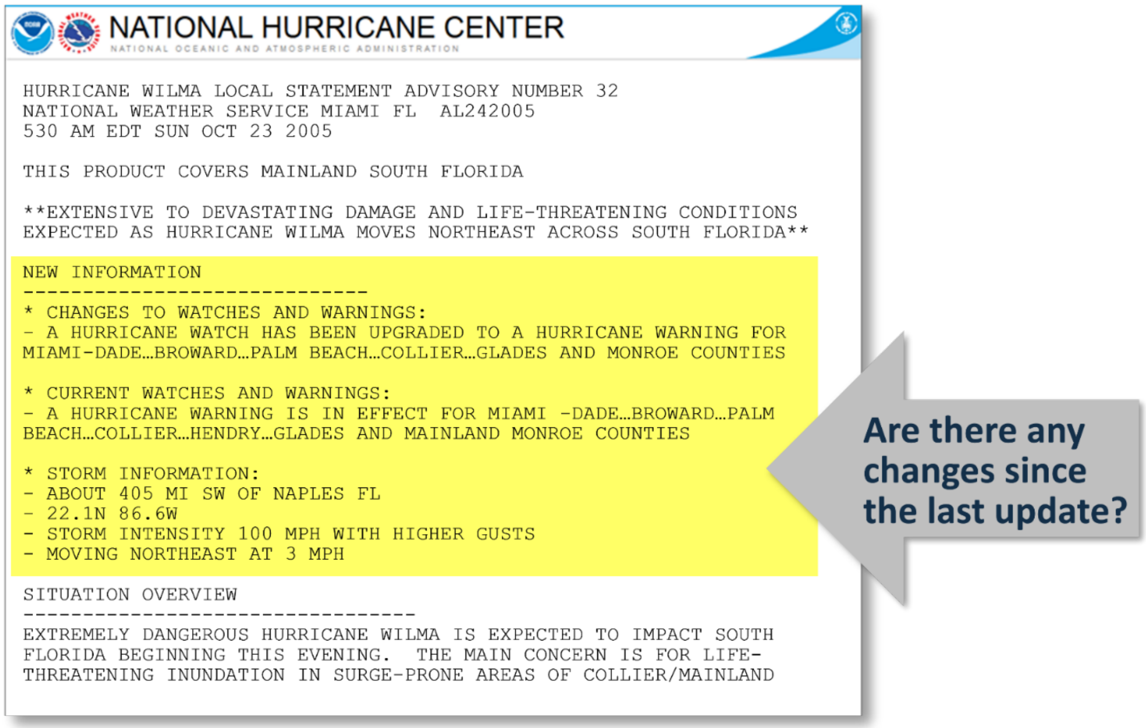

```
HURRICANE WILMA LOCAL STATEMENT ADVISORY NUMBER 32
NATIONAL WEATHER SERVICE MIAMI FL  AL242005
530 AM EDT SUN OCT 23 2005

THIS PRODUCT COVERS MAINLAND SOUTH FLORIDA

**EXTENSIVE TO DEVASTATING DAMAGE AND LIFE-THREATENING CONDITIONS
EXPECTED AS HURRICANE WILMA MOVES NORTHEAST ACROSS SOUTH FLORIDA**

NEW INFORMATION
-----------------------------
* CHANGES TO WATCHES AND WARNINGS:
- A HURRICANE WATCH HAS BEEN UPGRADED TO A HURRICANE WARNING FOR
MIAMI-DADE…BROWARD…PALM BEACH…COLLIER…GLADES AND MONROE COUNTIES

* CURRENT WATCHES AND WARNINGS:
- A HURRICANE WARNING IS IN EFFECT FOR MIAMI -DADE…BROWARD…PALM
BEACH…COLLIER…HENDRY…GLADES AND MAINLAND MONROE COUNTIES

* STORM INFORMATION:
- ABOUT 405 MI SW OF NAPLES FL
- 22.1N 86.6W
- STORM INTENSITY 100 MPH WITH HIGHER GUSTS
- MOVING NORTHEAST AT 3 MPH

SITUATION OVERVIEW
---------------------------------
EXTREMELY DANGEROUS HURRICANE WILMA IS EXPECTED TO IMPACT SOUTH
FLORIDA BEGINNING THIS EVENING.  THE MAIN CONCERN IS FOR LIFE-
THREATENING INUNDATION IN SURGE-PRONE AREAS OF COLLIER/MAINLAND
```

Key Points

Affected Area

This portion of the local statement provides the general location of the affected area and the expected level of impacts to that area.

Visual 81: Hurricane Local Statements 3



NATIONAL HURRICANE CENTER
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

HURRICANE WILMA LOCAL STATEMENT ADVISORY NUMBER 32
NATIONAL WEATHER SERVICE MIAMI FL AL242005
530 AM EDT SUN OCT 23 2005

THIS PRODUCT COVERS MAINLAND SOUTH FLORIDA

EXTENSIVE TO DEVASTATING DAMAGE AND LIFE-THREATENING CONDITIONS EXPECTED AS HURRICANE WILMA MOVES NORTHEAST ACROSS SOUTH FLORIDA

NEW INFORMATION
----

* CHANGES TO WATCHES AND WARNINGS:
\- A HURRICANE WATCH HAS BEEN UPGRADED TO A HURRICANE WARNING FOR MIAMI-DADE…BROWARD…PALM BEACH…COLLIER…GLADES AND MONROE COUNTIES

* CURRENT WATCHES AND WARNINGS:
\- A HURRICANE WARNING IS IN EFFECT FOR MIAMI -DADE…BROWARD…PALM BEACH…COLLIER…HENDRY…GLADES AND MAINLAND MONROE COUNTIES

* STORM INFORMATION:
\- ABOUT 405 MI SW OF NAPLES FL
\- 22.1N 86.6W
\- STORM INTENSITY 100 MPH WITH HIGHER GUSTS
\- MOVING NORTHEAST AT 3 MPH

SITUATION OVERVIEW

EXTREMELY DANGEROUS HURRICANE WILMA IS EXPECTED TO IMPACT SOUTH FLORIDA BEGINNING THIS EVENING. THE MAIN CONCERN IS FOR LIFE-THREATENING INUNDATION IN SURGE-PRONE AREAS OF COLLIER/MAINLAND

Key Points

New Information

This section of the product outlines any changes to the storm and resulting Watches/Warnings since the previous update. This is an easy way to quickly determine the new information that an EM will need.

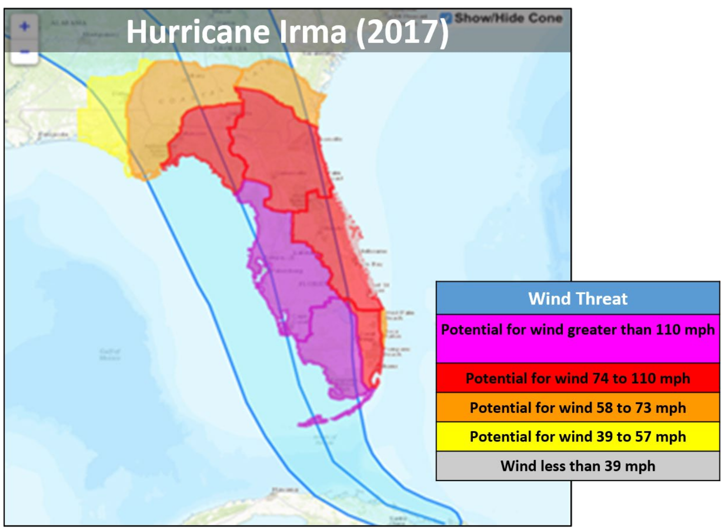
Visual 82: Hurricane Threats & Impacts (HTI)

Hazards

- Wind
- Storm surge flooding
- Inland flooding
- Tornadoes

Threats & Impacts

- Elevated (yellow)
- Moderate (orange)
- High (red)
- Extreme (magenta)



Key Points

This product provides a graphic that is color-coded based on threats (low, medium, high, and extreme) for a local area. This product is issued by local NWS forecast offices and is based on NHC guidance. Mouse-over capability allows users to get a description of what each threshold means.

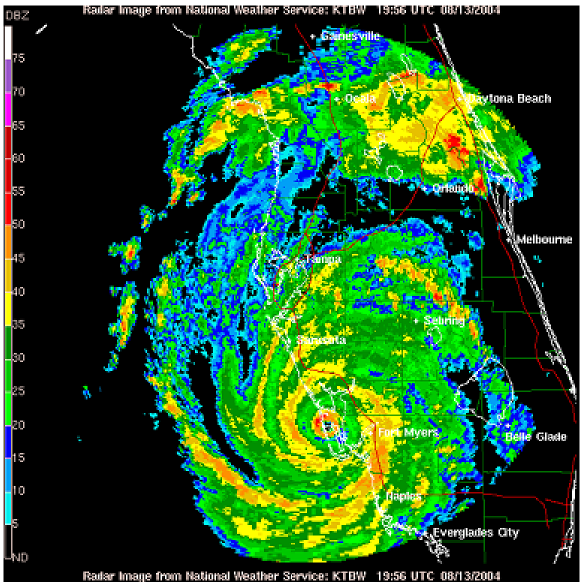
Visual 83: Extreme Wind Warning

"Inform the public of the need to take **immediate shelter** in an interior portion of a well-built structure **due to the onset of extreme tropical cyclone winds."**

Issuance criteria:

- Category 3 or higher
- Valid time of 2 hours or less

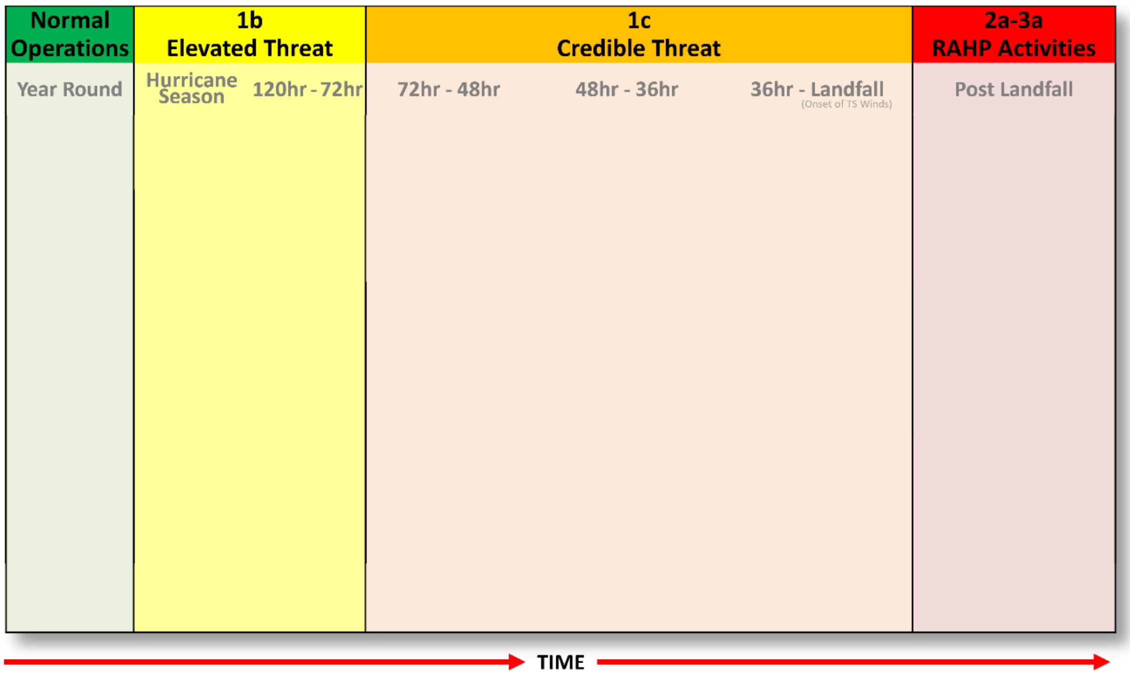
Activates WEA

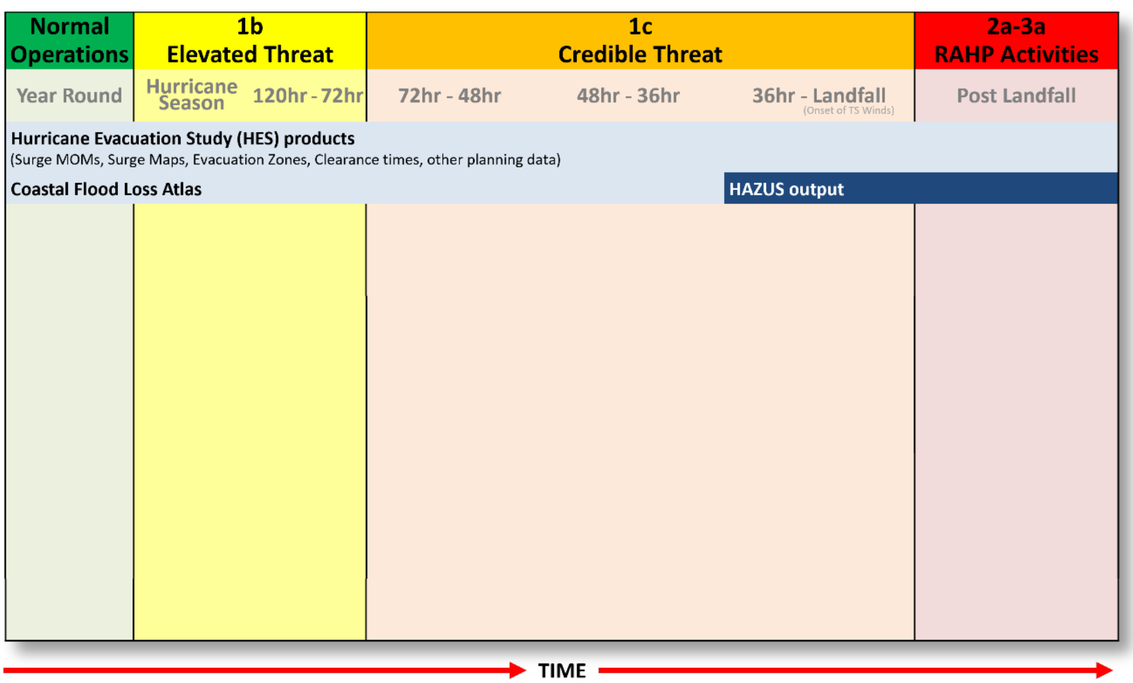


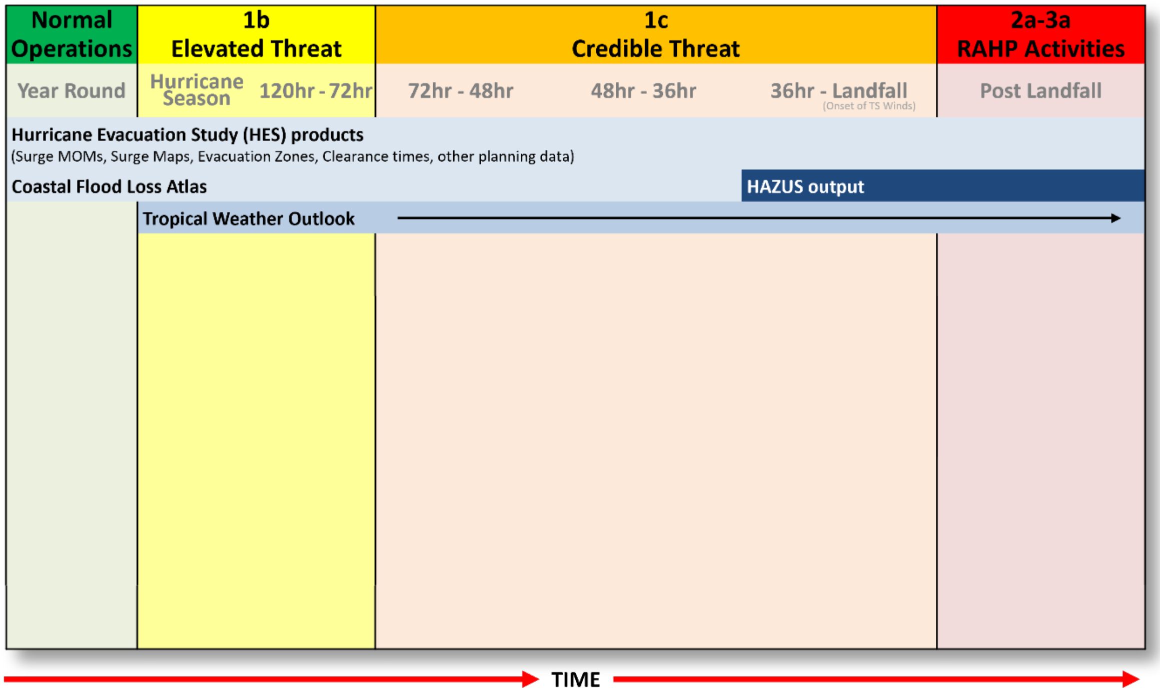
Key Points

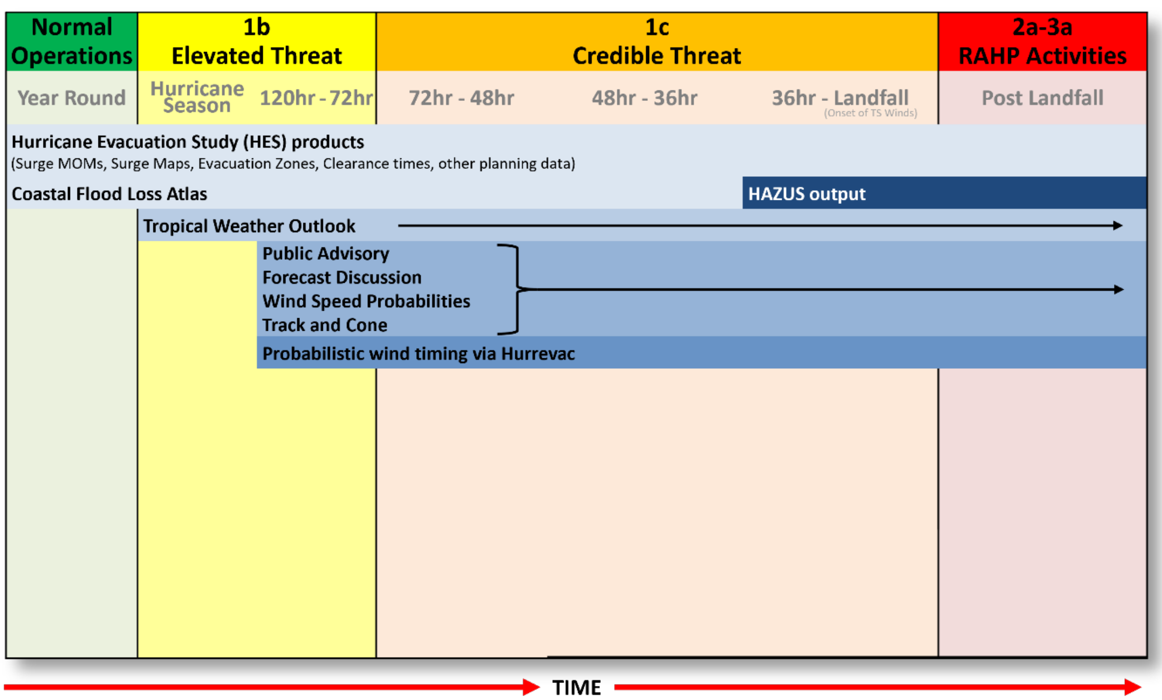
An Extreme Wind Warning is a short-fused Warning issued for winds of a major hurricane (Category 3 or higher – 115 mph or greater sustained winds). The Warning is issued just before the strongest winds of the eyewall are expected to impact land areas. The Warning has a valid time of 2 hours or less. Extreme Wind Warnings alert via Wireless Emergency Alerts.

Visual 84: NWS Products Timeline






Normal Operations
1b Elevated Threat
1c Credible Threat
2a-3a RAHP Activities
Year Round
Hurricane Season
120hr - 72hr
72hr - 48hr
48hr - 36hr
36hr - Landfall
(Onset of TS Winds)
Post Landfall
Hurricane Evacuation Study (HES) products
(Surge MOMs, Surge Maps, Evacuation Zones, Clearance times, other planning data)
Coastal Flood Loss Atlas
HAZUS output
Tropical Weather Outlook
TIME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Hurricane Season
120hr - 72hr
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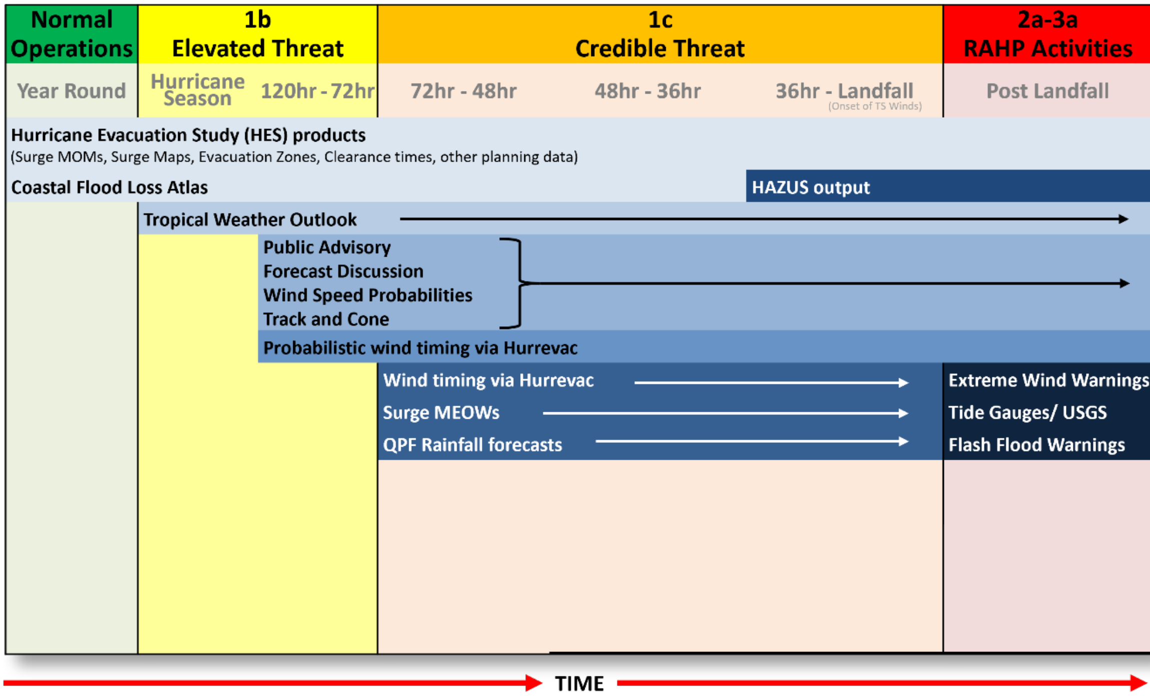
Coastal Flood Loss Atlas
HAZUS output
Tropical Weather Outlook
Public Advisory
Forecast Discussion
Wind Speed Probabilities
Track and Cone
Probabilistic wind timing via Hurrevac
TIME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Year Round
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120hr - 72hr
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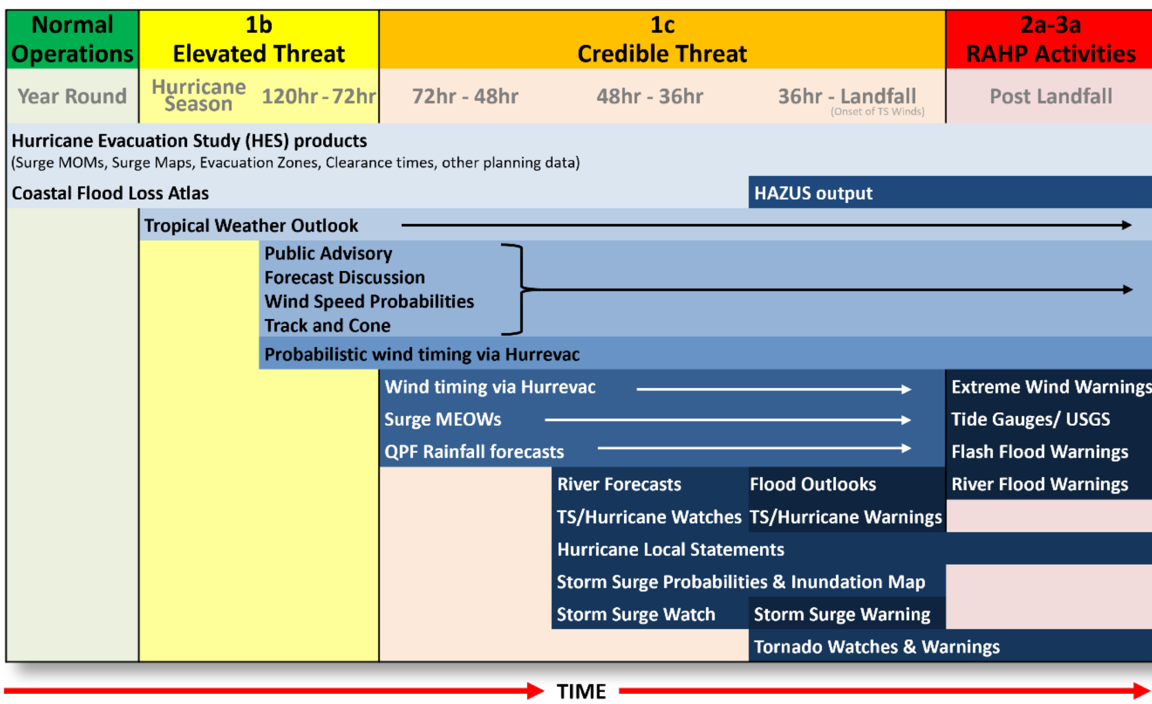
Track and Cone
Probabilistic wind timing via Hurrevac
Wind timing via Hurrevac
Surge MEOWs
QPF Rainfall forecasts
Extreme Wind Warnings
Tide Gauges/ USGS
Flash Flood Warnings
TIME


Normal Operations
1b Elevated Threat
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Year Round
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120hr - 72hr
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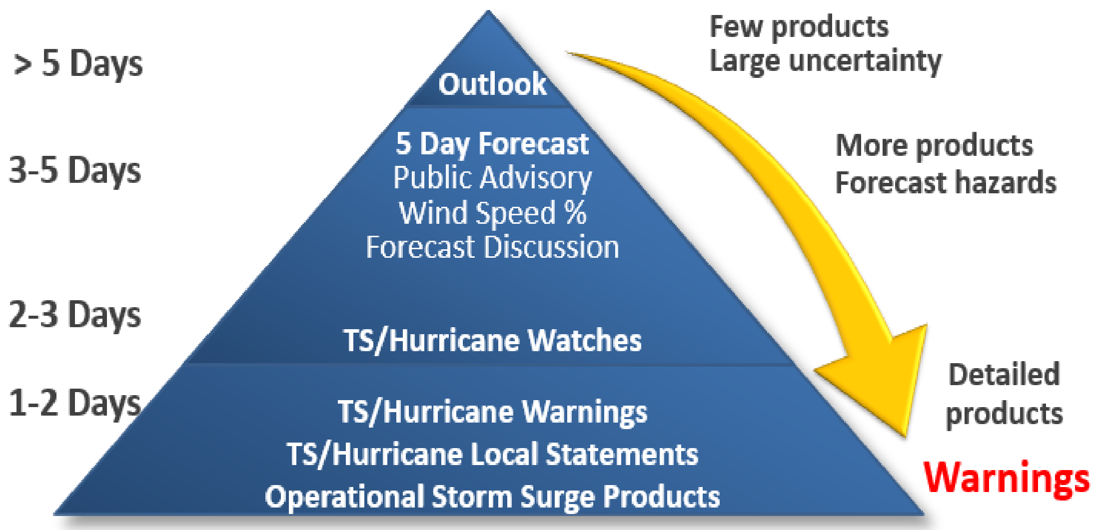
Surge MEOWs
QPF Rainfall forecasts
Extreme Wind Warnings
Tide Gauges/ USGS
Flash Flood Warnings
River Forecasts
Flood Outlooks
River Flood Warnings
TS/Hurricane Watches
TS/Hurricane Warnings
Hurricane Local Statements
Storm Surge Probabilities & Inundation Map
Storm Surge Watch
Storm Surge Warning
Tornado Watches & Warnings
TIME

Key Points

This is an example visualization from a Hurricane Annex that helps to organize when products are available, providing a quick reference for decision makers.

Blue-sky steady-state products are available year-round, for example, Hurricane Evacuation Studies. During hurricane season, and especially when there is an active threat, more products become available through time.

Visual 85: Tropical Cyclone Products Timeframe 2

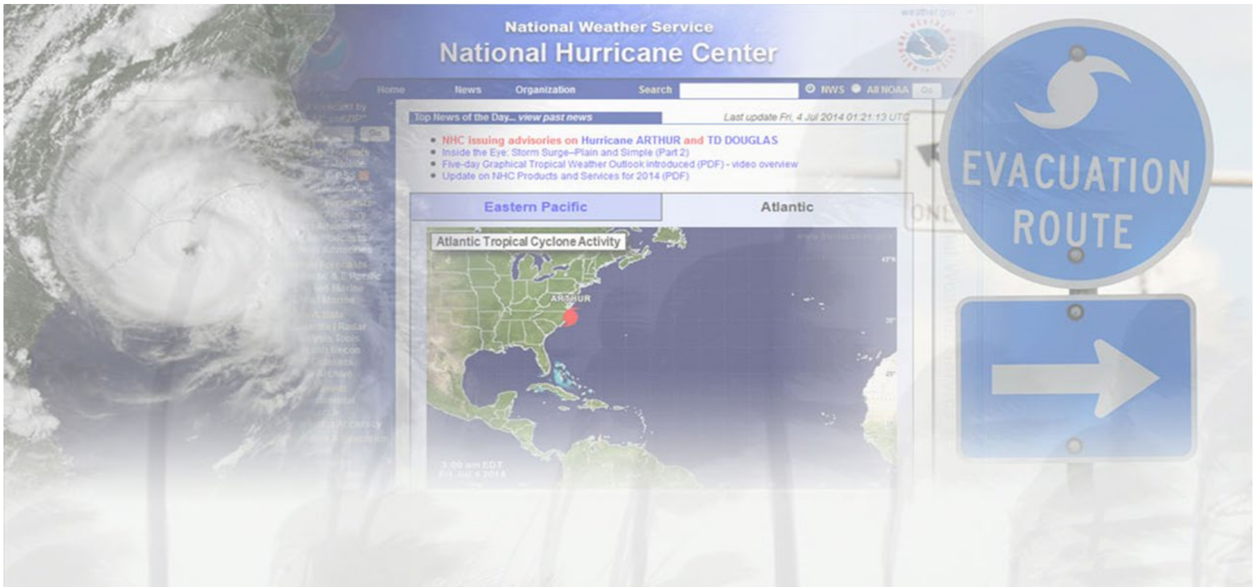


Key Points

To review the product timeline:

>5 days:	Outlook
3–5 days:	5-Day Forecast
	Public Advisory
	Wind Speed Probability
	Forecast Discussion
2–3 days:	Tropical Storm/Hurricane Watches
1–2 days:	Tropical Storm/Hurricane Warnings
	Tropical Storm/Hurricane Local Statements
	Operational Storm Surge Products

Visual 86: Questions/Comments?



Key Points

In this unit, you learned about the various products the NHC and WFO created to answer the questions frequently asked during a tropical cyclone situation. Text products and graphical products were discussed in detail. Timelines for advisories were provided, along with the situation under which the products are distributed.

Visual 87: What Do You Know? 1

Question 1
Which product shows the probable track or path of the center of the tropical cyclone?

A. Cumulative Wind History
B. Wind Speed Probability Graphic
C. Cone Graphic
D. Graphical Tropical Weather Outlook

Visual 88: What Do You Know? 2

Question 2
Which product gives the chance of tropical cyclone formation?

A. Tropical Weather Outlook
B. Tropical Cyclone Discussion
C. Public Advisory
D. Wind Speed Probability Graphic

Visual 89: What Do You Know? 3

Question 3

Which product provides wind timing information beyond 72 hours?

A. Forecast Advisory
B. Cone Graphic
C. Public Advisory
D. Wind Speed Probabilities

Visual 90: What Do You Know? 4

Question 4
Which product shows the current size of the tropical cyclone wind field?

A. Cone Graphic
B. Wind Speed Probability Graphic
C. Tropical Cyclone Cumulative Wind History
D. Tropical Cyclone Surface Wind Field Graphic

Visual 91: What Do You Know? 5

Question 5
Which product provides the reasoning behind the forecast?

A. Public Advisory
B. Forecast Discussion
C. Hurricane Local Statement
D. Forecast Advisory

Visual 92: What Do You Know? 6

Question 6
Which product shows areas of possible tropical cyclone formation?

A. Cone Graphic
B. Tropical Weather Outlook
C. Graphical Tropical Weather Outlook
D. Wind Speed Probability Graphic

Visual 93: What Do You Know? 7

Question 7
Which product contains forecast position, intensity, and wind radii information?

A. Public Advisory
B. Tropical Cyclone Discussion
C. Tropical Weather Outlook
D. Forecast Advisory

Visual 94: What Do You Know? 8

Question 8
When are Special Advisories issued?

A. Upon request
B. When a tropical cyclone is within radar range
C. When a significant, unexpected change in the storm occurs
D. Before an Emergency Management briefing

Visual 95: What Do You Know? 9

Question 9
Which products provide a continuous flow of information when a tropical cyclone is near land?

A. Public Advisory and Tropical Weather Outlook
B. Public Advisory and Forecast Discussion
C. Public Advisory and Cone Graphic
D. Public Advisory, Intermediate Advisory, and Tropical Cyclone Update

Visual 96: What Do You Know? 10

Question 10
How often is a new NHC track and intensity forecast routinely issued?

A. Every 3 hours
B. Every 6 hours
C. Every 8 hours
D. Only when there is a change in the models

Visual 97: What Do You Know? 11

Question 11
When are intermediate Public Advisories issued?

A. All the time
B. When the 5-day forecast reaches land
C. When ships are crossing the path of the storm
D. When coastal Watches and Warnings are in effect

Visual 98: What Do You Know? 12

Question 12
Which Warning is issued when a major (Category 3 or stronger) hurricane is about to make landfall?

A. Extreme Wind Warning
B. Hurricane Warning
C. Tornado Warning
D. Severe Thunderstorm Warning

Visual 99: What Do You Know? 13

Question 14

The lead time for a Hurricane Watch or Warning is tied to the arrival of _______.

A. Hurricane-force winds
B. Life-threatening inundation
C. The eye
D. Tropical storm-force winds

Visual 100: What Do You Know? 14

Question 15
NHC track forecasts are most accurate for this (strength) of Tropical Cyclones?

A. Hurricanes
B. Tropical Storms
C. Tropical Depressions
D. All the above

Visual 101: What Do You Know? 15

Question 16

The NHC assigns Saffir-Simpson Hurricane Scale categories based on what?

A. Size of the hurricane
B. Maximum sustained winds
C. Forecast Storm Surge
D. Minimum pressure

Visual 102: What Do You Know? 16

Question 17

Which one of the following is used to construct the size of the NHC forecast error cone?

A. Possible impact areas
B. Geographic size of the wind field
C. Model spread
D. Past 5 years of track forecast error

Visual 103: What Do You Know? 17

Question 18

The NHC’s 24- and 48-hour intensity forecasts are on average off by _______ Saffir-Simpson categories?

A. 1
B. 2
C. 3
D. 4

Unit 3: Forecast Uncertainty

Visual 1: Unit 3: Forecast Uncertainty

Unit 3:

Forecast Uncertainty

Key Points

Unit 3 covers forecasting errors and the inherent uncertainty that exists with tropical storm forecasting, which results in certain trends and expected patterns. This unit also covers how this information can be calculated into your planning decisions. Using forecast probabilities and the many tools and methods for generating them are also discussed.

Visual 2: Unit 3 Objectives

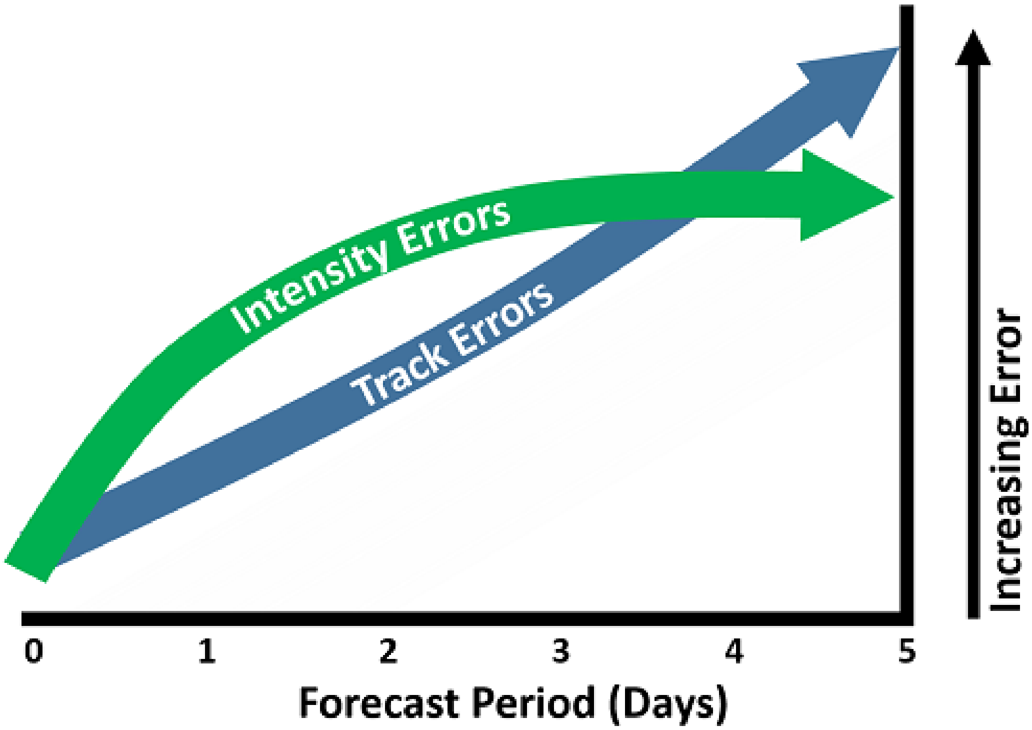
At the end of this unit, you will be able to:

- Explain how wind speed probability products are used to predict the chance and timing of hazardous winds.
- Explain uncertainty as it relates to arrival times for TS wind speeds.
- Identify products used to evaluate storm surge risk.
- Identify and discuss coastal surge models.

Key Points

These objectives work together to help you understand the uncertainty inherent to forecasting hurricanes and their impacts. This understanding can then be used to put “error bars” around predictions.

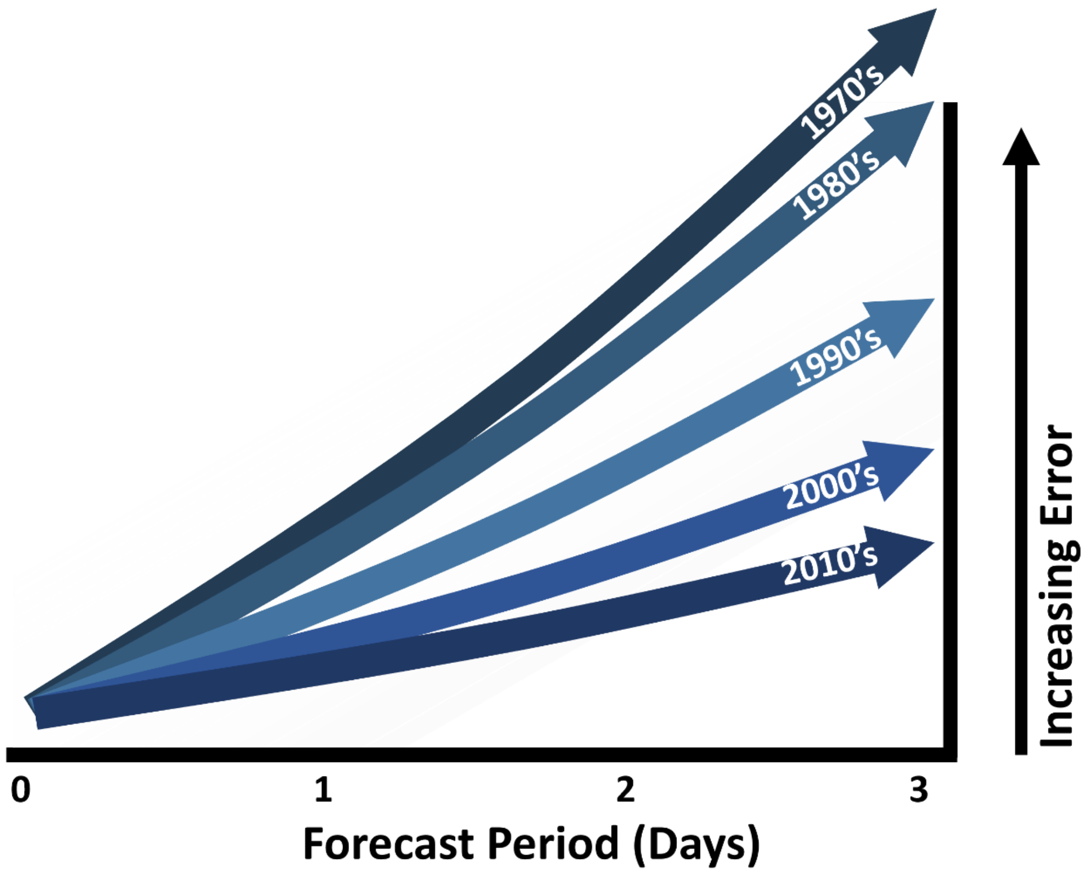
Visual 3: Forecast Errors



Key Points

National Hurricane Center (NHC) track forecast errors increase steadily the farther out the prediction is in time. Intensity errors tend to increase quickly during the first day or two, and then level off at Days 3–5.

Visual 4: Improving, But Not Perfect



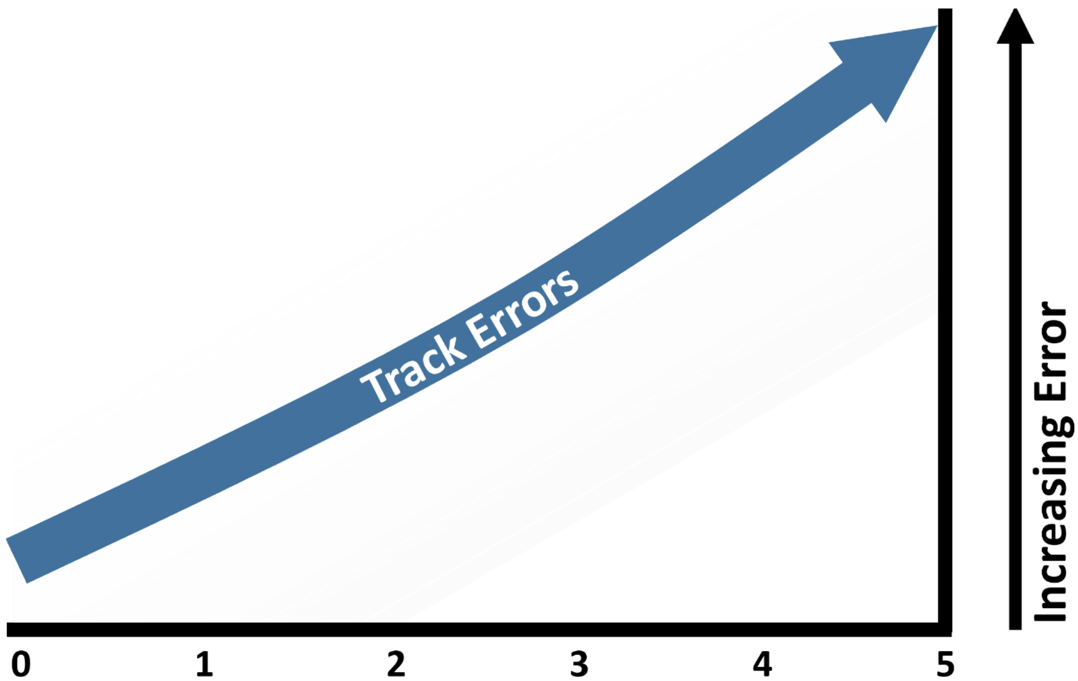
Key Points

Due to increased knowledge of tropical cyclones, improved technology, and more accurate computer models, significant improvements have been made in tropical cyclone track forecasting over the past several decades. Although we have made big improvements, forecasts will always contain some uncertainty. That means Emergency Managers will always need to make big decisions with incomplete or uncertain information.

Visual 5: NHC 5-Year Averages: Track Errors

Track Errors

- Increase 40 miles per day.



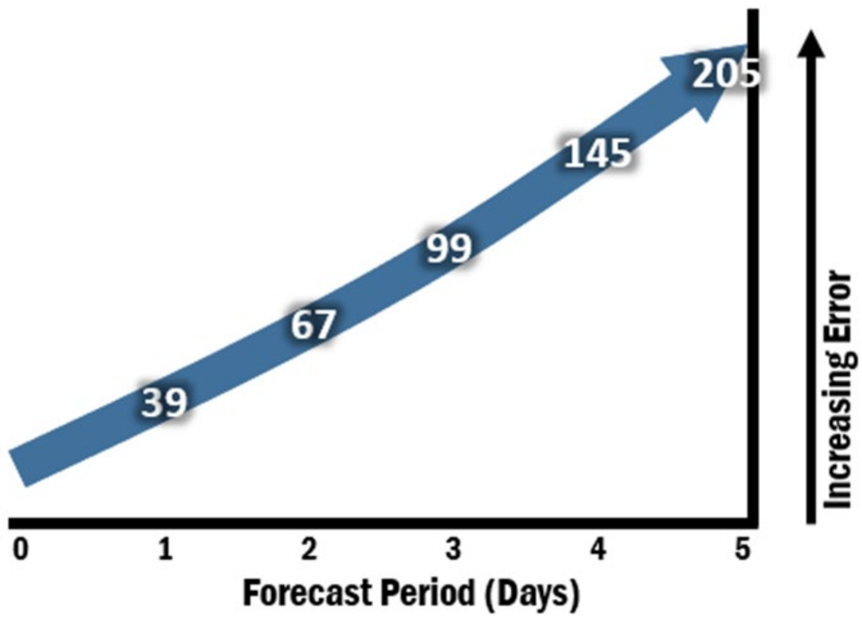
Key Points

The track error is larger the further out in the forecast period – the track error at 1 day is less than the error from the 5-day outlook. This is a function of compounding uncertainty (storm size/strength/speed, large weather systems, etc.).

Visual 6: Track Errors in Miles

Track Errors

- Increase 40 miles (35nm) per day.



Key Points

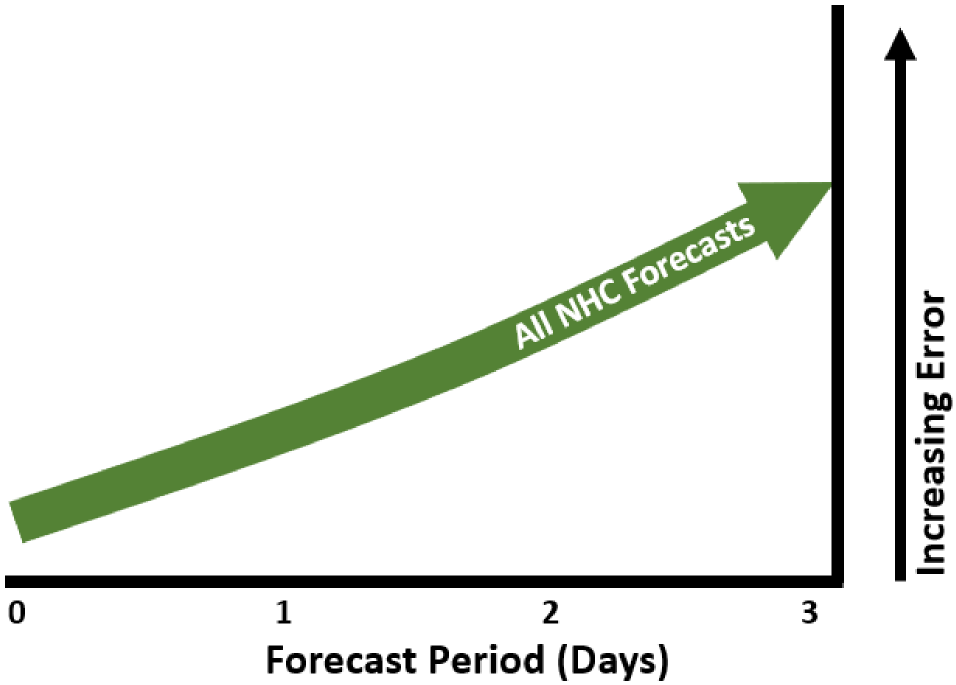
On average, the NHC track forecast errors increase by about 40–45 nautical miles per day. The 5-year average error values, valid for 2023:

- Day 1 average track error: 39 nautical miles per day
- Day 2 average track error: 67 nautical miles per day
- Day 3 average track error: 99 nautical miles per day
- Day 4 average track error: 15 nautical miles per day
- Day 5 average track error: 205 nautical miles per day

Visual 7: Track Errors Based on Initial Intensity

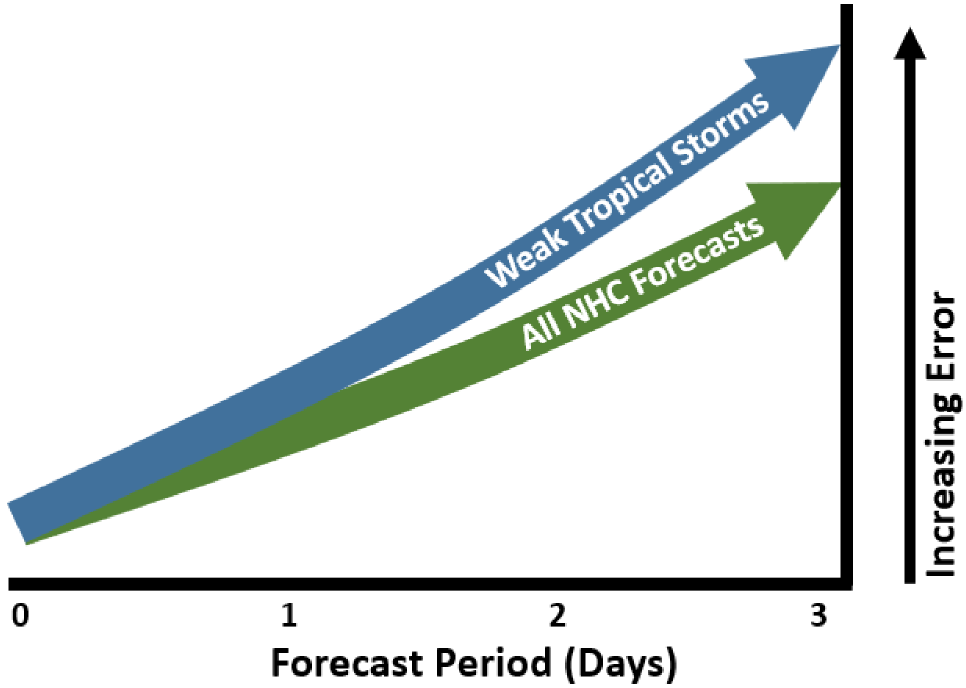
All NHC Forecasts

- Track errors increase about 35–40 miles per day.



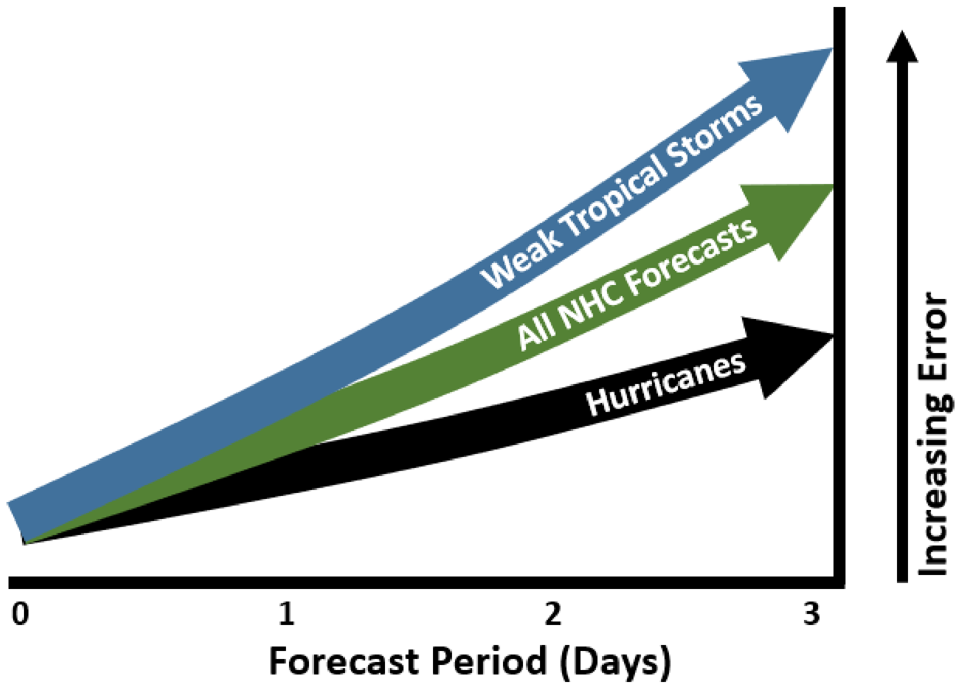
Weak Tropical Storms

Track errors increase about 40–45 miles per day.



Hurricanes

- Track errors increase about 30–35 miles per day.



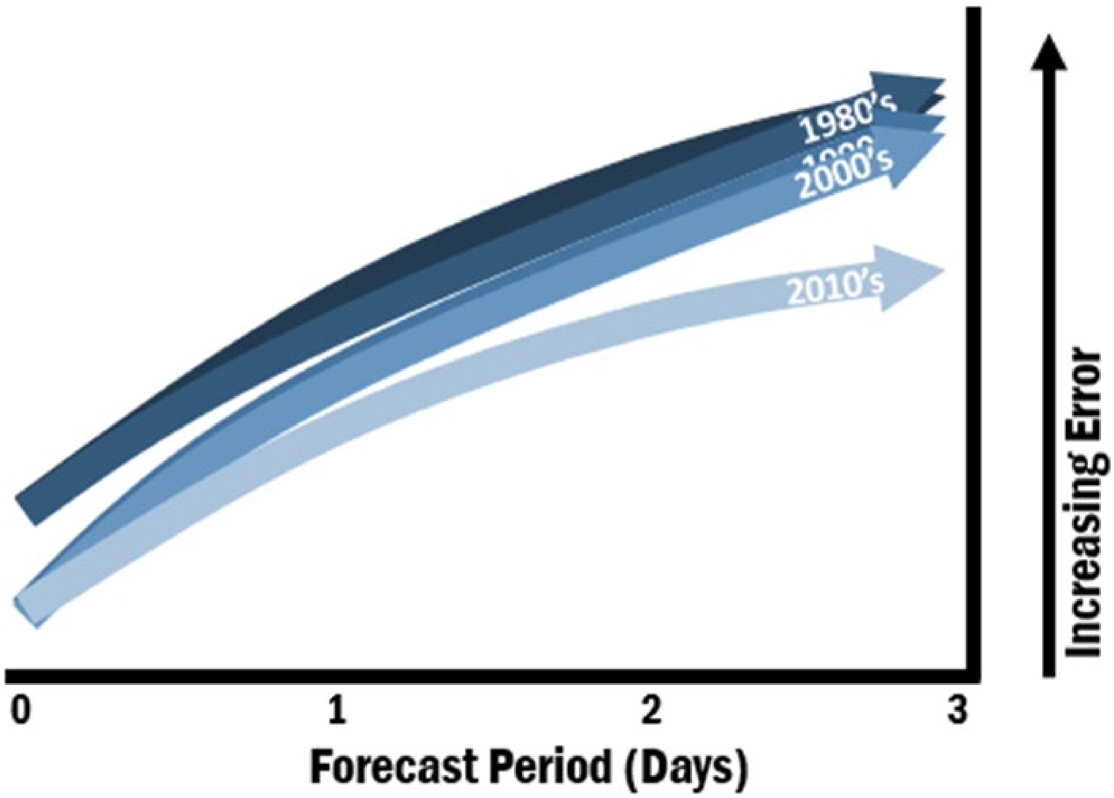
Key Points

NHC track forecasts are typically more accurate for stronger tropical cyclones (hurricanes) versus weaker systems (tropical depressions). When you look at forecast errors based on a tropical cyclone's initial intensity, these are how the track errors increase per day (on average).

NHC track forecasts are typically more accurate for stronger tropical cyclones (hurricanes) versus weaker systems (tropical depressions).

NHC track forecasts are typically more accurate for stronger tropical cyclones (hurricanes) versus weaker systems (tropical depressions).

Visual 8: Finally, Signs of Improvement!



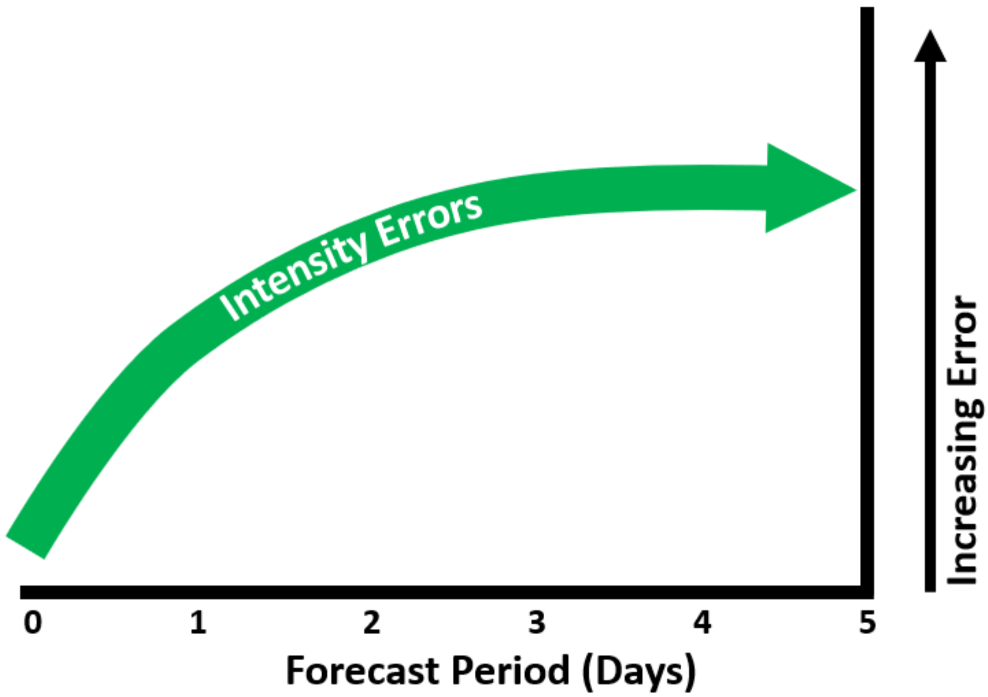
Key Points

Essentially, we had almost no improvement in the first 30–40 years of predictions regarding intensity forecasts. Over the past decade, there has been a significant reduction in the forecast intensity error. This trend is likely to continue with intensity forecast error continuing to diminish. This is due to improvements in science and technology.

Visual 9: NHC 5-Year Averages: Intensity Errors

Intensity Errors

- Increase the first 2–3 days and then level off.



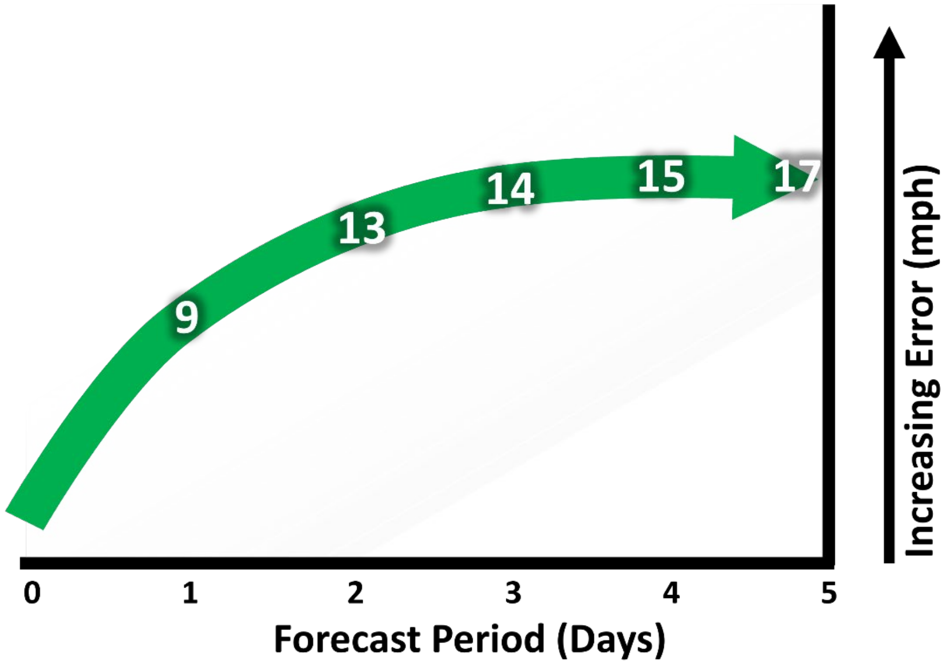
Key Points

Intensity errors increase for the first 2–3 days and then level off at about 17 mph or about one Saffir-Simpson Hurricane Wind Scale category.

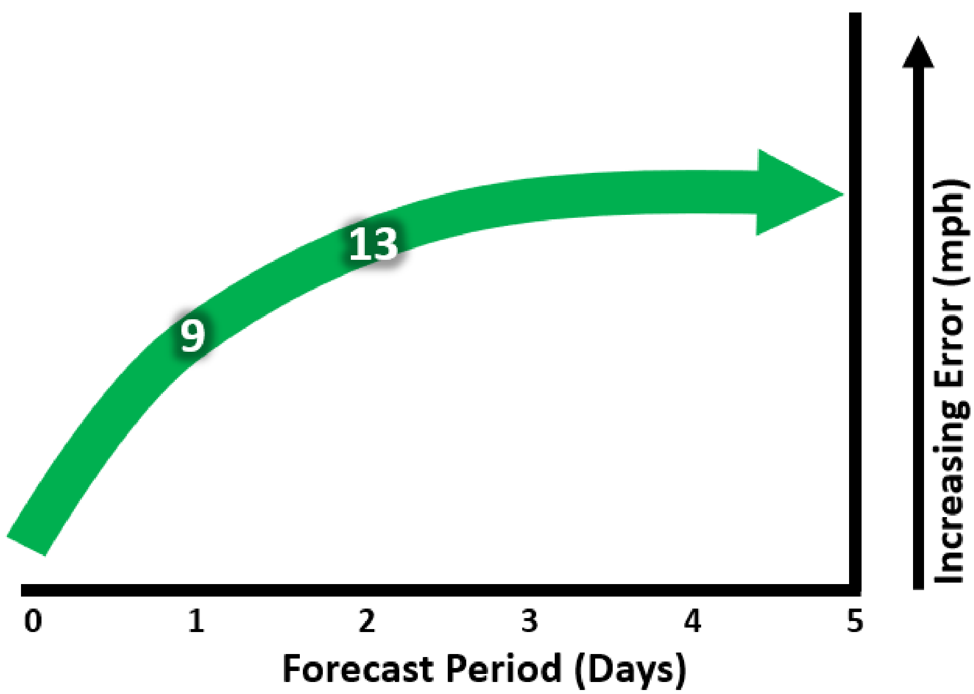
Visual 10: Intensity Errors in MPH

Intensity Errors

- Increase the first 2–3 days and then level off.



- The 24- and 48-hour NHC intensity forecasts are, on average, off by one Saffir-Simpson category.



Key Points

Day 1 intensity error is 9 miles an hour, then increases to 14 miles an hour by Day 3, and then it is more or less flat after that from Days 3–5.

These numbers are on the order of about one Saffir Simpson category. A good preparation tool is to prepare for a storm one category higher. This is particularly important for people living in a zone where storms can rapidly intensify, such as along the Gulf of Mexico. For locations in the Mid-Atlantic or Northeast, it is generally not necessary to prepare for storms one category higher as storms are usually weakening when they move that high north and are moving towards the sub-tropics.

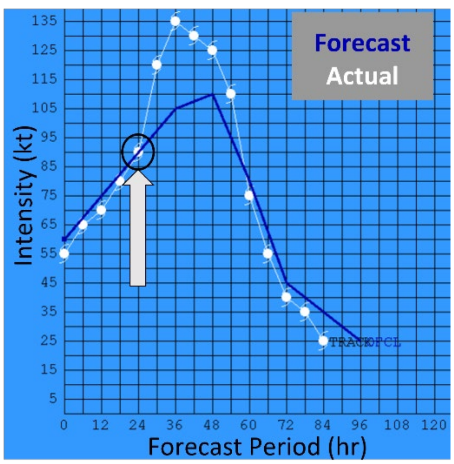
Visual 11: Forecast Intensity Errors: RI

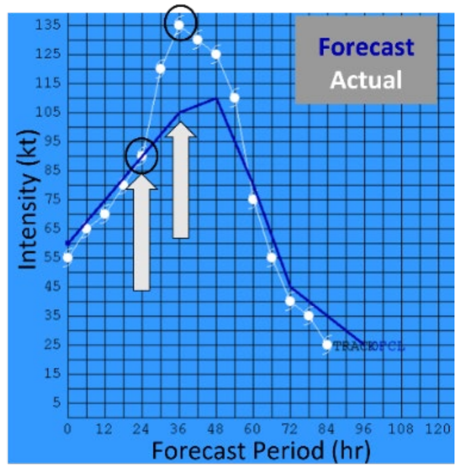
RAPID INTENSIFICATION

- A forecast challenge.
- Often results in very large errors.
- Forecasting the extent and timing of that intensification remains difficult.

Example: Iota Advisory 7 (2020)

Initial Intensity:	65 mph	Initial Intensity:	65 mph
24h Forecast:	105 mph	36h Forecast:	120 mph
Actual Intensity:	105 mph	Actual Intensity:	155 mph
24 h Error:	**0 mph**	**36 h Error:**	**35 mph**





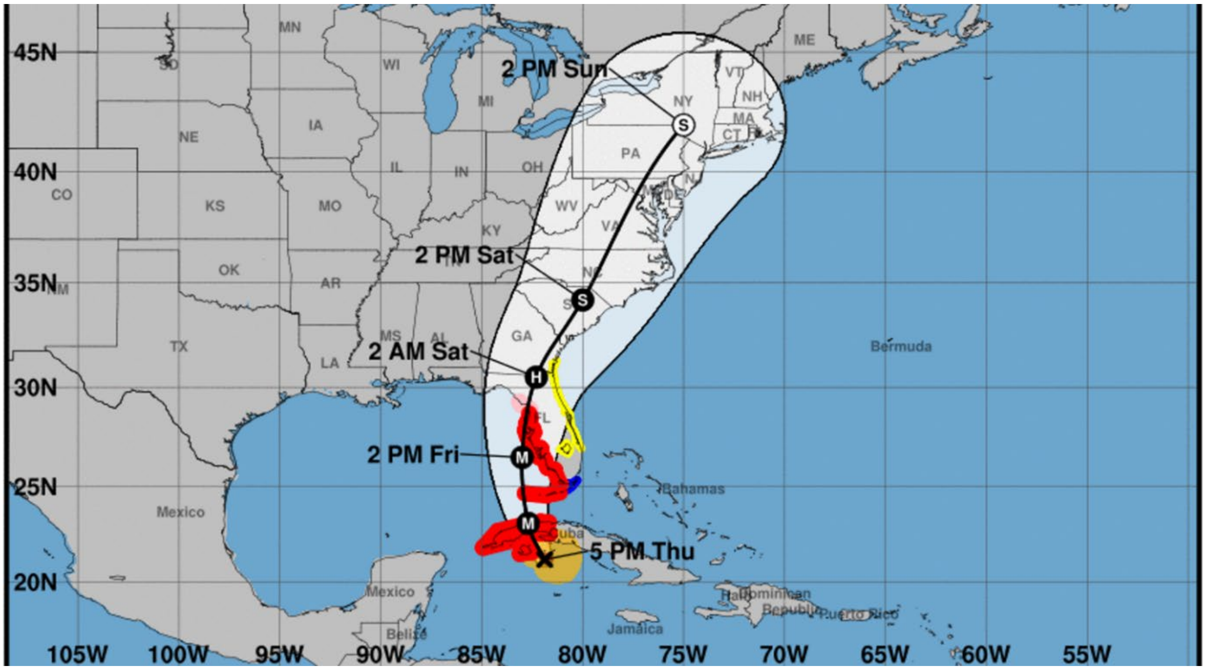
Key Points

Rapid intensification of a tropical cyclone remains a forecast challenge and often results in large errors.

Our ability to recognize conditions that favor rapid intensification has improved; however, forecasting the extent and timing of that intensification remains difficult.

Hurricane Iota is an example of a win and a loss for hurricane intensity forecasting. The NHC made a bold prediction that the storm would experience rapid intensification in the 24-hour forecast. It hit the 24-hour forecast precisely. For the 36-hour prediction, the forecaster predicted it would get stronger, which it did, but it continued to rapidly intensify, increasing to 155 mph and leaving us with a 35-mph error. This shows the limits of our forecast ability. We were able to predict it accurately in 24 hours but failed to predict continuing rapid intensification.

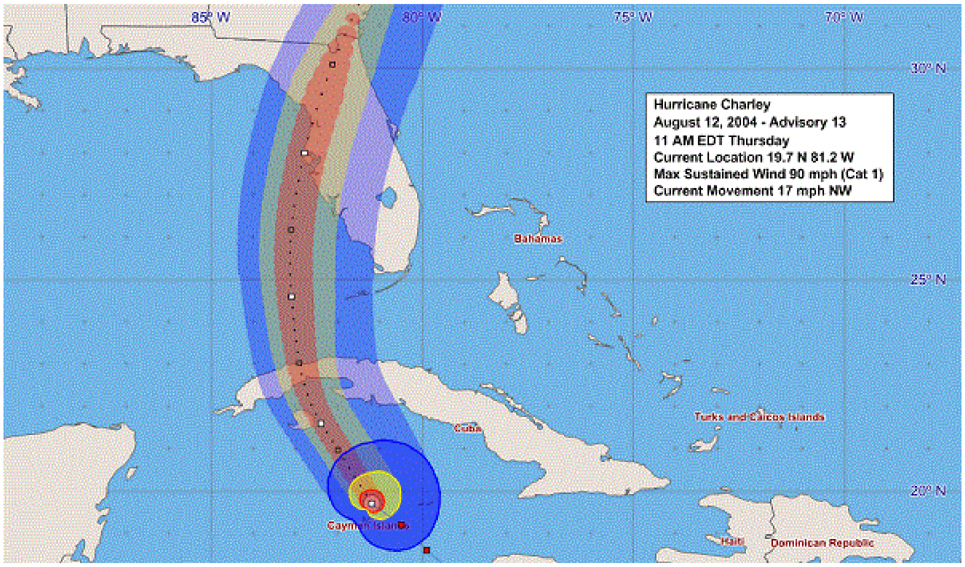
Visual 12: Don't Focus on the Skinny Black Line



Key Points

This graphic shows the forecast track of Hurricane Charley about 24 hours before it made landfall in Southwest Florida. In this case, the forecast track was relatively good (the errors were less than average), but given the storm's angle of approach, Charley made landfall much farther south along the west coast of Florida than anticipated. Notice, however, that the area was under a Hurricane Warning, so residents should have been prepared.

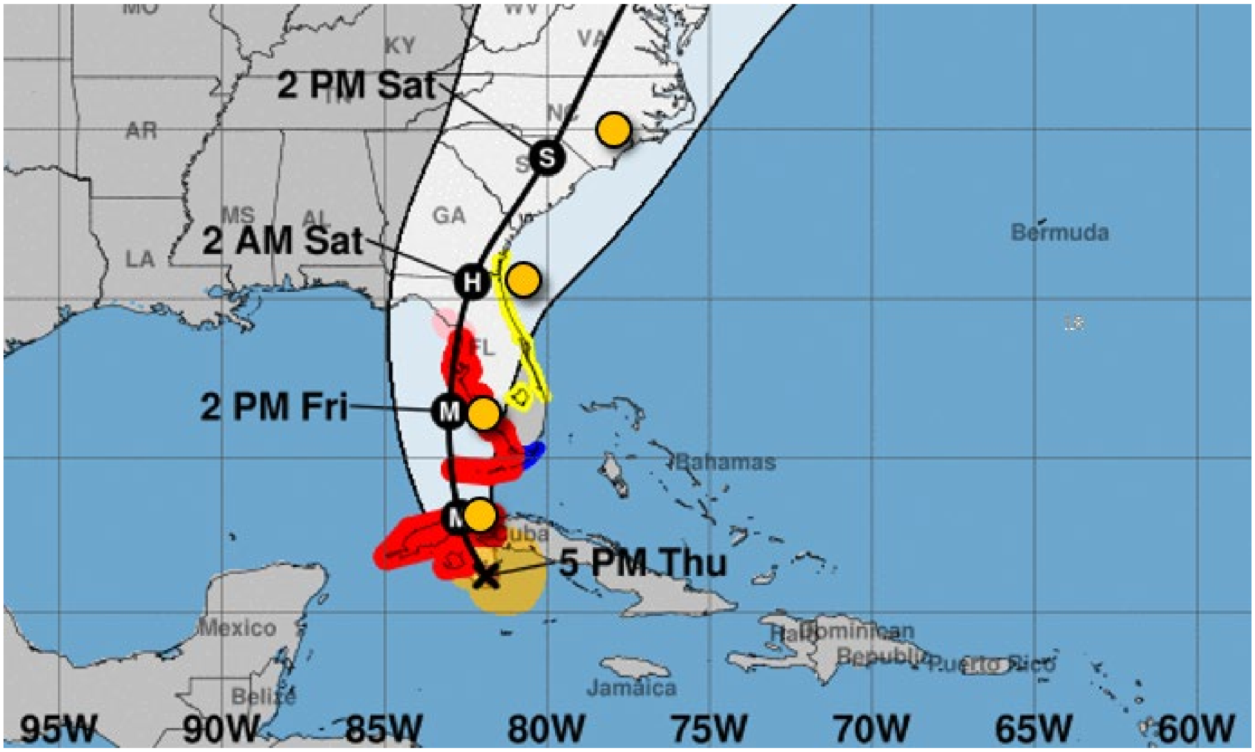
Visual 13: Hurricane Charley



Key Points

Here is the deterministic forecast wind swath for Hurricane Charley about 24 hours before landfall.

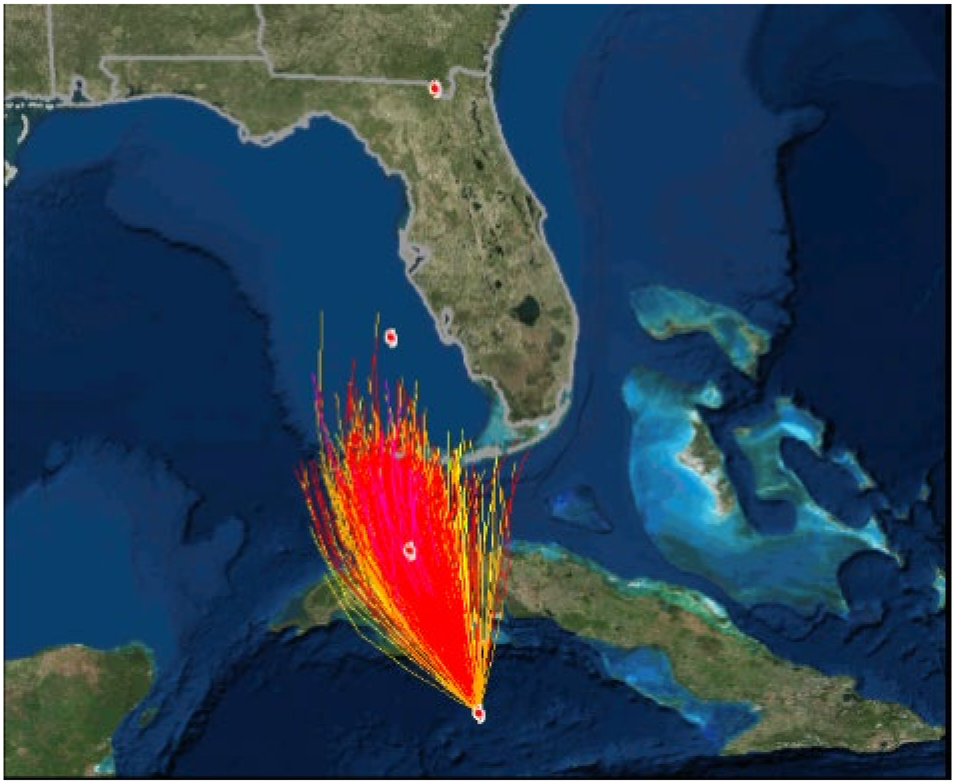
Visual 14: Forecast vs. Observed



Key Points

It is important to realize that the skinny black line does not tell the whole story. Just because the line is not crossing your area does not mean you will not be substantially impacted. Note the location of the yellow dots to the east of the storm track, but still within the error cone, that represent the actual location of the storm.

Visual 15: Would Alternate Scenarios Help?



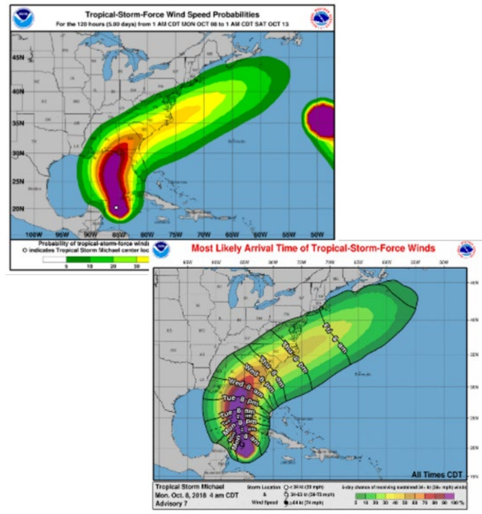
Key Points

This visual shows 1,000 tracks around the NHC official forecast for Hurricane Charley (small hurricane symbols). The 1,000 tracks use historical NHC track and intensity errors to show plausible alternative scenarios. These scenarios are used to create the NHC wind speed probability products.

Visual 16: Wind Speed Probabilities

NATIONAL HURRICANE CENTER
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

```
TROPICAL STORM MICHAEL WIND SPEED PROBABILITIES NUMBER   7
NWS NATIONAL HURRICANE CENTER MIAMI FL       AL142018
0900 UTC MON OCT 08 2018

  - - - - WIND SPEED PROBABILITIES FOR SELECTED LOCATIONS - - - -

                FROM    FROM    FROM    FROM    FROM    FROM    FROM
  TIME        06Z MON 18Z MON 06Z TUE 18Z TUE 06Z WED 06Z THU 06Z FRI
PERIODS         TO      TO      TO      TO      TO      TO      TO
              18Z MON 06Z TUE 18Z TUE 06Z WED 06Z THU 06Z FRI 06Z SAT

FORECAST HOUR    (12)    (24)     (36)    (48)    (72)    (96)   (120)
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
LOCATION       KT

TALLAHASSEE FL 34  X    X( X)    1( 1)   6( 7)  68(75)   6(81)   X(81)
TALLAHASSEE FL 50  X    X( X)    X( X)   1( 1)  41(42)   6(48)   X(48)
TALLAHASSEE FL 64  X    X( X)    X( X)   X( X)  20(20)   4(24)   X(24)

APALACHICOLA   34  X    X( X)    5( 5)  29(34)  57(91)   1(92)   X(92)
APALACHICOLA   50  X    X( X)    X( X)   6( 6)  59(65)   2(67)   X(67)
APALACHICOLA   64  X    X( X)    X( X)   1( 1)  39(40)   1(41)   X(41)

PANAMA CITY FL 34  X    X( X)    4( 4)  26(30)  60(90)   1(91)   X(91)
PANAMA CITY FL 50  X    X( X)    X( X)   6( 6)  57(63)   1(64)   X(64)
PANAMA CITY FL 64  X    X( X)    X( X)   1( 1)  37(38)   X(38)   X(38)
```



Key Points

Remember, the wind speed probability text product will give you the likelihood of different wind levels for different locations:

- Tropical storm force
- 58 miles per hour (mph)
- Hurricane force

Wind probabilities give good information to use for decision-making purposes. Wind probabilities tell you how likely the wind threat is (tropical storm force or hurricane force), when they are going to arrive, and what the inland threat could be.

Visual 17: WSP – Knowledge Check

The chance of hurricane-force winds occurring at Pensacola during the next 5 days is between _______.

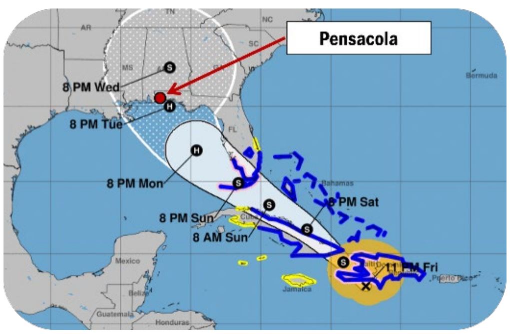
A. 1% to 10%

B. 10%–20%

C. 20%–30%

D. 30%–40%

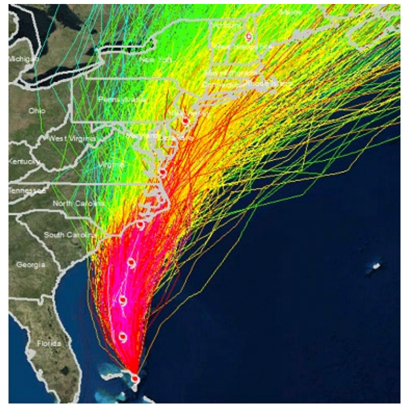
E. 40%–50%



Visual 18: Generating Probabilities

MORE SCENARIOS

- 1,000 realistic alternative scenarios are generated.
  - Official NHC forecast.
  - Historical track and intensity forecast errors.
- Weakening over land.
- Track model spread.
- Forecast track errors are correlated to the spread of model guidance.



Key Points

Probabilities provide a more easily understood way of conveying the predicted impact of a large and capricious storm.

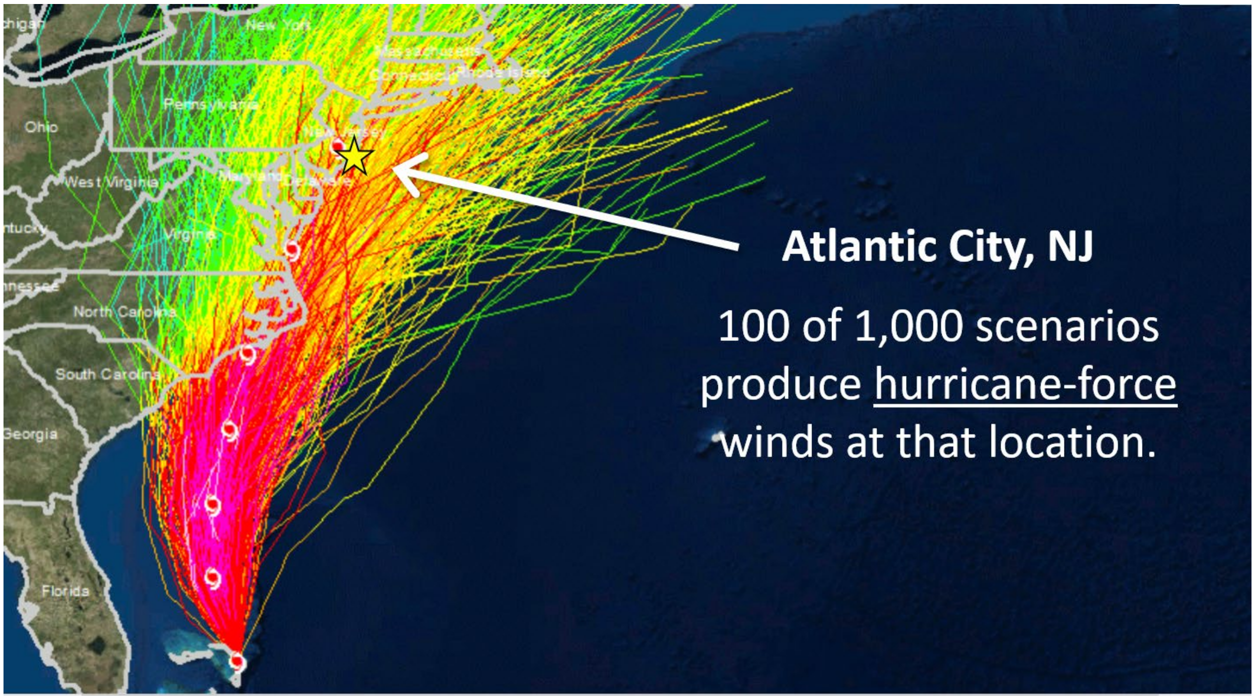
To arrive at the numbers we give as probabilities, we generate 1,000 realistic alternative scenarios based on data from the:

- Official NHC forecast
- Historical NHC track and intensity forecast errors
- Climatology and persistence wind radii model

The technique accounts for tracks that move over land by realistically weakening those realizations. Track model spread is also considered.

Past NHC track forecast errors are correlated to the spread of track model guidance. When the track guidance has less spread, NHC track forecasts typically have lower errors. Conversely, when the track guidance has more spread, NHC forecasts have higher errors.

Visual 19: Generating Probabilities 2

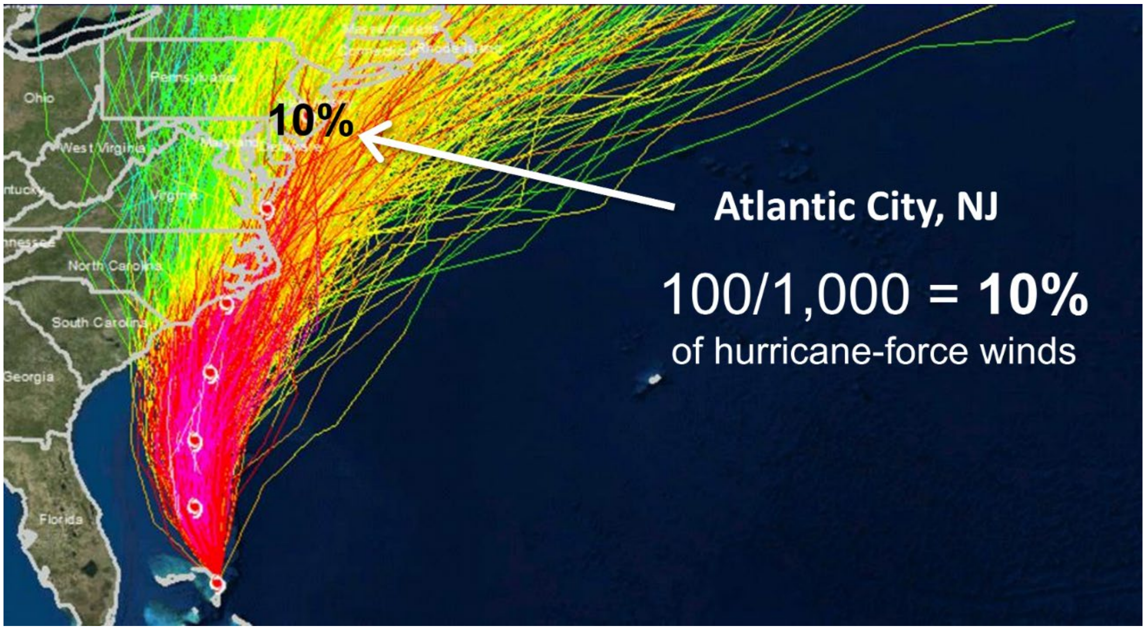


Key Points

As an example, let’s consider the probability for the specific location of Atlantic City, New Jersey.

- 100 of 1,000 scenarios created produced hurricane-force winds for Atlantic City.

Visual 20: Generating Probabilities 3



Key Points

Continuing from the previous slide of 100/1,000 scenarios producing hurricane-force winds…

- 100/1000 = 10% chance of hurricane-force winds.
- Therefore, the forecast for Atlantic City is that they have a 10% chance of experiencing tropical storm-force winds.

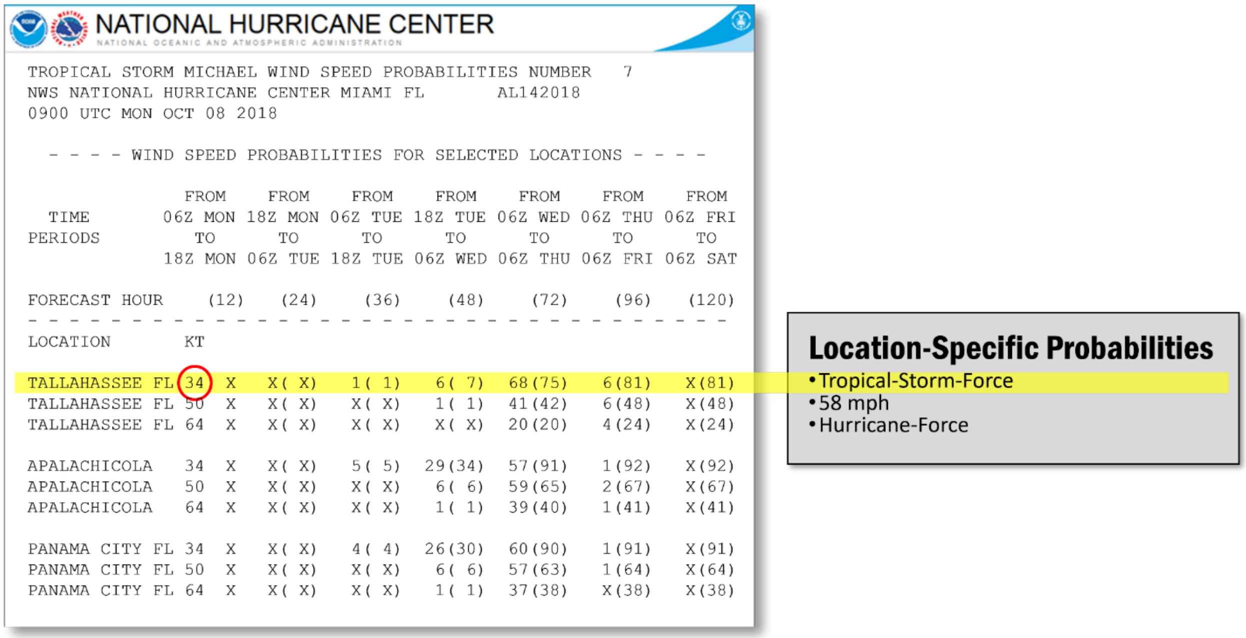
Visual 21: What Does 10% Chance Mean?

Key Points

With a 10% chance of rain, you might not bring your umbrella. With a 10% chance of getting struck by a car while crossing the street, you are likely to be on the lookout for cars.

The event that the probability is tied to is what matters. Do people understand the event? Getting caught without an umbrella versus getting hit by a car.

Visual 22: Location-Specific Probabilities 1



TROPICAL STORM MICHAEL WIND SPEED PROBABILITIES NUMBER 7
NWS NATIONAL HURRICANE CENTER MIAMI FL AL142018
0900 UTC MON OCT 08 2018

- - - - WIND SPEED PROBABILITIES FOR SELECTED LOCATIONS - - - -

TIME PERIODS		FROM 06Z MON TO 18Z MON	FROM 18Z MON TO 06Z TUE	FROM 06Z TUE TO 18Z TUE	FROM 18Z TUE TO 06Z WED	FROM 06Z WED TO 06Z THU	FROM 06Z THU TO 06Z FRI	FROM 06Z FRI TO 06Z SAT
FORECAST HOUR		(12)	(24)	(36)	(48)	(72)	(96)	(120)
LOCATION	KT							
TALLAHASSEE FL	34	X	X(X)	1(1)	6(7)	68(75)	6(81)	X(81)
TALLAHASSEE FL	50	X	X(X)	X(X)	1(1)	41(42)	6(48)	X(48)
TALLAHASSEE FL	64	X	X(X)	X(X)	X(X)	20(20)	4(24)	X(24)
APALACHICOLA	34	X	X(X)	5(5)	29(34)	57(91)	1(92)	X(92)
APALACHICOLA	50	X	X(X)	X(X)	6(6)	59(65)	2(67)	X(67)
APALACHICOLA	64	X	X(X)	X(X)	1(1)	39(40)	1(41)	X(41)
PANAMA CITY FL	34	X	X(X)	4(4)	26(30)	60(90)	1(91)	X(91)
PANAMA CITY FL	50	X	X(X)	X(X)	6(6)	57(63)	1(64)	X(64)
PANAMA CITY FL	64	X	X(X)	X(X)	1(1)	37(38)	X(38)	X(38)

Key Points

There are multiple ways to get data; let's start with the most cumbersome way. When you open the text product, look for the city or location of interest. Multiple entries for the same city indicate the different thresholds for wind speeds. The 1st row lists the 34 knots or tropical storm-force wind speed probabilities.

Visual 23: Location-Specific Probabilities 2

NATIONAL HURRICANE CENTER

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

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TROPICAL STORM MICHAEL WIND SPEED PROBABILITIES NUMBER   7
NWS NATIONAL HURRICANE CENTER MIAMI FL       AL142018
0900 UTC MON OCT 08 2018

  - - - - WIND SPEED PROBABILITIES FOR SELECTED LOCATIONS - - - -

               FROM    FROM    FROM    FROM    FROM    FROM    FROM
  TIME       06Z MON 18Z MON 06Z TUE 18Z TUE 06Z WED 06Z THU 06Z FRI
PERIODS         TO      TO      TO      TO      TO      TO      TO
             18Z MON 06Z TUE 18Z TUE 06Z WED 06Z THU 06Z FRI 06Z SAT

FORECAST HOUR    (12)    (24)    (36)    (48)    (72)    (96)   (120)
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
LOCATION       KT

TALLAHASSEE FL 34  X    X( X)   1( 1)   6( 7)  68(75)   6(81)   X(81)
TALLAHASSEE FL 50  X    X( X)   X( X)   1( 1)  41(42)   6(48)   X(48)
TALLAHASSEE FL 64  X    X( X)   X( X)   X( X)  20(20)   4(24)   X(24)

APALACHICOLA   34  X    X( X)   5( 5)  29(34)  57(91)   1(92)   X(92)
APALACHICOLA   50  X    X( X)   X( X)   6( 6)  59(65)   2(67)   X(67)
APALACHICOLA   64  X    X( X)   X( X)   1( 1)  39(40)   1(41)   X(41)

PANAMA CITY FL 34  X    X( X)   4( 4)  26(30)  60(90)   1(91)   X(91)
PANAMA CITY FL 50  X    X( X)   X( X)   6( 6)  57(63)   1(64)   X(64)
PANAMA CITY FL 64  X    X( X)   X( X)   1( 1)  37(38)   X(38)   X(38)
```

Location-Specific Probabilities

- Tropical-Storm-Force
- 58 mph
- Hurricane-Force

Key Points

The yellow highlights on this example show where to find information on 58-mph winds for the location city.

Visual 24: Location-Specific Probabilities 3

NATIONAL HURRICANE CENTER

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

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TROPICAL STORM MICHAEL WIND SPEED PROBABILITIES NUMBER   7
NWS NATIONAL HURRICANE CENTER MIAMI FL       AL142018
0900 UTC MON OCT 08 2018

  - - - - WIND SPEED PROBABILITIES FOR SELECTED LOCATIONS - - - -

               FROM    FROM    FROM    FROM    FROM    FROM    FROM
  TIME       06Z MON 18Z MON 06Z TUE 18Z TUE 06Z WED 06Z THU 06Z FRI
PERIODS         TO      TO      TO      TO      TO      TO      TO
             18Z MON 06Z TUE 18Z TUE 06Z WED 06Z THU 06Z FRI 06Z SAT

FORECAST HOUR    (12)   (24)    (36)    (48)    (72)    (96)   (120)
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
LOCATION       KT

TALLAHASSEE FL 34  X    X( X)   1( 1)   6( 7)  68(75)   6(81)   X(81)
TALLAHASSEE FL 50  X    X( X)   X( X)   1( 1)  41(42)   6(48)   X(48)
TALLAHASSEE FL 64  X    X( X)   X( X)   X( X)  20(20)   4(24)   X(24)

APALACHICOLA   34  X    X( X)   5( 5)  29(34)  57(91)   1(92)   X(92)
APALACHICOLA   50  X    X( X)   X( X)   6( 6)  59(65)   2(67)   X(67)
APALACHICOLA   64  X    X( X)   X( X)   1( 1)  39(40)   1(41)   X(41)

PANAMA CITY FL 34  X    X( X)   4( 4)  26(30)  60(90)   1(91)   X(91)
PANAMA CITY FL 50  X    X( X)   X( X)   6( 6)  57(63)   1(64)   X(64)
PANAMA CITY FL 64  X    X( X)   X( X)   1( 1)  37(38)   X(38)   X(38)
```

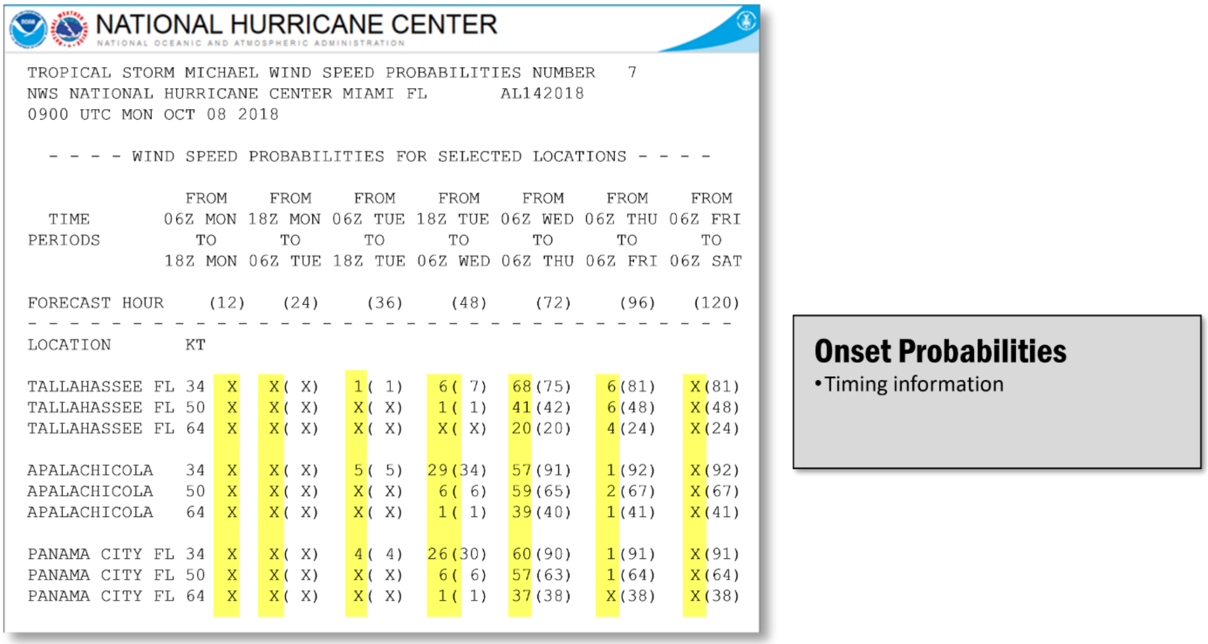
Location-Specific Probabilities

- Tropical-Storm-Force
- 58 mph
- Hurricane-Force

Key Points

The yellow highlights on this example show where to find information on hurricane-force winds for the location city.

Visual 25: Onset Probabilities



NATIONAL HURRICANE CENTER

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

TROPICAL STORM MICHAEL WIND SPEED PROBABILITIES NUMBER 7
NWS NATIONAL HURRICANE CENTER MIAMI FL AL142018
0900 UTC MON OCT 08 2018

- - - - WIND SPEED PROBABILITIES FOR SELECTED LOCATIONS - - - -

TIME PERIODS		FROM 06Z MON TO 18Z MON	FROM 18Z MON TO 06Z TUE	FROM 06Z TUE TO 18Z TUE	FROM 18Z TUE TO 06Z WED	FROM 06Z WED TO 06Z THU	FROM 06Z THU TO 06Z FRI	FROM 06Z FRI TO 06Z SAT
FORECAST HOUR		(12)	(24)	(36)	(48)	(72)	(96)	(120)
LOCATION	KT							
TALLAHASSEE FL	34	X	X(X)	1(1)	6(7)	68(75)	6(81)	X(81)
TALLAHASSEE FL	50	X	X(X)	X(X)	1(1)	41(42)	6(48)	X(48)
TALLAHASSEE FL	64	X	X(X)	X(X)	X(X)	20(20)	4(24)	X(24)
APALACHICOLA	34	X	X(X)	5(5)	29(34)	57(91)	1(92)	X(92)
APALACHICOLA	50	X	X(X)	X(X)	6(6)	59(65)	2(67)	X(67)
APALACHICOLA	64	X	X(X)	X(X)	1(1)	39(40)	1(41)	X(41)
PANAMA CITY FL	34	X	X(X)	4(4)	26(30)	60(90)	1(91)	X(91)
PANAMA CITY FL	50	X	X(X)	X(X)	6(6)	57(63)	1(64)	X(64)
PANAMA CITY FL	64	X	X(X)	X(X)	1(1)	37(38)	X(38)	X(38)

Key Points

The yellow highlights on this example show where to find information on the chance of the wind beginning during the individual time periods indicated for the event for all the locations listed.

In the column, the first number outside the parenthesis corresponds to the onset timing. The timing probability shown at the top of the product.

Visual 26: Cumulative Probabilities

NATIONAL HURRICANE CENTER

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

TROPICAL STORM MICHAEL WIND SPEED PROBABILITIES NUMBER 7
NWS NATIONAL HURRICANE CENTER MIAMI FL AL142018
0900 UTC MON OCT 08 2018

- - - - WIND SPEED PROBABILITIES FOR SELECTED LOCATIONS - - - -

TIME PERIODS		FROM 06Z MON TO 18Z MON	FROM 18Z MON TO 06Z TUE	FROM 06Z TUE TO 18Z TUE	FROM 18Z TUE TO 06Z WED	FROM 06Z WED TO 06Z THU	FROM 06Z THU TO 06Z FRI	FROM 06Z FRI TO 06Z SAT
FORECAST HOUR		(12)	(24)	(36)	(48)	(72)	(96)	(120)
LOCATION	KT							
TALLAHASSEE FL	34	X	X(X)	1(1)	6(7)	68(75)	6(81)	X(81)
TALLAHASSEE FL	50	X	X(X)	X(X)	1(1)	41(42)	6(48)	X(48)
TALLAHASSEE FL	64	X	X(X)	X(X)	X(X)	20(20)	4(24)	X(24)
APALACHICOLA	34	X	X(X)	5(5)	29(34)	57(91)	1(92)	X(92)
APALACHICOLA	50	X	X(X)	X(X)	6(6)	59(65)	2(67)	X(67)
APALACHICOLA	64	X	X(X)	X(X)	1(1)	39(40)	1(41)	X(41)
PANAMA CITY FL	34	X	X(X)	4(4)	26(30)	60(90)	1(91)	X(91)
PANAMA CITY FL	50	X	X(X)	X(X)	6(6)	57(63)	1(64)	X(64)
PANAMA CITY FL	64	X	X(X)	X(X)	1(1)	37(38)	X(38)	X(38)

Cumulative Probabilities

- Total chance through the time period

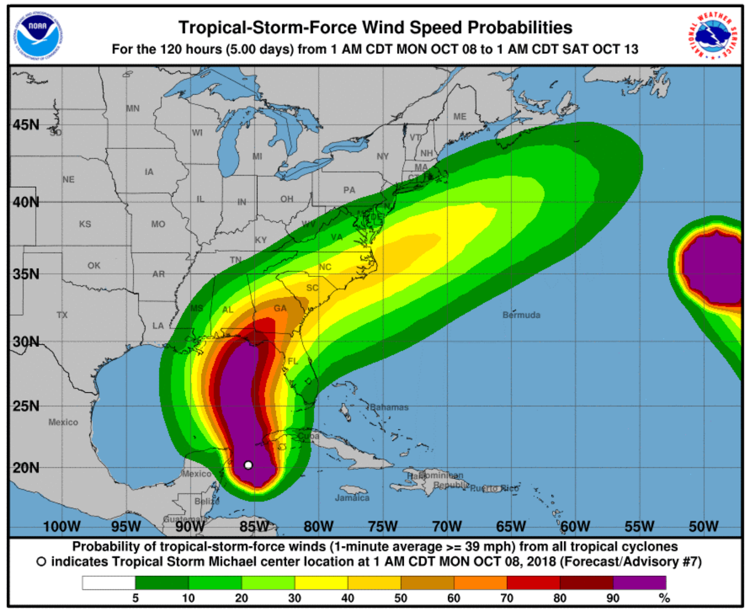
Key Points

The number shown inside the parentheses shows the cumulative probability that gives a sense of the overall risk over the time period.

Visual 27: 5-Day Cumulative Graphic: TS-Force

Location-specific Probabilities

- **Tropical Storm-Force**
- 58 mph ("Strong" Trop Storm)
- Hurricane-Force

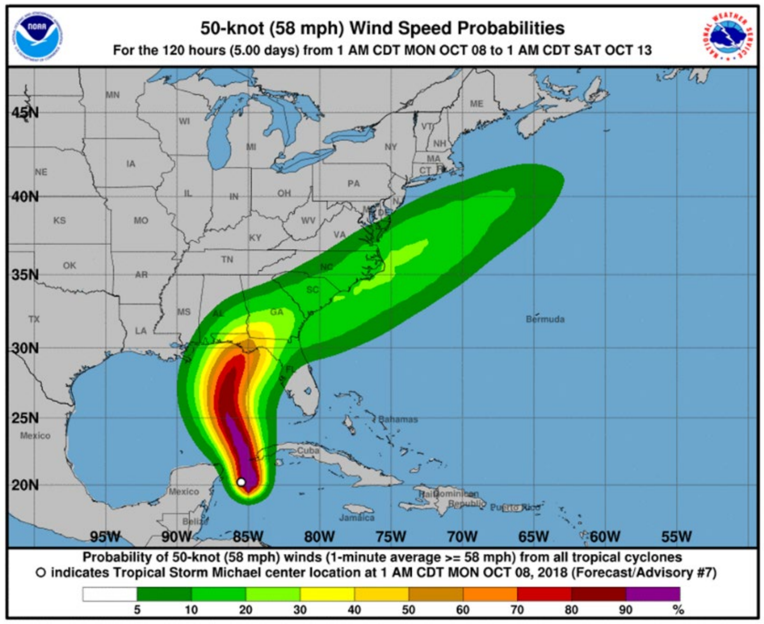


Key Points

The Wind Speed Probability (WSP) Cumulative Graphics are visual representations of the "spaghetti string" versions seen in previous visuals. The possibility of each level of wind is presented by groupings of 10% and mapped for clear and quick legibility. They are available for tropical storm-force winds (>34mph), "strong" tropical storm-force winds (>58 mph), and hurricane-force winds (>74 mph).

Visual 28: 5-Day Cumulative Graphic: 58 mph

<table>
<tr>
<td>
Location-specific Probabilities

- Tropical Storm-Force
- **58 mph (“Strong” Trop Storm)**
- Hurricane-Force
</td>
<td>


</td>
</tr>
</table>

Key Points

The WSP Cumulative Graphics are visual representations of the “spaghetti string” versions seen in previous visuals. The possibility of each level of wind is presented by groupings of 10% and mapped for clear and quick legibility. They are available for tropical storm-force winds (>34mph), “strong” tropical storm-force winds (>58 mph), and hurricane-force winds (>74 mph).

Visual 29: 5-Day Cumulative Graphic: Hurricane

Location-specific Probabilities

- Tropical Storm-Force
- 58 mph (“Strong” Trop Storm)
- Hurricane-Force

Key Points

The WSP Cumulative Graphics are visual representations of the “spaghetti string” versions seen in previous visuals. The possibility of each level of wind is presented by groupings of 10% and mapped for clear and quick legibility. They are available for tropical storm-force winds (>34mph), “strong” tropical storm-force winds (>58 mph), and hurricane-force winds (>74 mph).

Visual 30: Location-Specific Probabilities 4

NATIONAL HURRICANE CENTER

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

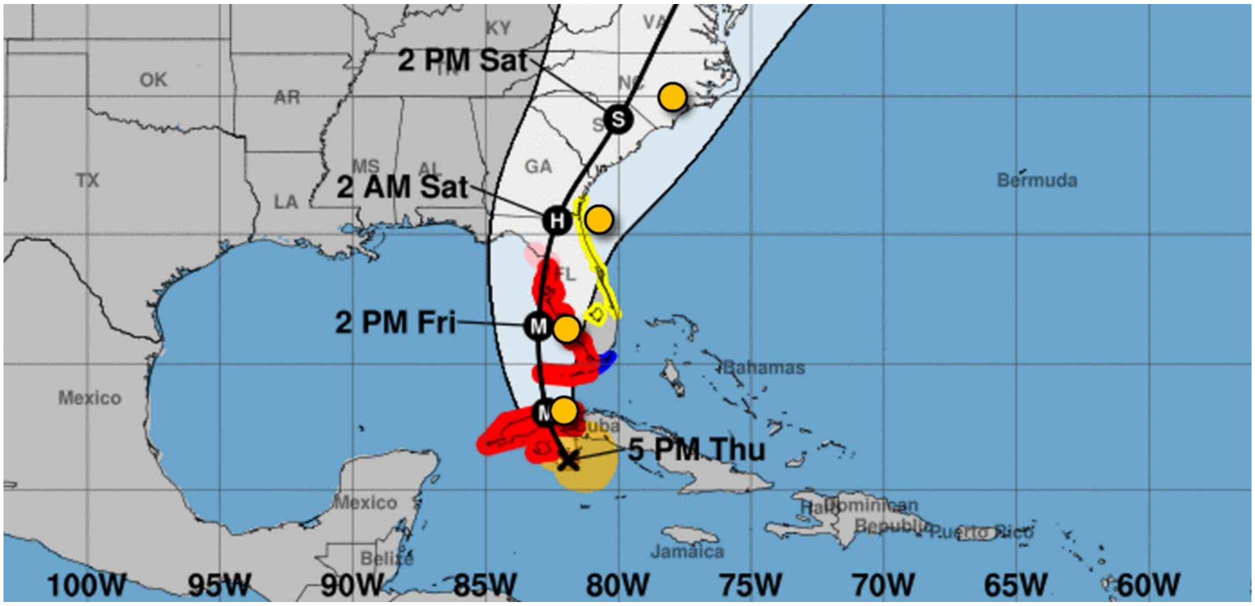
TIME PERIODS		FROM 06Z MON TO 18Z MON	FROM 18Z MON TO 06Z TUE	FROM 06Z TUE TO 18Z TUE	FROM 18Z TUE TO 06Z WED	FROM 06Z WED TO 06Z THU	FROM 06Z THU TO 06Z FRI	FROM 06Z FRI TO 06Z SAT
FORECAST HOUR		(12)	(24)	(36)	(48)	(72)	(96)	(120)
LOCATION	KT							
CEDAR KEY FL	34	X	X(X)	3(3)	15(18)	43(61)	2(63)	X(63)
CEDAR KEY FL	50	X	X(X)	X(X)	1(1)	20(21)	1(22)	X(22)
CEDAR KEY FL	64	X	X(X)	X(X)	X(X)	7(7)	1(8)	X(8)
TALLAHASSEE FL	34	X	X(X)	1(1)	6(7)	68(75)	6(81)	X(81)
TALLAHASSEE FL	50	X	X(X)	X(X)	1(1)	41(42)	6(48)	X(48)
TALLAHASSEE FL	64	X	X(X)	X(X)	X(X)	20(20)	4(24)	X(24)
APALACHICOLA	34	X	X(X)	5(5)	29(34)	57(91)	1(92)	X(92)
APALACHICOLA	50	X	X(X)	X(X)	6(6)	59(65)	2(67)	X(67)
APALACHICOLA	64	X	X(X)	X(X)	1(1)	39(40)	1(41)	X(41)
PANAMA CITY FL	34	X	X(X)	4(4)	26(30)	60(90)	1(91)	X(91)
PANAMA CITY FL	50	X	X(X)	X(X)	6(6)	57(63)	1(64)	X(64)
PANAMA CITY FL	64	X	X(X)	X(X)	1(1)	37(38)	X(38)	X(38)
PENSACOLA FL	34	X	X(X)	1(1)	8(9)	43(52)	2(54)	X(54)
PENSACOLA FL	50	X	X(X)	X(X)	1(1)	20(21)	1(22)	X(22)
PENSACOLA FL	64	X	X(X)	X(X)	X(X)	9(9)	X(9)	X(9)

Key Points

Let’s marry the two products together. The graphic is a cumulative, 5-day graph, using the number in the parenthesis. Now, let’s map it out. (Corresponds to the graphic above but with the floating numbers)

Cedar Key 8% chance of HF winds, Tallahassee a 24% chance, Apalachicola a 41% chance, Panama City a 38% chance, and Pensacola, a 9% chance of HF winds.

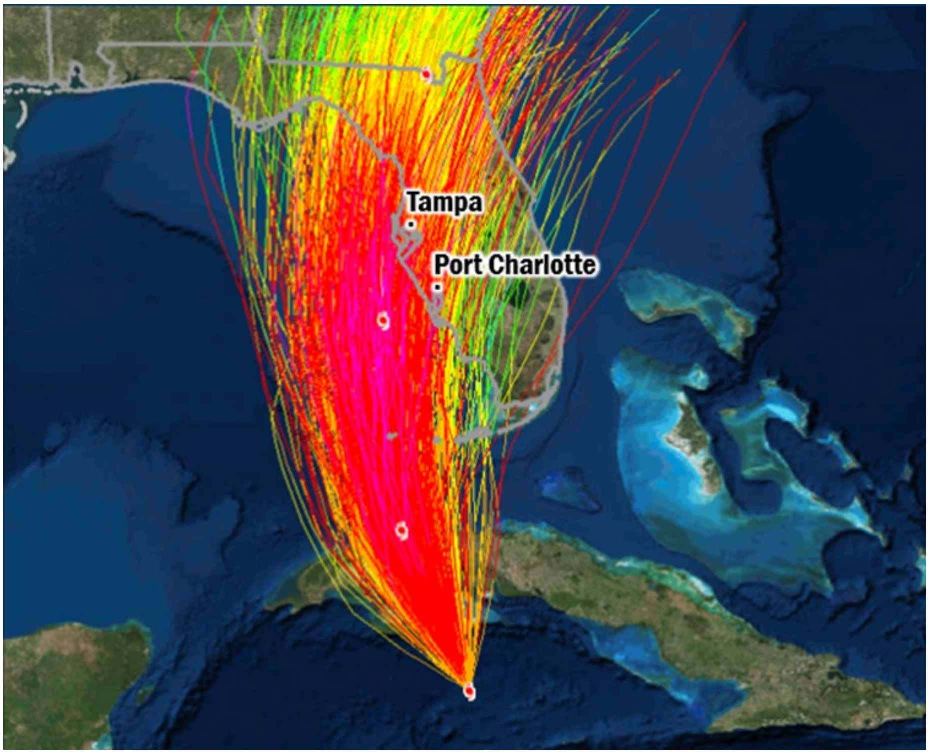
Visual 31: Forecast vs. Observed 2



Key Points

It is important to realize that the skinny black line does not tell the whole story. Just because the line is not crossing your area does not mean you will not be substantially impacted.

Visual 32: Would Alternate Scenarios Help? 2



Key Points

This visual shows 1,000 tracks around the NHC official forecast for Hurricane Charley (small hurricane symbols). Comparing this graphic to the forecast error cone in the previous slide, would you act differently if presented with one vs. both of the graphics?

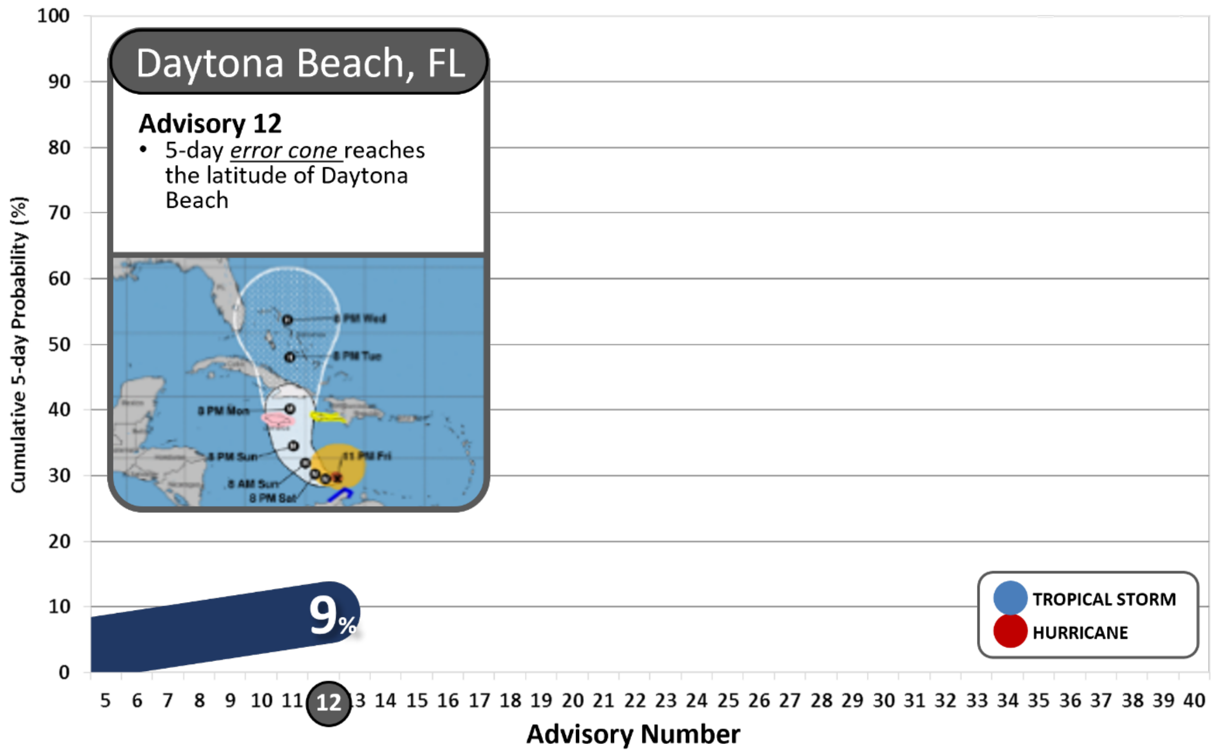
Visual 33: Would Alternate Scenarios Help? 3

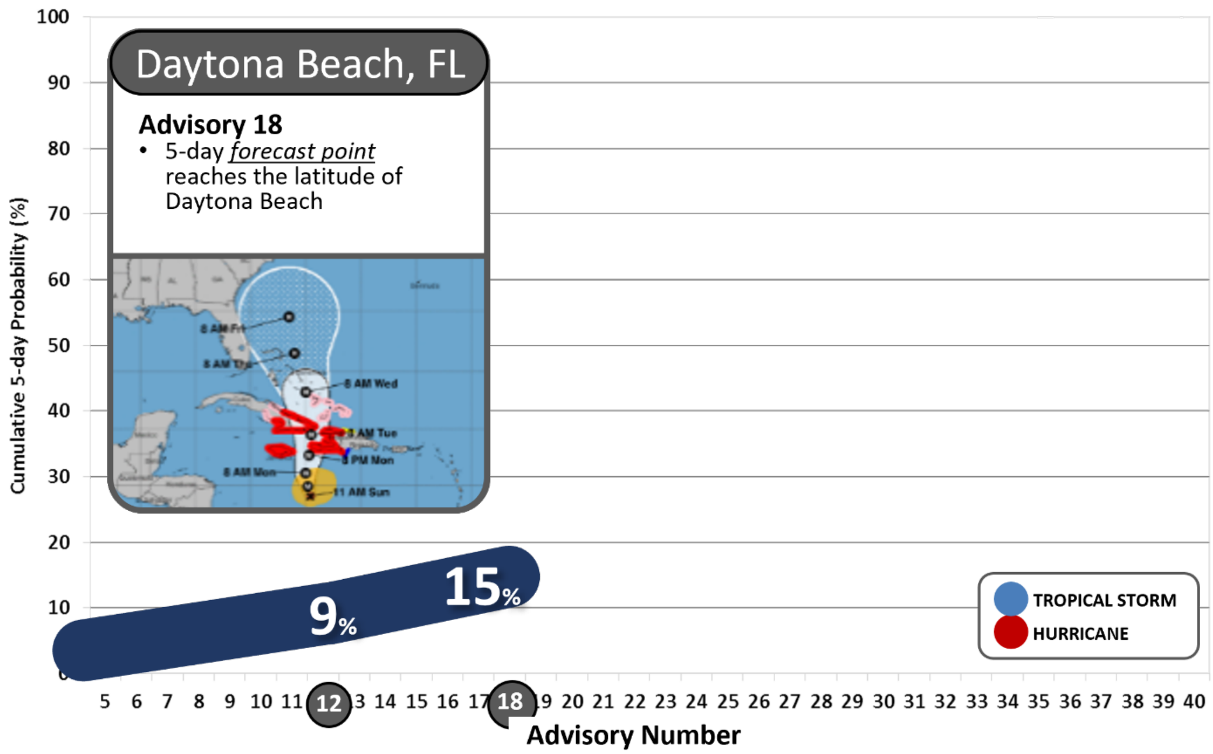
Chances of hurricane-force winds at Tampa Bay and Port Charlotte are both around 30%.

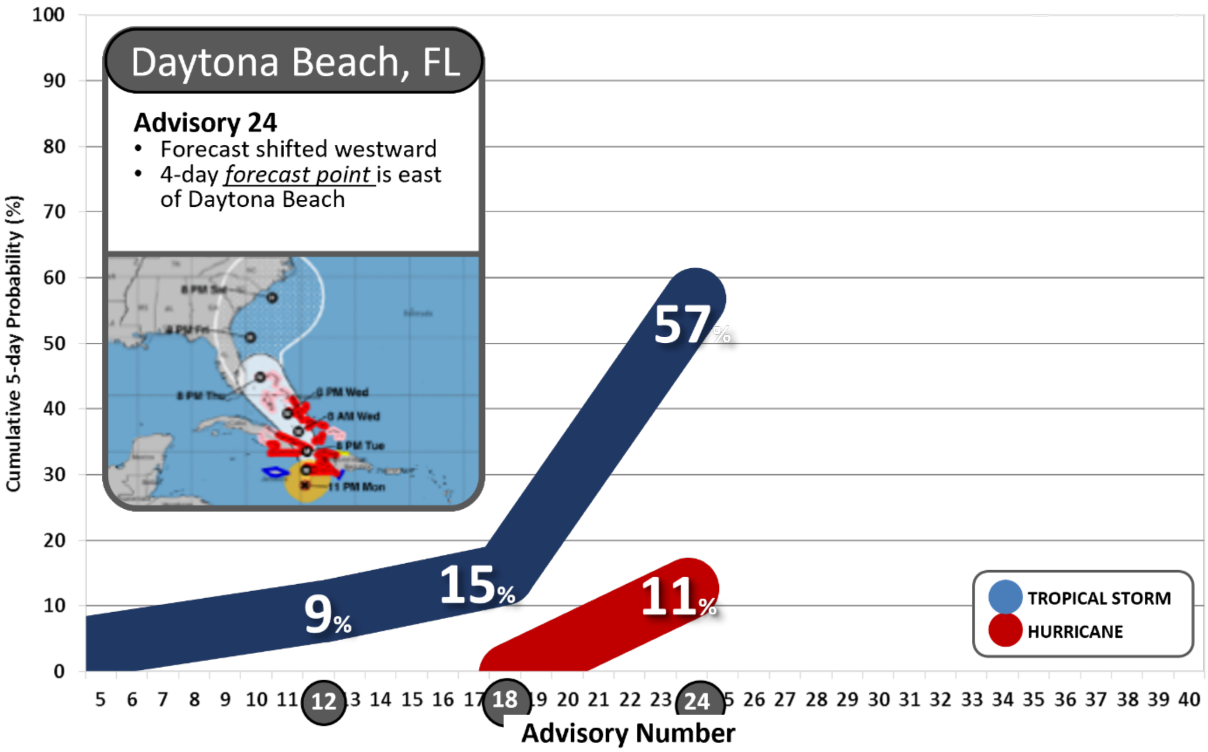
Key Points

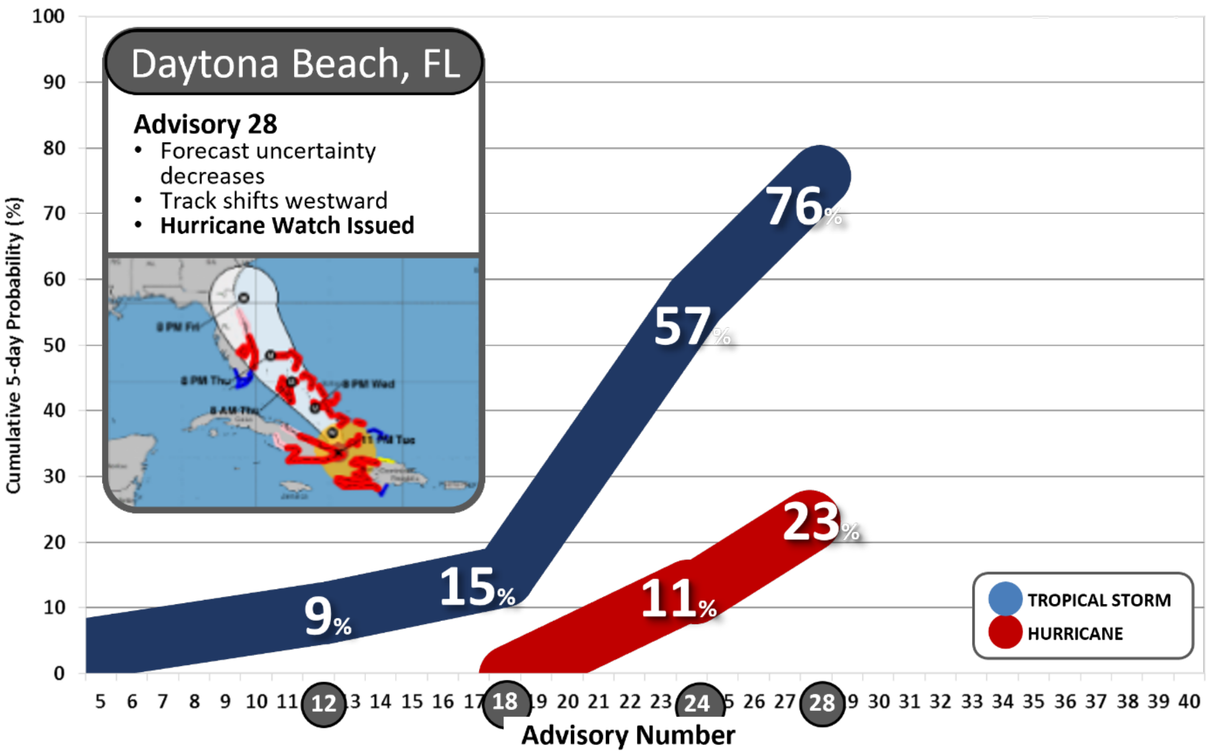
The spaghetti strings from the previous image are condensed into this Wind Speed Probability Graphic, which is easier to read and helps to quickly make decisions. How does this graphic's communication style influence decision making?

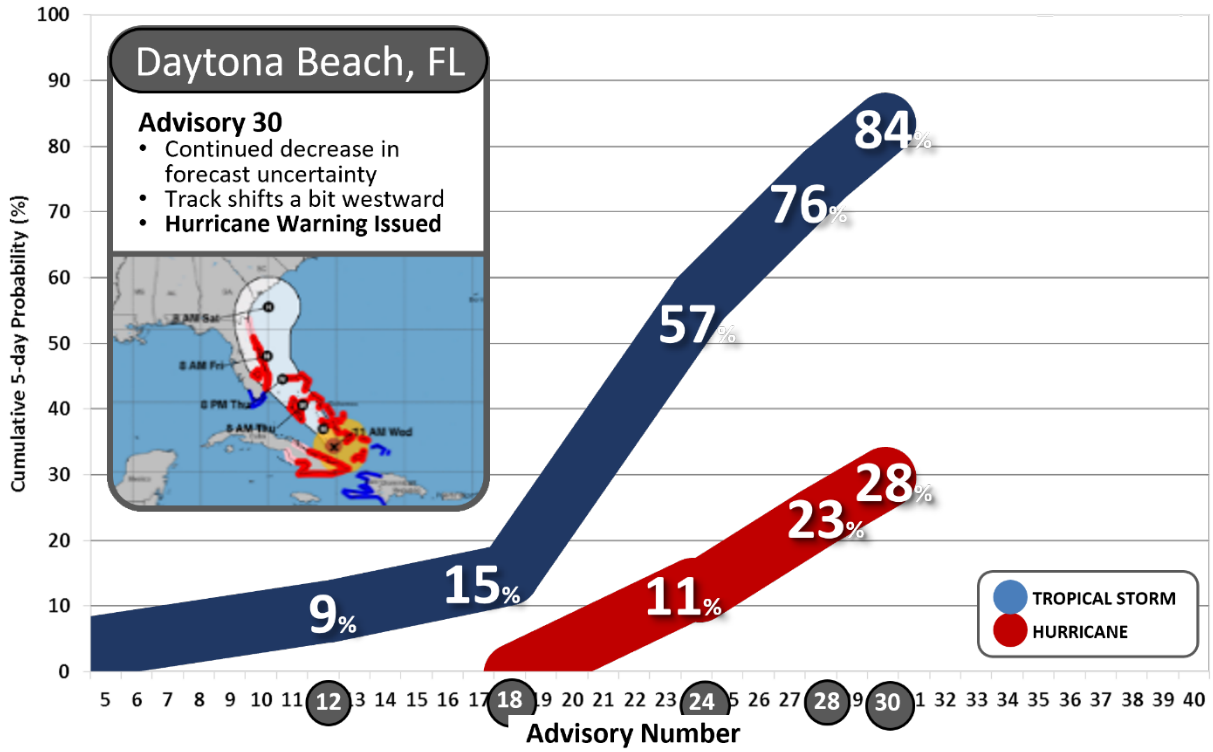
Visual 34: Hurricane Matthew (2016)

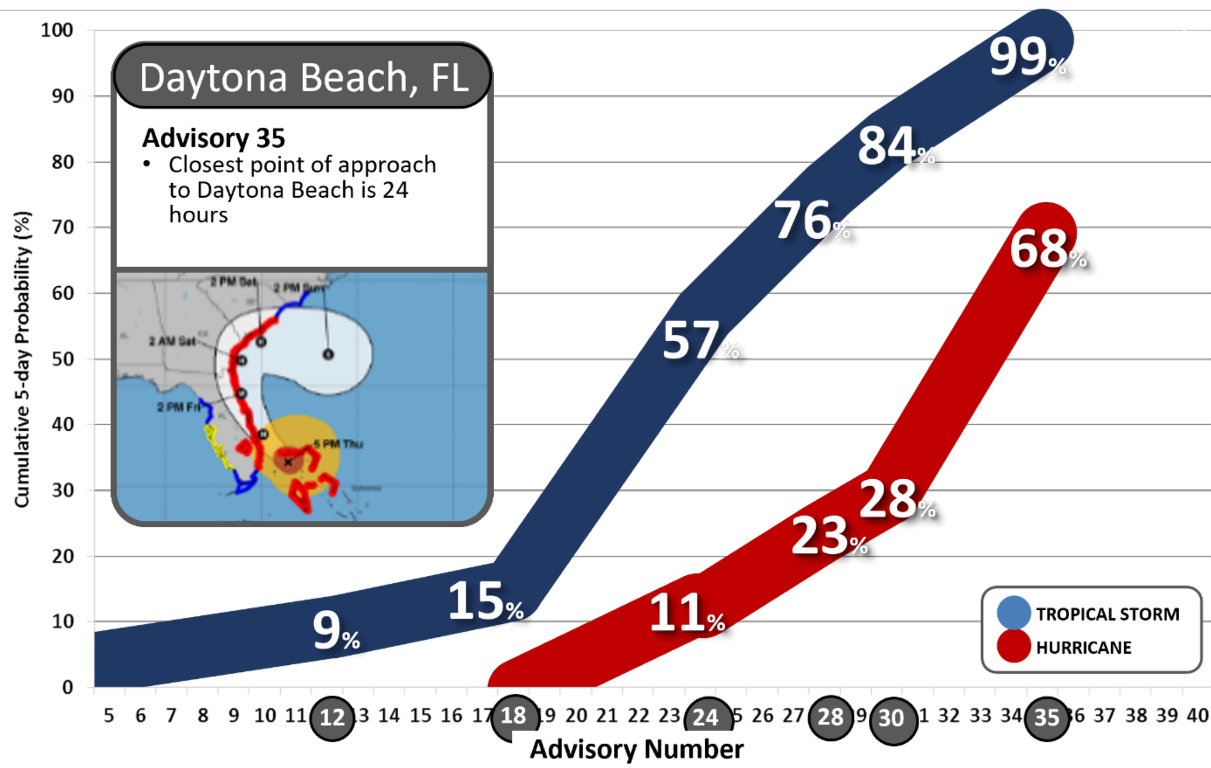





Daytona Beach, FL
Advisory 24
• Forecast shifted westward
• 4-day *forecast point* is east of Daytona Beach
Cumulative 5-day Probability (%)
Advisory Number
9%
15%
57%
11%
TROPICAL STORM
HURRICANE


Daytona Beach, FL
Advisory 28
• Forecast uncertainty decreases
• Track shifts westward
• **Hurricane Watch Issued**
Cumulative 5-day Probability (%)
Advisory Number
9%
15%
57%
76%
11%
23%
TROPICAL STORM
HURRICANE


Daytona Beach, FL
Advisory 30
• Continued decrease in forecast uncertainty
• Track shifts a bit westward
• Hurricane Warning Issued
Cumulative 5-day Probability (%)
Advisory Number
9%
15%
57%
76%
84%
11%
23%
28%
TROPICAL STORM
HURRICANE


Daytona Beach, FL
Advisory 35
• Closest point of approach to Daytona Beach is 24 hours
Cumulative 5-day Probability (%)
Advisory Number
9%
15%
57%
76%
84%
99%
11%
23%
28%
68%
TROPICAL STORM
HURRICANE

Key Points

Let's look at how to use the probabilities to assess the risk and how the trends can be your friend when making decisions. This is Hurricane Matthew in 2016. Let's imagine we are Emergency Managers in Daytona Beach. At advisory 12 when Matthew is in the Caribbean, it is a major hurricane, and Daytona Beach was outside the cone. At that time, Daytona has tropical wind-force probabilities of 9%. No chance of hurricane-force winds. Six advisories later (advisory 18), Daytona is still barely outside of the cone, TS-force winds up to 15%. Advisory 24, significant change, the forecast has shifted westward, and Daytona Beach is within the cone. TS-force wind probabilities have shot up to 57%, and we have an 11% chance of hurricane-force winds. Advisory 28, the storm continues to track westward, and the probabilities increase even more (76% and 23%). Advisory 30, there is less uncertainty in the mix with an 84% TS probability and a 28% hurricane force. Last advisory, 35, the system is bearing down on Florida, and the forecast point is right on top of Daytona Beach. The trend wasn't pleasant, but it is your friend for making decisions. Evaluate probabilities with every cycle to get data that is important to your location.

Visual 35: WSP – Knowledge Check Revisit

What is the chance of hurricane-force winds occurring at Pensacola during the next 5 days?

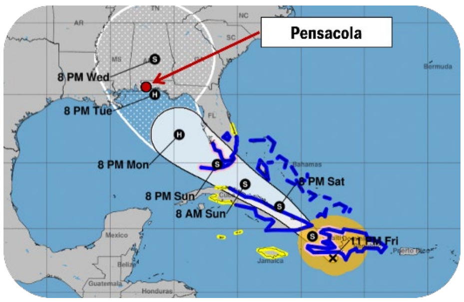
A. 1% to 10%

B. 10%–20%

C. 20%–30%

D. 30%–40%

E. 40%–50%



Key Points

In that circumstance, with the strategy we use and incorporating the error, there was a 6% chance of HF winds and a 51% chance of TS-force winds.

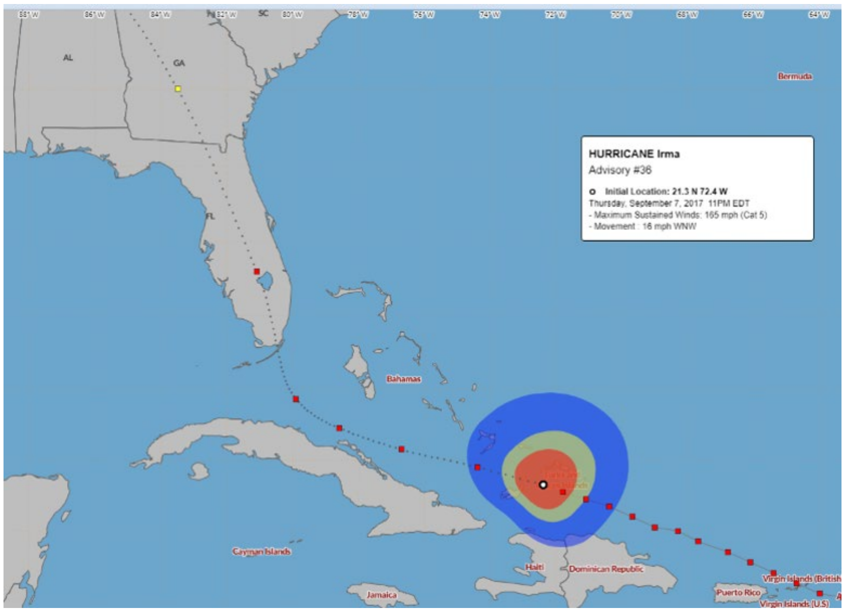
Visual 36: Wind Timing Importance and Causes

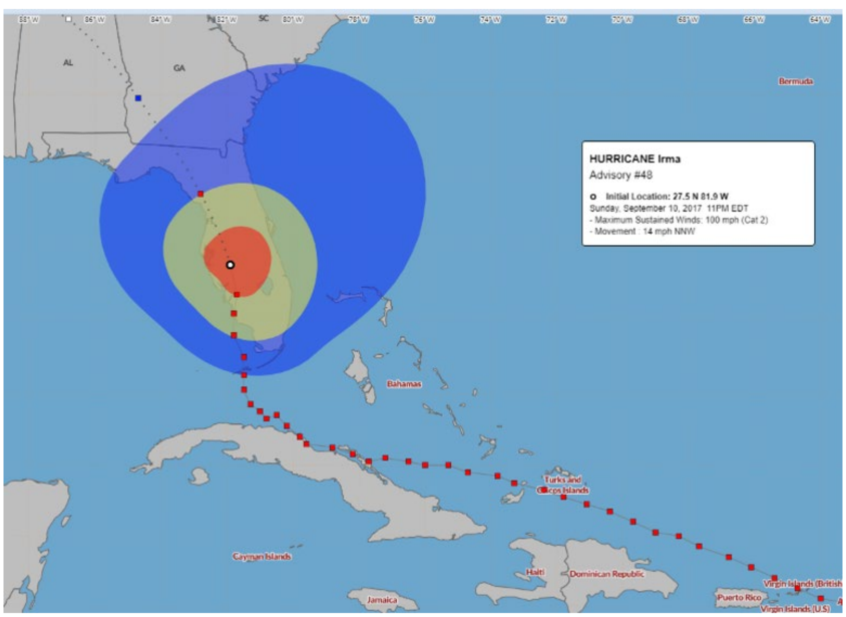
- **Uncertainty in wind timing:**
  - Track – Forward speed, direction of motion, and location of center relative to given location.
  - Storm Size – How far will TS winds extend from the center? Difficult to forecast and highly variable.
- **Time of Arrival graphics** designed to account for uncertainty in arrival of TS-force winds and provide timing information.

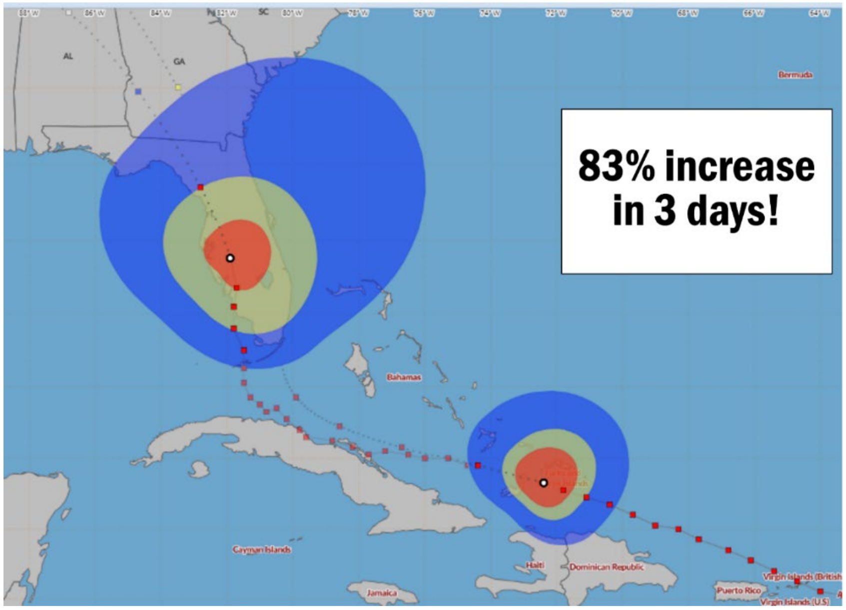
Key Points

Wind timing is critical for evacuation decisions, and there is some uncertainty related to the timing, one related to the track (forward speed, direction of motion, and location of the center). The other is a bit more mysterious, related to the storm size, how far out the TS winds will extend from the center. It is variable. But you don’t have to guess about these uncertainties; the time of arrival graphics are calculated to account of uncertainty and provide solid decision support data.

Visual 37: Importance and Causes







Key Points

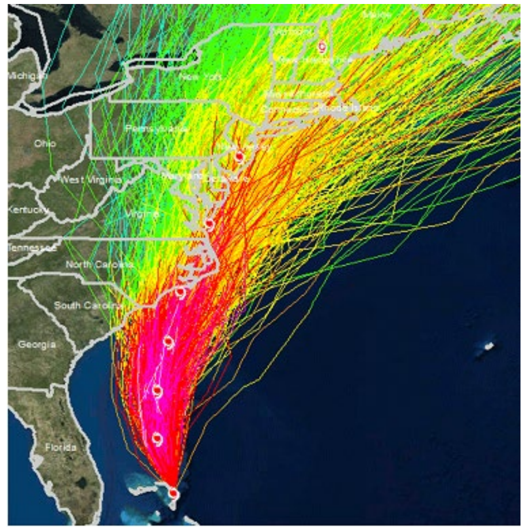
Let's look at the size differences that do occur with hurricanes. First image is Hurricane Irma, advisory 36, 11 a.m. EDT on September 7. While it is a Category 5 hurricane, it's not very big. The radius of the tropical storm-force winds is right at the mean for an Atlantic system. Irma is very average here. A few days later (advisory 48), the storm is much bigger, but weaker. The tropical storm-force winds have a radius of 275 miles—an 83% increase in 3 days. There is a lot of variability in size. Even though the maximum winds decrease in Irma as it approached Florida, the area that damaging winds covered increased dramatically.

Wind Time of Arrival (TOA) products will not handle the timing of storms with an unusually large or small wind field well, especially beyond the first 24–36 hours.

Visual 38: Generating Time of Arrival Graphics

MORE SCENARIOS

- **1,000 realistic alternative scenarios are generated.**
  - Official NHC forecast and historical errors
  - Weakening over land
  - Track model spread
- **Produce information about:**
  - Chance of wind occurring
  - Probabilistic onset timing



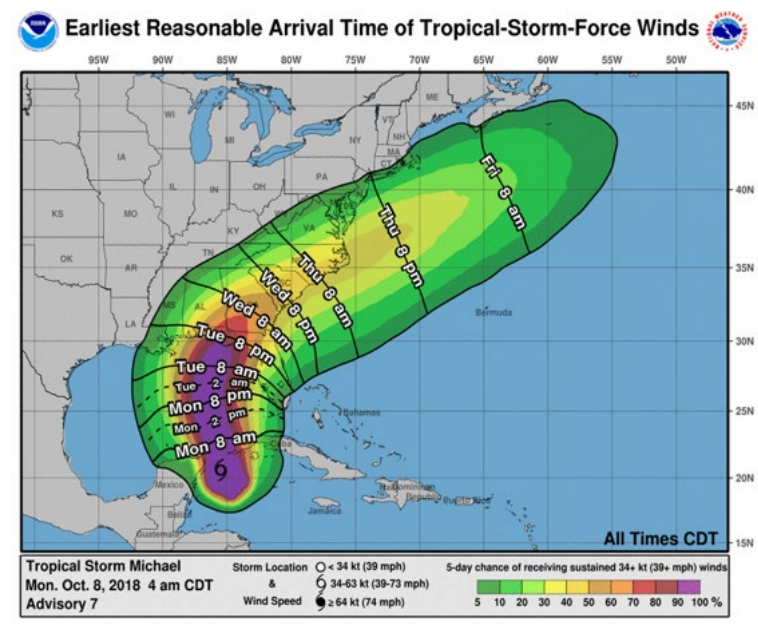
Key Points

These scenarios consider all the different variables that play into uncertainty. We use them to assess risk/chance of wind occurring at certain locations in the WSP graphics, but now we are using these scenarios to identify probabilistic information about when winds could start or onset time at certain locations.

Visual 39: Earliest Reasonable Onset of TS Winds

EARLIEST REASONABLE

- 10% chance of onset
  - Most conservative timing
- Arrival time of TS Winds
  - Black contours
- 5-day cumulative TS probabilities
- Color fill



Key Points

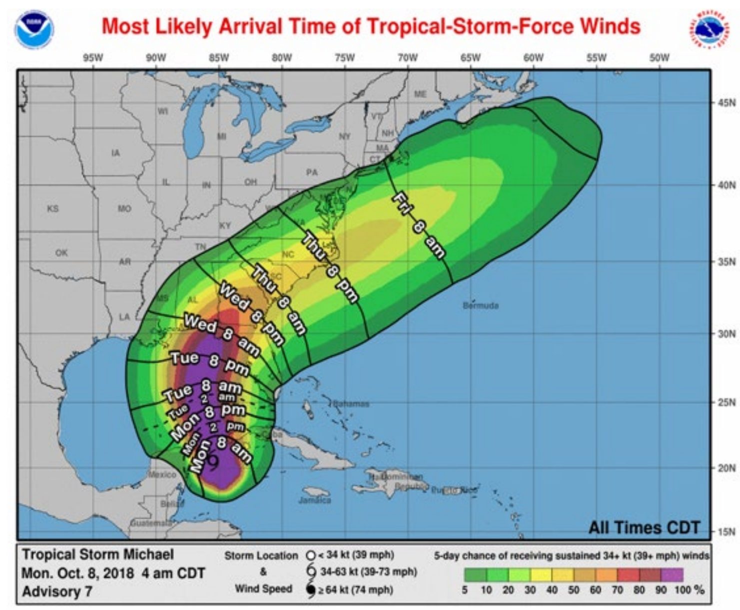
This example shows the earliest reasonable onset of TS winds. This example describes the 10% chance onset, which is the most conservative timing. If you have a low tolerance of risk and want to have everything done ahead of time, this may be the option for you.

Time of arrival graphics are available in two different styles. The first is Earliest Reasonable. Earliest Reasonable onset of tropical storm-strength winds is the point in time for which only 10% of the generated WSP tracks will arrive earlier. If the 1,000 simulations were each runners in a race, then Earliest Reasonable means 100 runners arrive before this time, 900 runners arrive afterwards.

Visual 40: Most Likely Onset of TS Winds

MOST LIKELY

- 50% chance of onset
  - Most conservative timing
- Arrival time of TS Winds
  - Black contours
- 5-day cumulative TS probabilities
- Color fill



Key Points

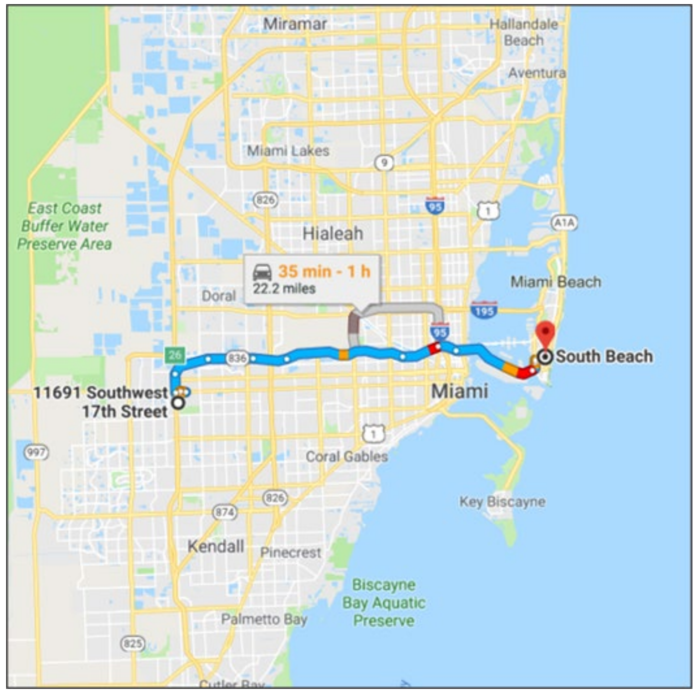
The arrival times for tropical-force winds are shown by the black lines. The 5-day cumulative probabilities are colored in just like before for TSFW threshold. Then, we also have the most likely timing; this is the time we think will be the most accurate. If you have a low tolerance for risk, this is not the answer for you. This is the best guest for when those winds will begin.

The Most Likely onset of tropical storm-strength winds is the point in time for which 50% of the generated WSP tracks will arrive earlier. If the 1,000 simulations were each runners in a race, then Most Likely means 500 runners arrive before this time, 500 runners arrive afterwards.

Visual 41: NHC – South Beach

TIMING UNCERTAINTY

- **Earliest Reasonable**
  - Absolutely must be there by 5 p.m.
  - Leave by 4:10 p.m. (50 min)
- **Most Likely**
  - Some wiggle room
  - Can afford to be a little late if traffic
  - Leave by 4:34 pm (26 min)
- Window to leave: 24 min
  - 4:10 p.m.–4:34 p.m.



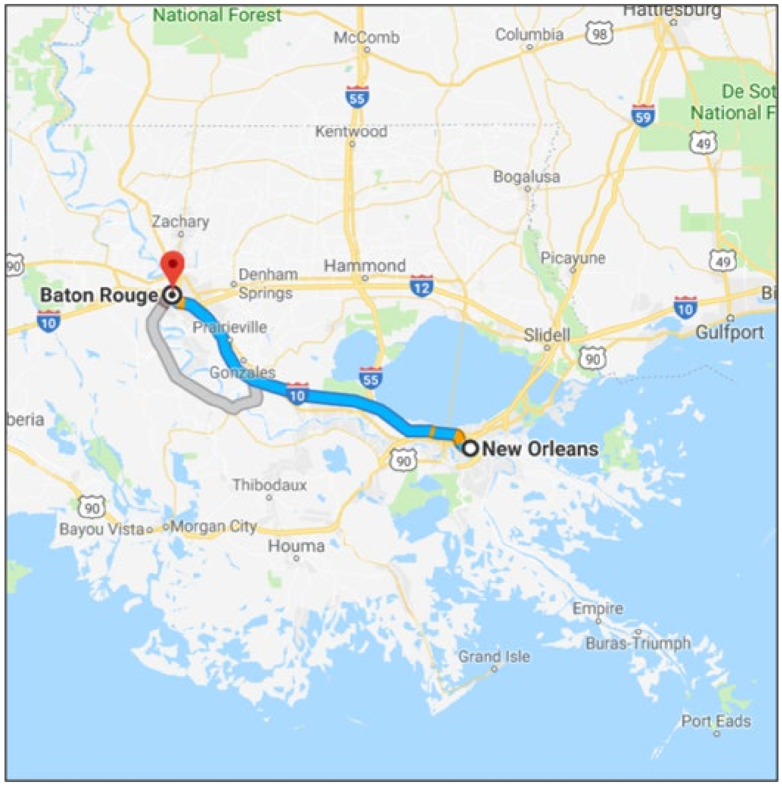
Key Points

When traveling, there are many factors that determine your arrival time. Depending on the likelihood of traffic and how acceptable it would be for you to arrive late, you will adjust your departure time. You as the traveler determine your departure time based on the risk you can handle. The same came be said for wind speed probabilities and timing information. What is your acceptable risk? What cushion factors do you take into account?

Visual 42: New Orleans – Baton Rouge

TIMING UNCERTAINTY

- **Earliest Reasonable**
  - Absolutely must be there by 5 p.m.
  - Leave by 4:10 p.m. (50 min)
- **Most Likely**
  - Some wiggle room
  - Can afford to be a little late if traffic
  - Leave by 4:34 p.m. (26 min)
- Window to leave: 24 min
  - 4:10 p.m.–4:34 p.m.



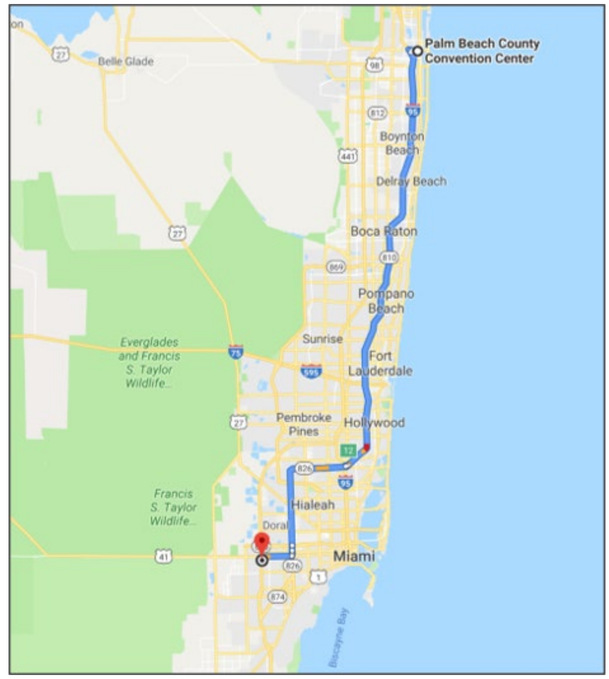
Key Points

When traveling, there are many factors that determine your arrival time. Depending on the likelihood of traffic and how acceptable it would be for you to arrive late, you will adjust your departure time. You as the traveler determine your departure time based on the risk you can handle. The same came be said for wind speed probabilities and timing information. What is your acceptable risk? What cushion factors do you take into account?

Visual 43: GHC – National Hurricane Center

TIMING UNCERTAINTY

- **Earliest Reasonable**
  - Absolutely must be there by 3 p.m.;
  - Leave by 1 p.m. (2hr)
- **Most Likely**
  - Some wiggle room
  - Can afford to be a little late if traffic
  - Leave by 1:35 p.m. (1hr 25min)
- **Window to leave: 35 min**
- 1 p.m.–1:35 p.m



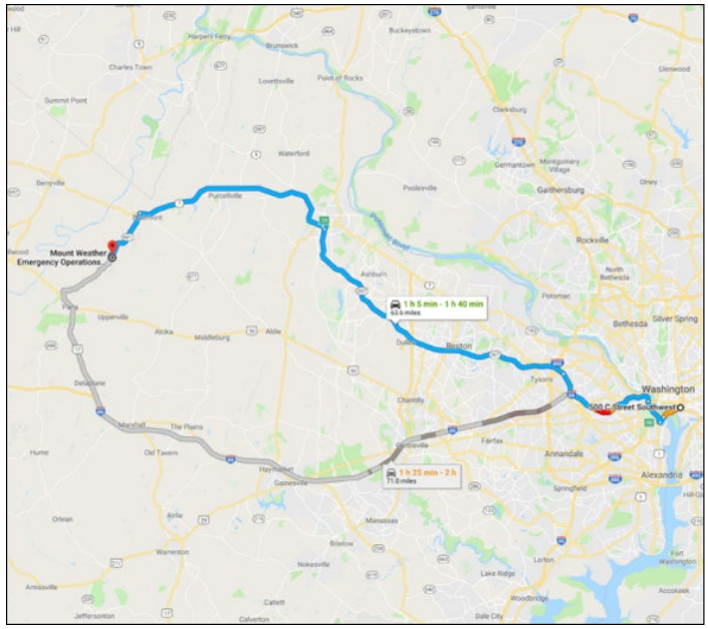
Key Points

When traveling, there are many factors that determine your arrival time. Depending on the likelihood of traffic and how acceptable it would be for you to arrive late, you will adjust your departure time. You as the traveler determine your departure time based on the risk you can handle. The same came be said for wind speed probabilities and timing information. What is your acceptable risk? What cushion factors do you take into account?

Visual 44: FEMA HQ – Mt. Weather

TIMING UNCERTAINTY

- **Earliest Reasonable**
  - Must be at Mt. Weather by 4 p.m.
  - Leave by 2:20 p.m. (1 h 40 min)
- **Most Likely**
  - Can afford to be a little late if traffic
  - Leave by 2:55 p.m. (1 h 5 min)
- **Window to leave: 35 min**
  - 2:20 p.m.–2:55 p.m.



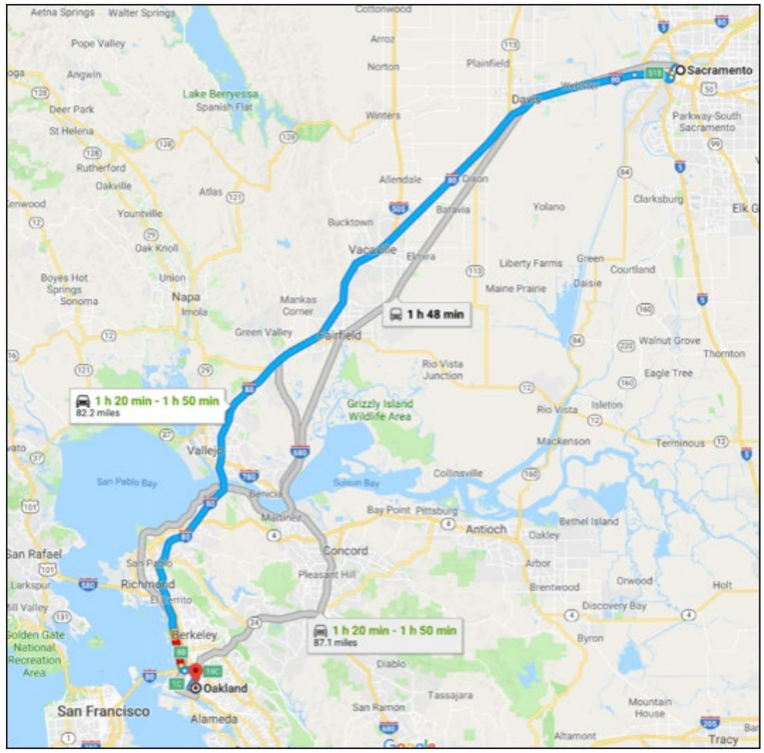
Key Points

When traveling, there are many factors that determine your arrival time. Depending on the likelihood of traffic and how acceptable it would be for you to arrive late, you will adjust your departure time. You as the traveler determine your departure time based on the risk you can handle. The same came be said for wind speed probabilities and timing information. What is your acceptable risk? What cushion factors do you take into account?

Visual 45: Sacramento, CA – Oakland, CA

TIMING UNCERTAINTY

- **Earliest Reasonable**
  - Absolutely must be in Oakland by 3 p.m.;
  - Leave by 1:10 p.m. (1 h 50 min)
- **Most Likely**
  - Some wiggle room
  - Can afford to be a little late if traffic
  - Leave by 1:40 p.m. (1 h 20 min)
- **Window to leave: 30 min**
  - 1:10 p.m.–1:40 p.m.



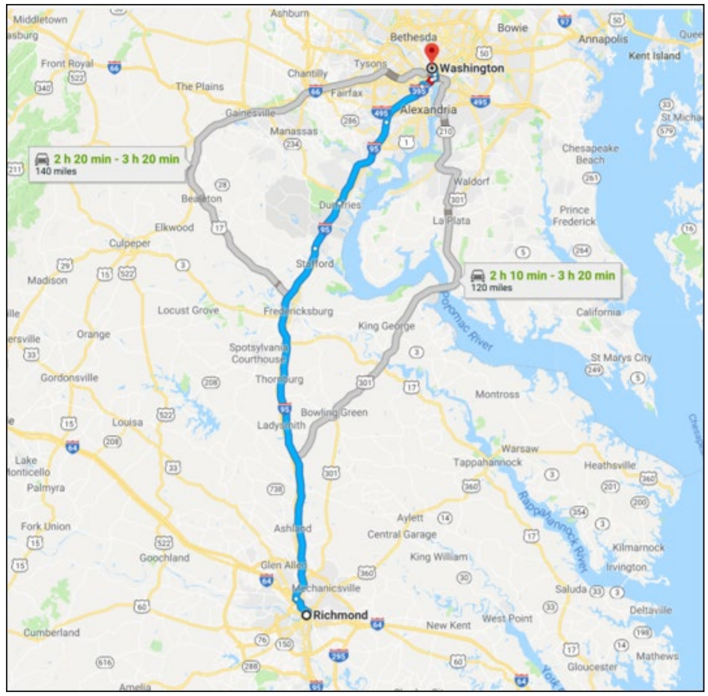
Key Points

When traveling, there are many factors that determine your arrival time. Depending on the likelihood of traffic and how acceptable it would be for you to arrive late, you will adjust your departure time. You as the traveler determine your departure time based on the risk you can handle. The same came be said for wind speed probabilities and timing information. What is your acceptable risk? What cushion factors do you take into account?

Visual 46: Richmond, VA – Washington, DC

TIMING UNCERTAINTY

- **Earliest Reasonable**
  - Absolutely must be in DC by 5 p.m.;
  - Leave by 4:10 p.m. (50 min)
- **Most Likely**
  - Some wiggle room
  - Can afford to be a little late if traffic
  - Leave by 4:34 p.m. (26 min)
- **Window to leave: 24 min**
  - 4:10 p.m.–4:34 p.m.



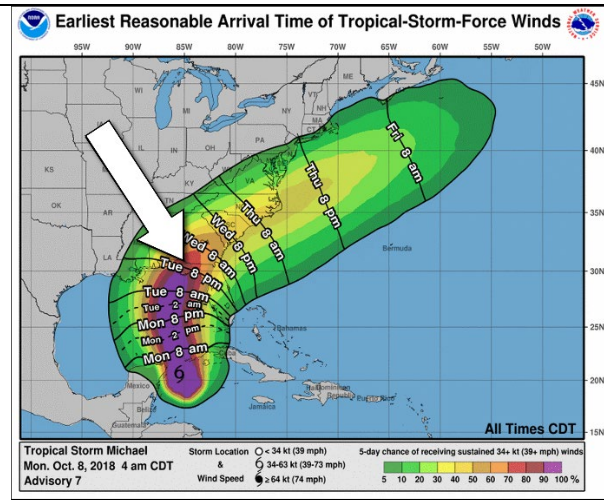
Key Points

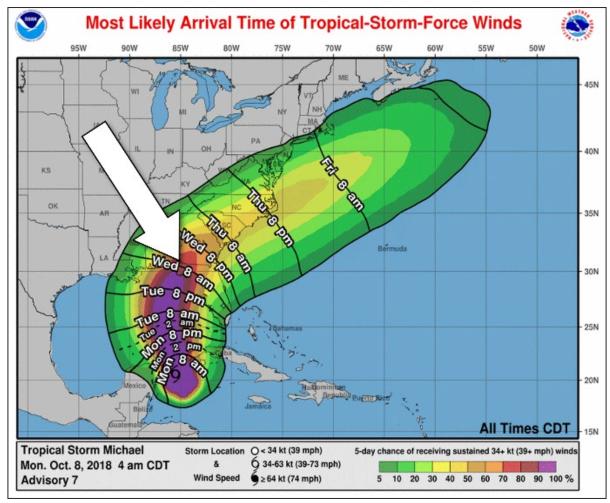
When traveling, there are many factors that determine your arrival time. Depending on the likelihood of traffic and how acceptable it would be for you to arrive late, you will adjust your departure time. You as the traveler determine your departure time based on the risk you can handle. The same came be said for wind speed probabilities and timing information. What is your acceptable risk? What cushion factors do you take into account?

Visual 47: Hurricane Michael – Tallahassee, FL

TIMING UNCERTAINTY

- **Earliest Reasonable**
  - 10% chance of onset
  - Most conservative timing
  - Tuesday 8 p.m.
- **Most Likely**
  - 50% chance of onset
  - Equally likely before as after
  - Wednesday 8 a.m.
- **Range of wind arrival: 12 h**
  - Tue 8 p.m.–Wed 8 a.m.





Key Points

This example is of Hurricane Michael in Tallahassee. You can use both earliest reasonable and most likely arrival estimates to make decisions and plans.

Visual 48: Wind Timing Uncertainty

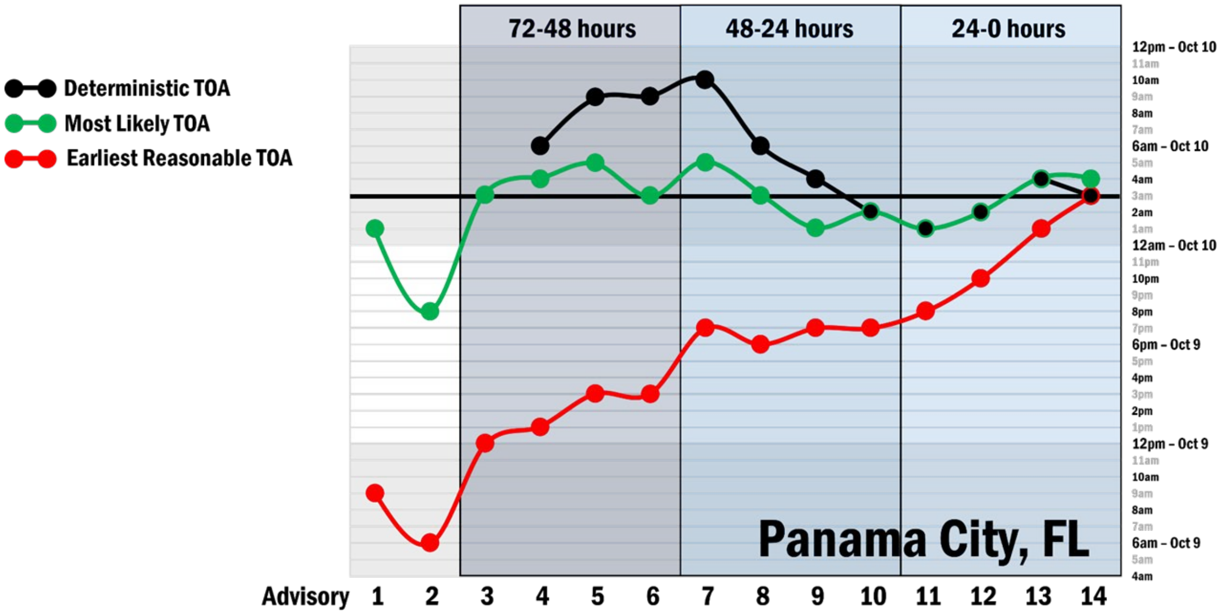
TOA Product Limitations

- Storm Size:
    - Unusually large or small storms may not be handled well, especially beyond the first 24–36 hours.
- Slow Forward Speed
    - Storms that stall or move slowly (<5mph) can have much earlier onset times than what is conveyed in the official forecast.

Key Points

In some situations, wind timing uncertainty increases, and differences between the Earliest Reasonable and Most Likely Time of Arrival graphics can become more dramatic. Cases include when the storm is unusually large or small, forecast to experience a large change in size or forecast to experience a stall or very slow movement speed.

Visual 49: Hurricane Michael (2018)

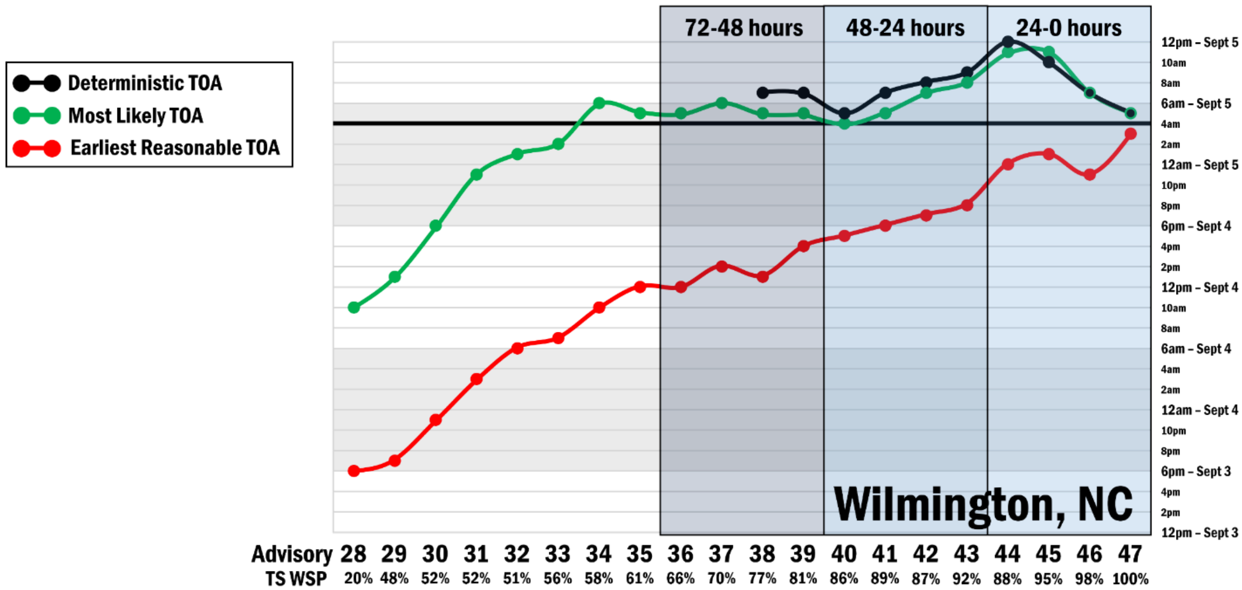


Key Points

The earliest reasonable and most likely scenarios account for track, intensity, and size uncertainty. The deterministic does not account for these things. Incorporating 0 uncertainty is going to be wrong. The range between Time of Arrival (TOA) products can be large, but they will converge as we get closer to the event.

TOA products have limitations, especially with unusually large or small storms, particularly beyond the first 24–36 hours, and with storms that stall or move slowly. In slow-moving storms, the earliest reasonable is usually way too early and is way before the actual event.

Visual 50: Hurricane Dorian (2019)

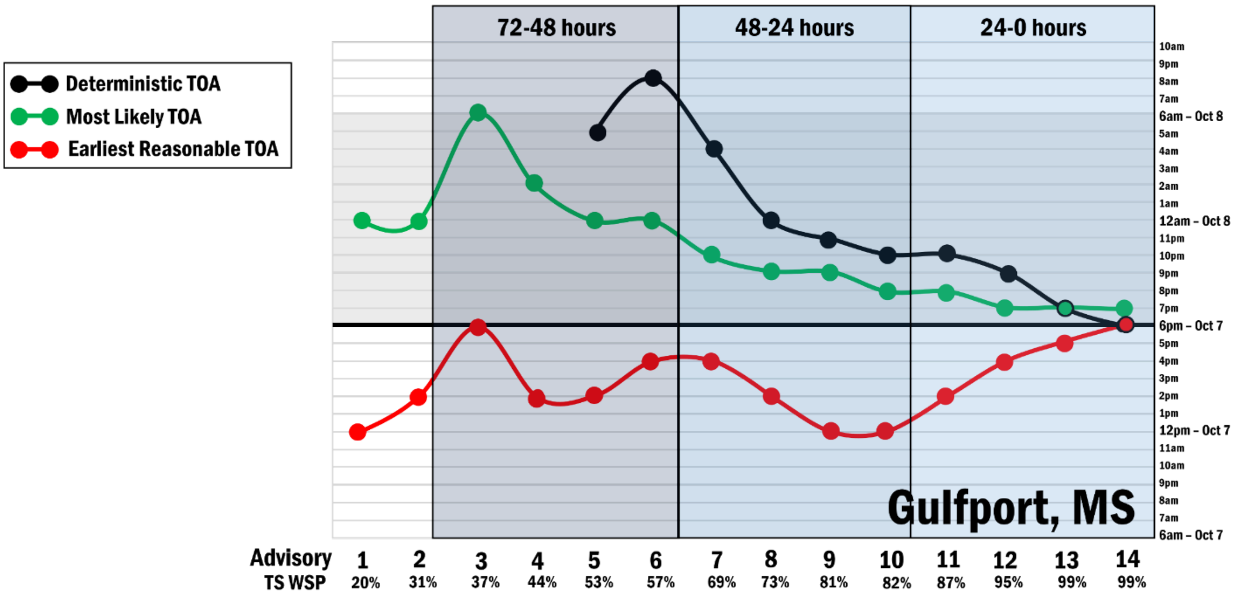


Key Points

Current Time of Arrival (TOA) products have some limitations:

- **Storms that stall or move very slowly (<5 mph)**
  - TOA products can show much earlier onset times than what is conveyed in the official forecast (e.g., Dorian).

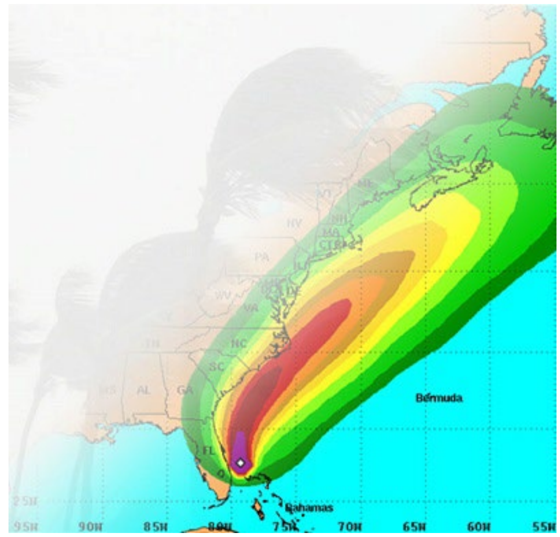
Visual 51: Hurricane Nate (2017)



Key Points

Hurricane Nate was one of the few cases where the earliest reasonable was closer to the actual start time from 48–72 hours out. Nate was the fastest moving tropical cyclone in the Gulf of Mexico on record, and its continual acceleration resulted in a lag in the most likely TOA as forecasts were catching up to its increasing speed.

Visual 52: Summary - Wind Speed Probabilities

• NHC's forecasts are improving, but errors remain. o Error cone is not the cure for the skinny black line. • Wind speed probabilities o Likelihood of tropical storm and hurricane winds o Onset timing of wind hazards • Incorporates track, intensity, and size uncertainty. o Includes weakening due to land. o Provides an assessment of wind timing and threat that accounts for NHC forecast errors.	

Key Points

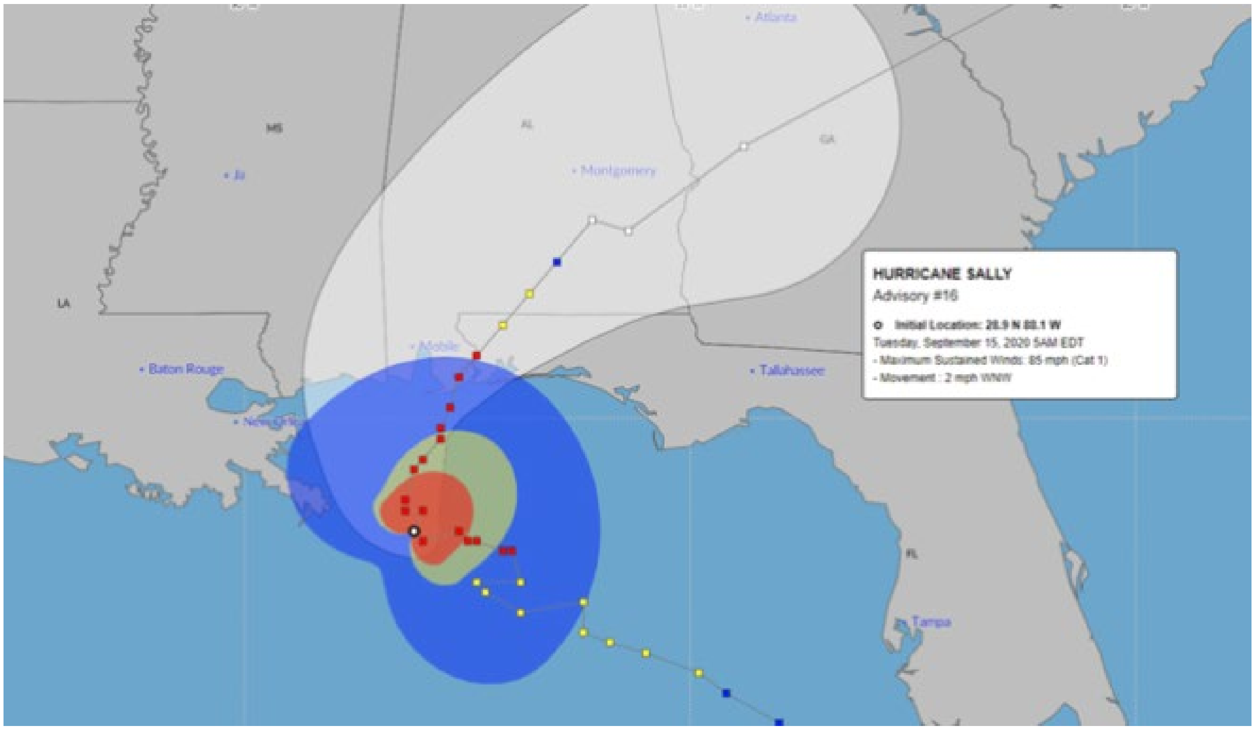
Note that these WSPs are generated by computers, not by staff, meaning they are more susceptible to the "wind shield wiper" effect and can change advisory to advisory.

Visual 53: Unit 3 Objectives Revisited

At the end of Unit 3, you should be able to:

- Explain how wind speed probability products are used to predict the chance and timing of hazardous winds.
- Explain uncertainty as it relates to arrival times for TS wind speeds.
- Identify products used to evaluate storm surge risk.
- Identify and discuss coastal surge models.

Visual 54: Hurricane Sally

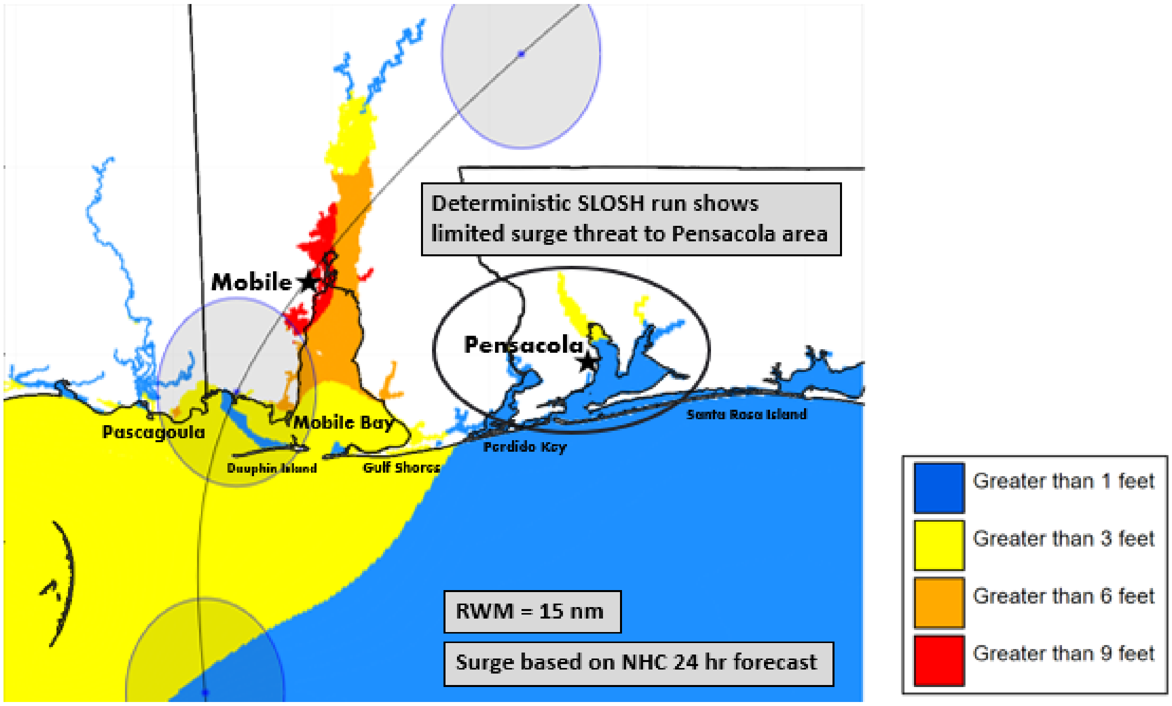


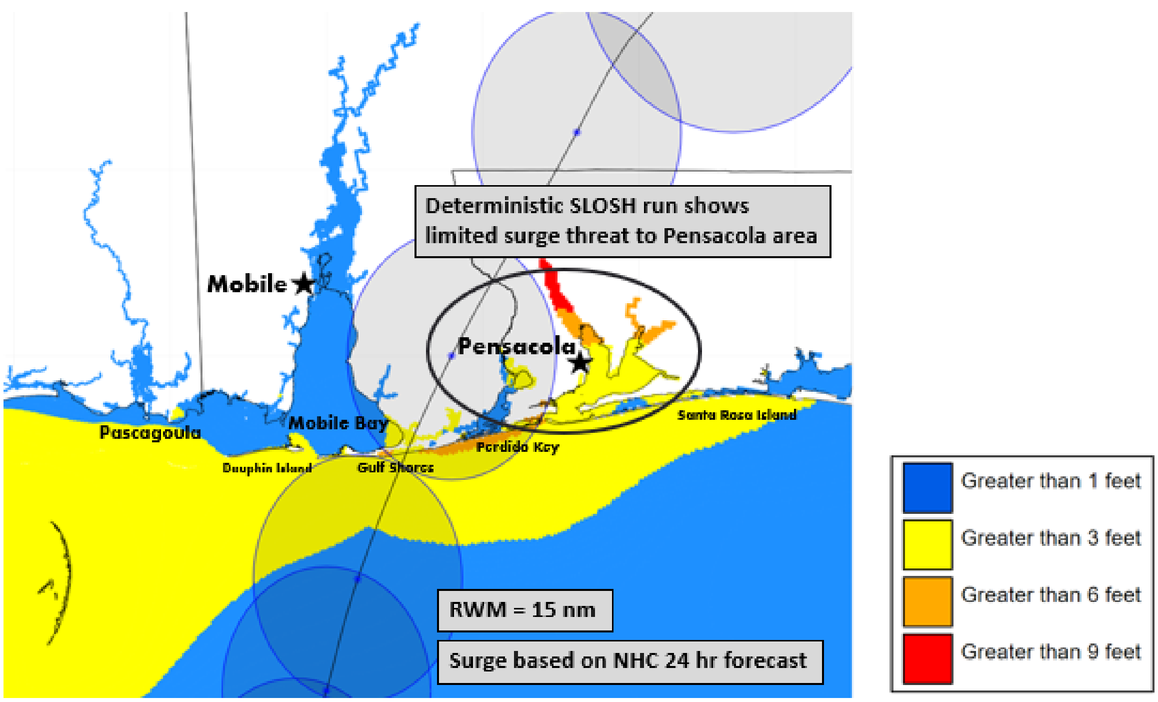
Key Points

The geography and layout of the land, as well as the track and intensity forecast uncertainty, can have a significant impact on what areas will experience the highest storm surge. As an example, we are going to use Hurricane Sally and how the storm surge was affected in and around Mobile Bay over to Pensacola, Florida.

Storm surge height depends on the coastline shape, exactly where landfall occurs, the intensity of the storm, the size of the storm, etc. It is a very complicated system with a lot of variables.

Visual 55: What a Difference a Bay Makes





Key Points

This is the forecast storm surge using a single-track, deterministic forecast for Hurricane Sally using the NHC forecast track about 12 hours before Sally's landfall. The first map shows extreme storm surge within Mobile Bay, with little to no surge threat to Pensacola.

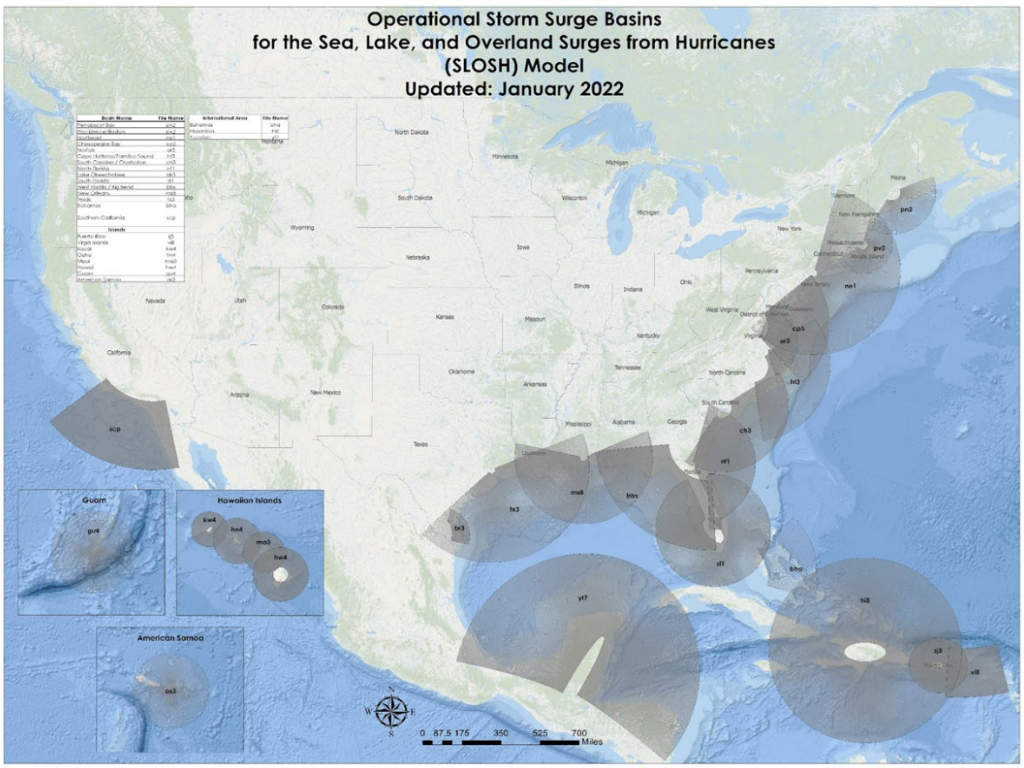
In trying to forecast storm surge for Mobile, Alabama, and Pensacola, Florida, this deterministic single run (top image) of the Sea, Lake, and Overland Surges from Hurricanes (SLOSH) model, based on the assumption of a perfect NHC forecast, showed a limited threat to Pensacola.

The final image shows the actual track. Hurricane Sally moved in the eastern side of the forecast cone and made landfall just east of Mobile Bay. This brought the highest storm surge to the Pensacola area and less surge than anticipated to Mobile Bay. This shows the risk of using a single-run deterministic model to forecast storm surge.

Visual 56: SLOSH Model

Sea,
Lake, and
Overland
Surges from
Hurricanes

A numerical model used to estimate storm surge heights for historical, hypothetical, or predicted hurricanes. The graphic shows various "basins" for the storm surge model.

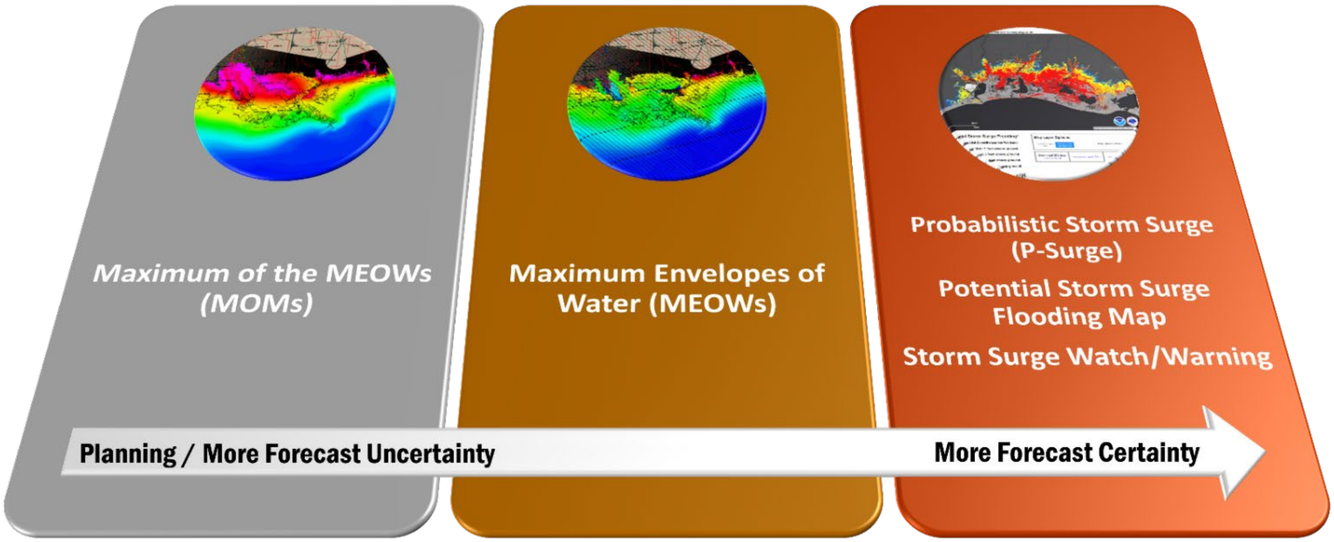


Key Points

The SLOSH model is a useful tool to help us predict storm surge.

To inform this risk, we use the SLOSH model (spell out acronym), a numerical model used to estimate storm surge heights resulting from historical, hypothetical, or predicted hurricanes. It is the NWS model for hurricanes. It works with different grids lined up along different segments of coastline, covering the extent of U.S. coasts exposed to hurricanes. The model is run in the specific grid where impact is expected.

Visual 57: Storm Surge Risk Tools



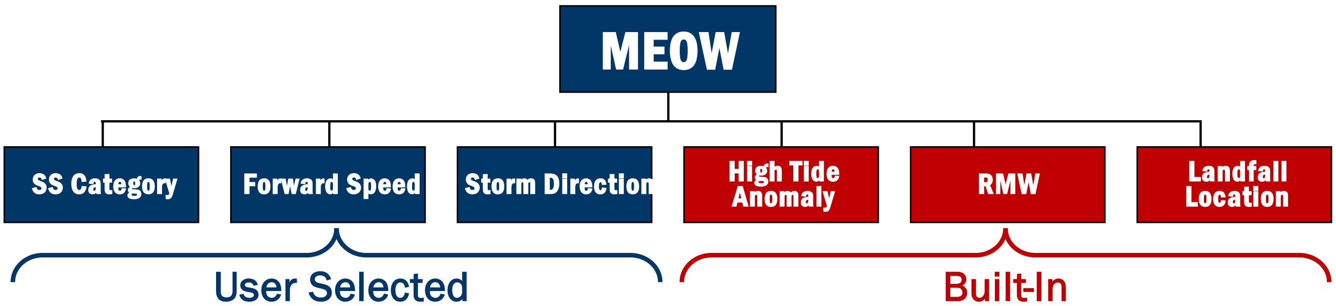
Key Points

SLOSH is the baseline model to create these products. Starting from the left side, MOMs are products used when there is a lot of uncertainty, we don't know exactly where the storm is going to make landfall, who it is going to affect, or how large the surge will be. MOMs are best used for the planning stages. When we get a bit more certain about what the surge will do, we shift to the MEOWs, allowing us to determine the general region landfall is likely to occur, what direction the storm will make landfall from, and its approximate forward speed. As we get closer to impact, we have a lot more certainty about where the storm is going to go, its size, strength, and movement that we can use real-time products, such as the P-surge (probabilistic surge) product and the Storm Surge Watch and Warning.

Visual 58: Maximum Envelope of Water

MEOWS

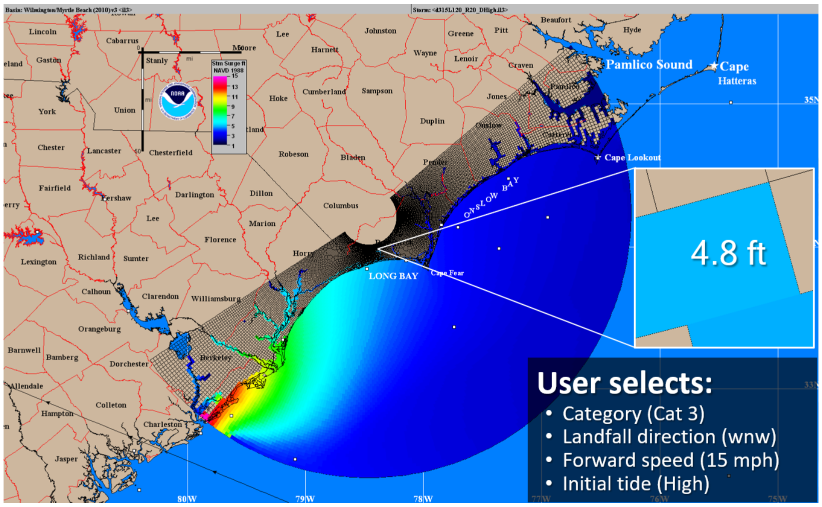
- Composite of maximum storm surge for a given set of parameters (by basin)
- Used as guidance of planning and operations

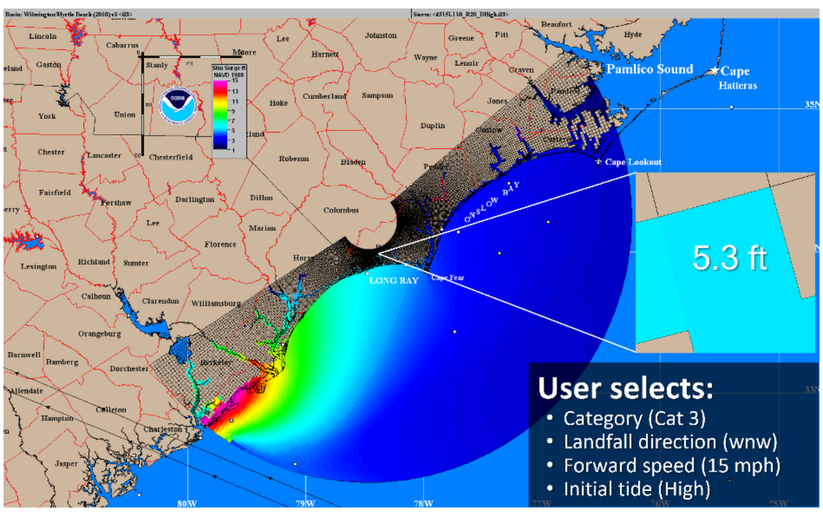


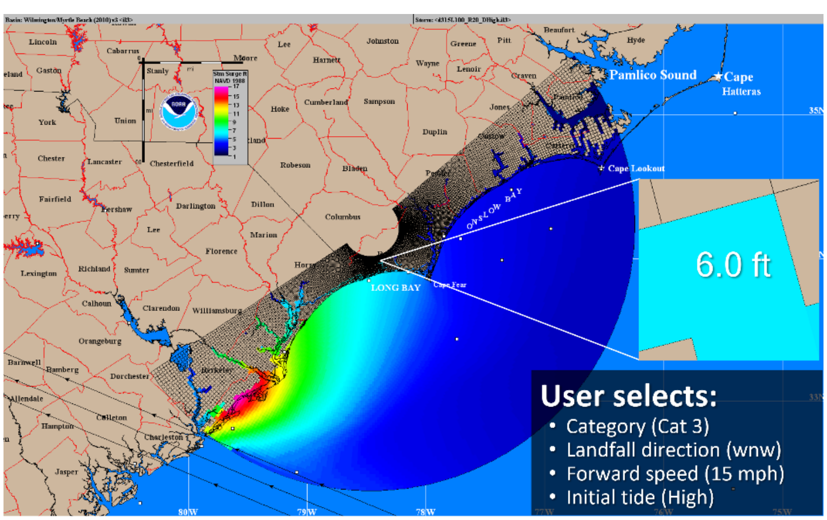
Key Points

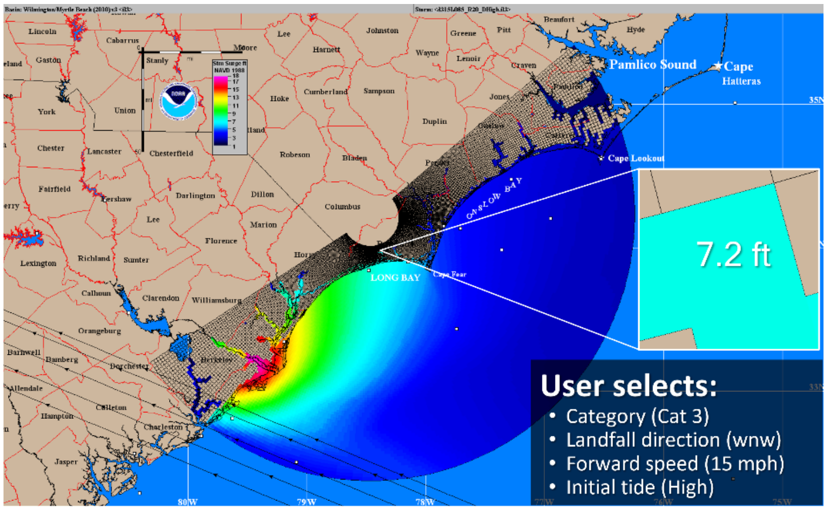
MEOW is an acronym used in storm surge prediction. MEOW stands for the Maximum Envelope of Water and contains data from the categories listed on the visual.

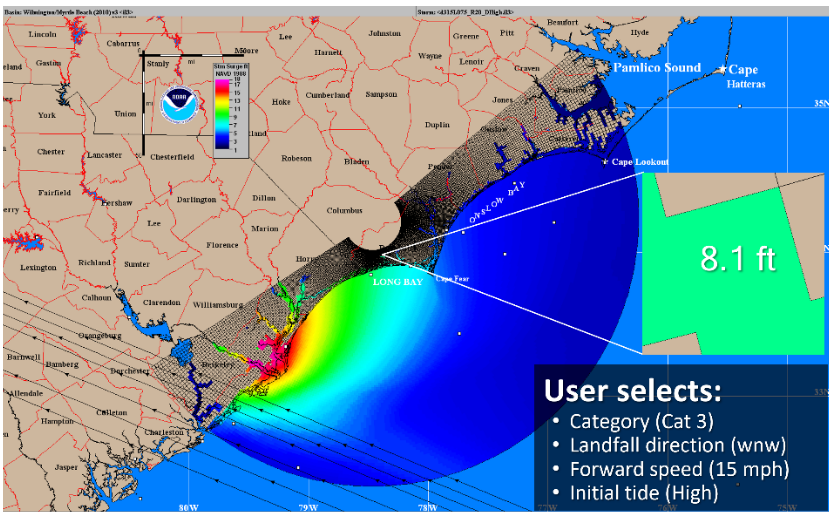
Visual 59: MEOW Example

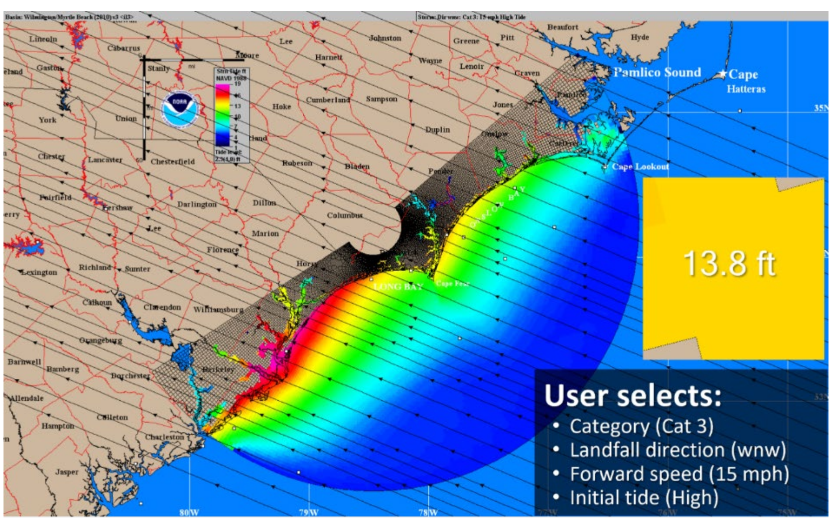







Pamlico Sound
Cape Hatteras
Cape Lookout
Onslow Bay
LONG BAY
7.2 ft
User selects:
• Category (Cat 3)
• Landfall direction (wnw)
• Forward speed (15 mph)
• Initial tide (High)


Pamlico Sound
Cape Hatteras
Cape Lookout
Onslow Bay
LONG BAY
8.1 ft
User selects:
• Category (Cat 3)
• Landfall direction (wnw)
• Forward speed (15 mph)
• Initial tide (High)


Pamlico Sound
Cape Hatteras
Cape Lookout
13.8 ft
User selects:
• Category (Cat 3)
• Landfall direction (wnw)
• Forward speed (15 mph)
• Initial tide (High)

Key Points

The MEOW provides a worst-case basin snapshot for a particular storm category, forward speed, trajectory, and initial tide level, incorporating uncertainty in forecast landfall location. MEOWs are not storm-specific and are available to view in the SDP for all operational basins. No single hurricane will produce the regional flooding depicted in the MEOWs. Instead, the product is intended to capture the worst-case high-water value at a particular location for hurricane evacuation planning.

Visual 60: Maximum of Maximums (MOM)

Worst-case for a particular category storm
Combination of many scenarios

- Forward speed
- Angle of approach
- Size (Radius of maximum wind)
- Initial tide level

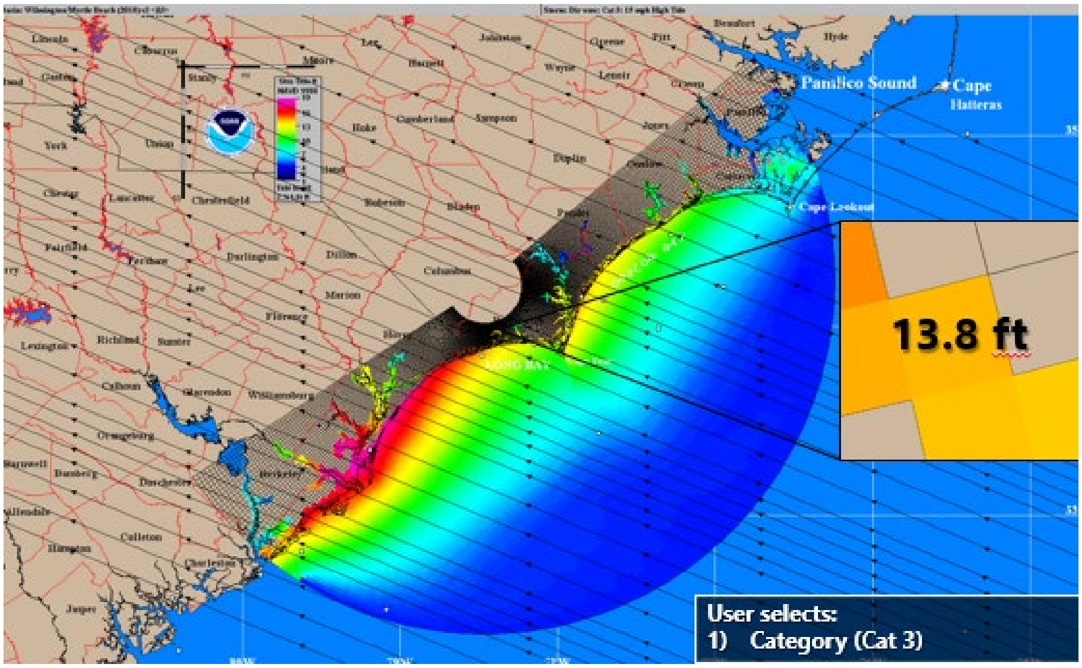
No single hurricane will produce the regional flooding depicted in a Maximum of Maximums (MOMs).

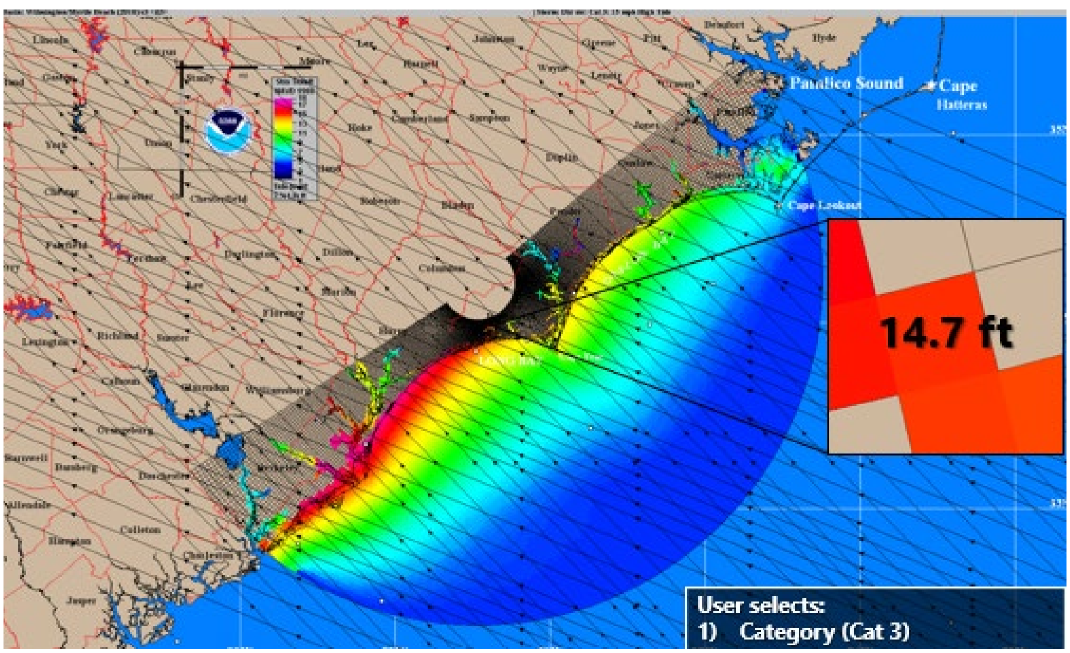
Key Points

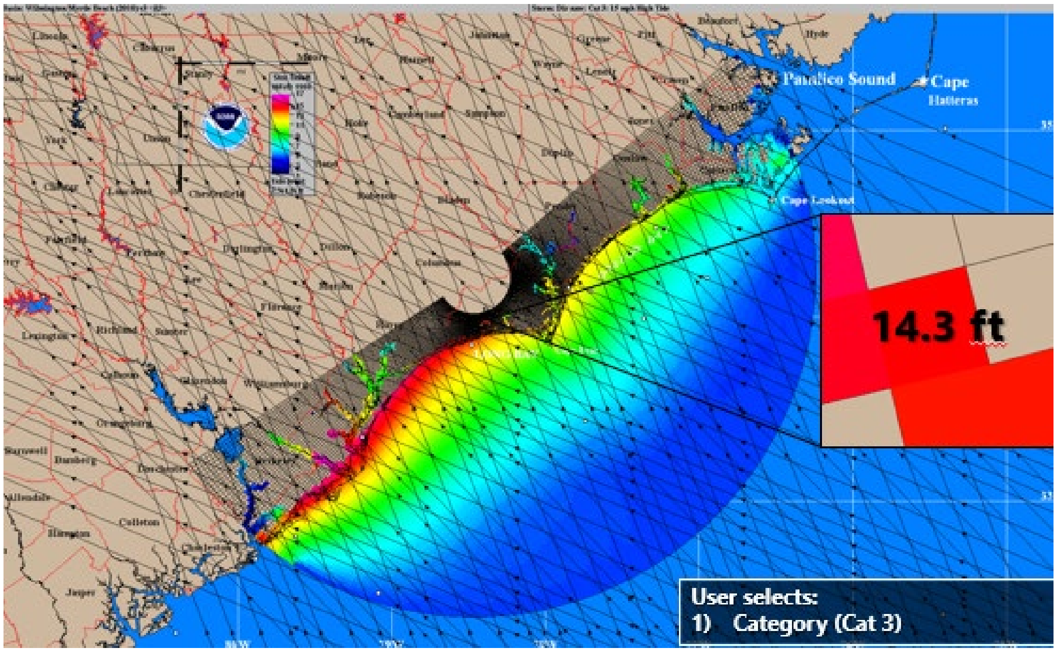
MOM is another acronym used in storm surge prediction. MOM stands for Maximum of the MEOWs. MOMs are the worst-case for a particular category and are a combination of many scenarios:

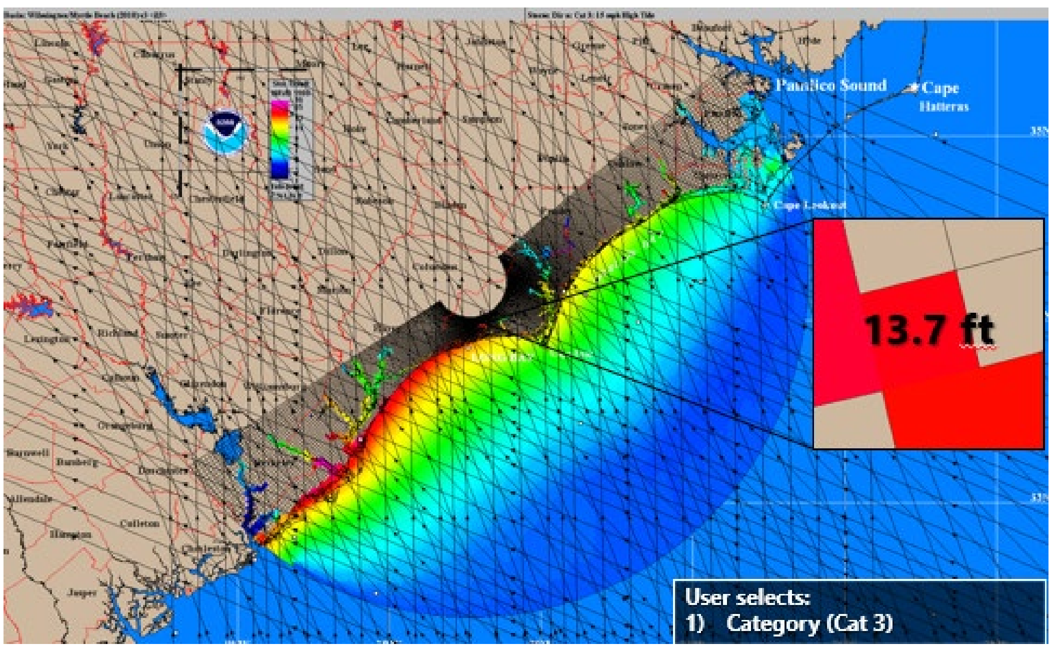
- Forward speed
- Trajectory (Angle of approach)
- Size (RMW)
- Initial tide level. No single hurricane will produce the regional flooding depicted in the MOMs. MOMs are used to develop the Nation's evacuation zones.
- It is built by collecting all the different MEOWs from a particular category and putting them together in a composite; that's the MOM. In most cases, there will only be five MOMs. For locations above North Carolina climatologically, we won't have CAT 5 hurricanes, so we only have MOMs up to Category 4.
- MOMs and MEOWs are precomputed.

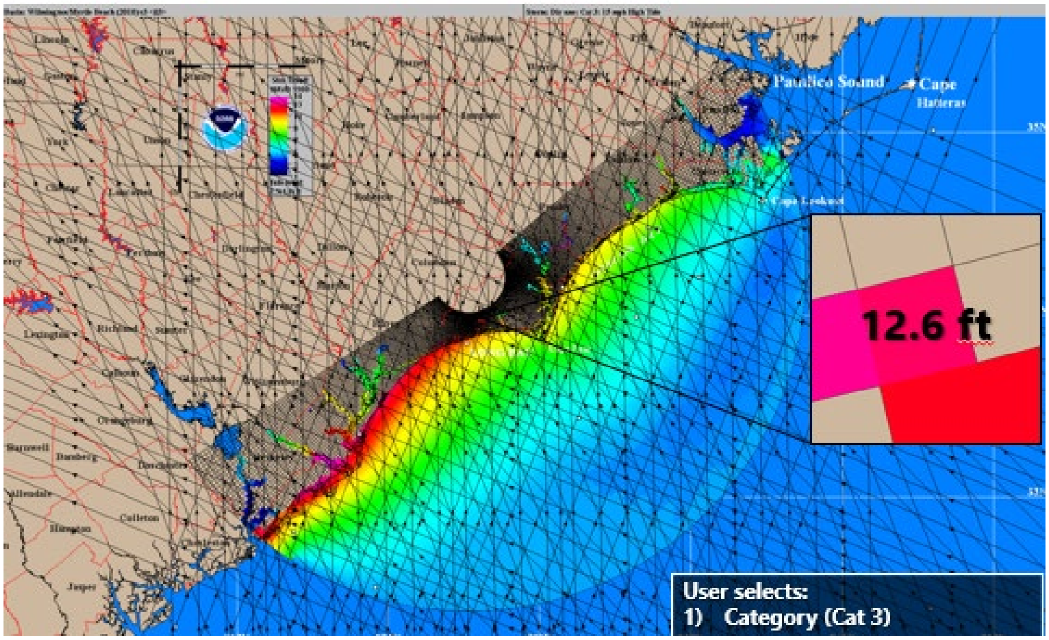
Visual 61: Maximum of Maximums (MOM) 2

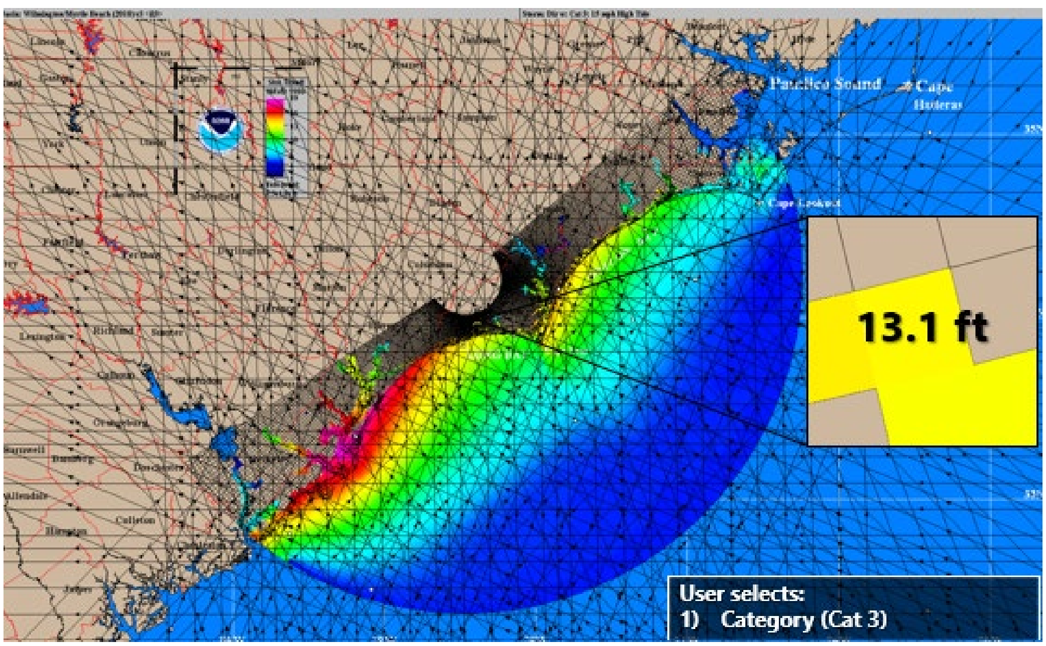


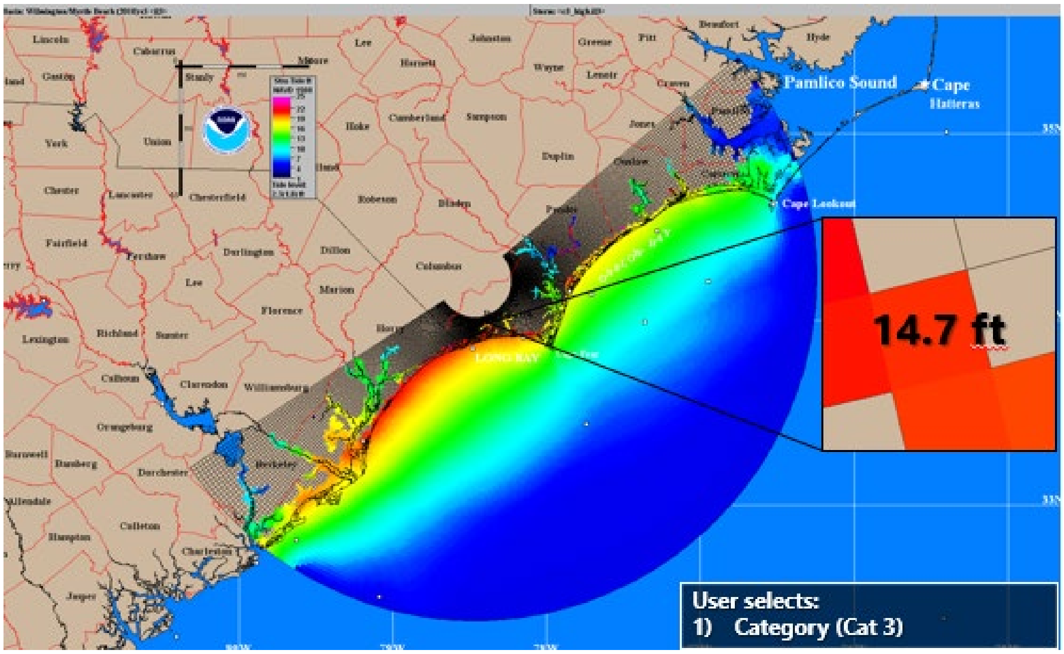



Pamlico Sound
Cape Hatteras
14.3 ft
User selects:
1) Category (Cat 3)


Pamlico Sound
Cape Hatteras
13.7 ft
User selects:
1) Category (Cat 3)


Pamlico Sound
Cape Hatteras
Cape Lookout
12.6 ft
User selects:
1) Category (Cat 3)


Pamlico Sound
Cape Hatteras
Cape Lookout
13.1 ft
User selects:
1) Category (Cat 3)



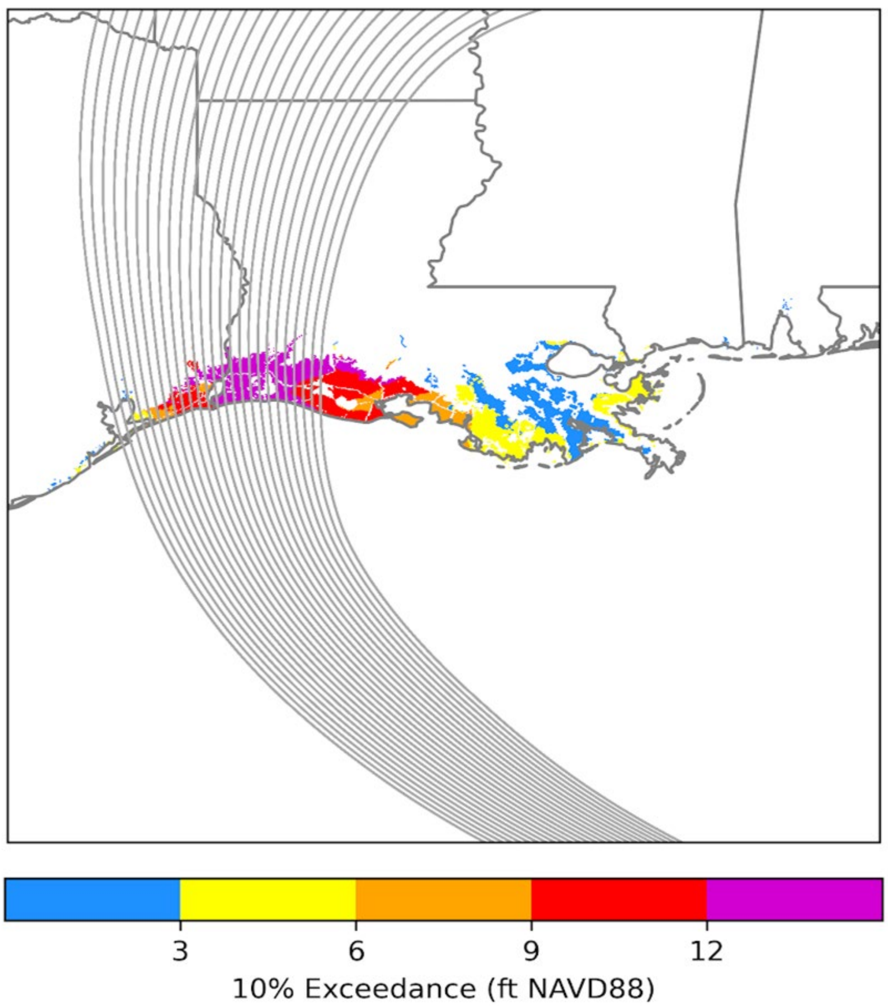
Key Points

MOM is another acronym used in storm surge prediction. MOM stands for Maximum of the MEOWs. MOMs are the worst-case for a particular category and are a combination of many scenarios.

In the above example, Cat 3 MEOWs are layered from each direction. The peak values observed from these different directions are what is displayed at each location on the Category 3 MOM.

Visual 62: Probabilistic Storm Surge (P-Surge)

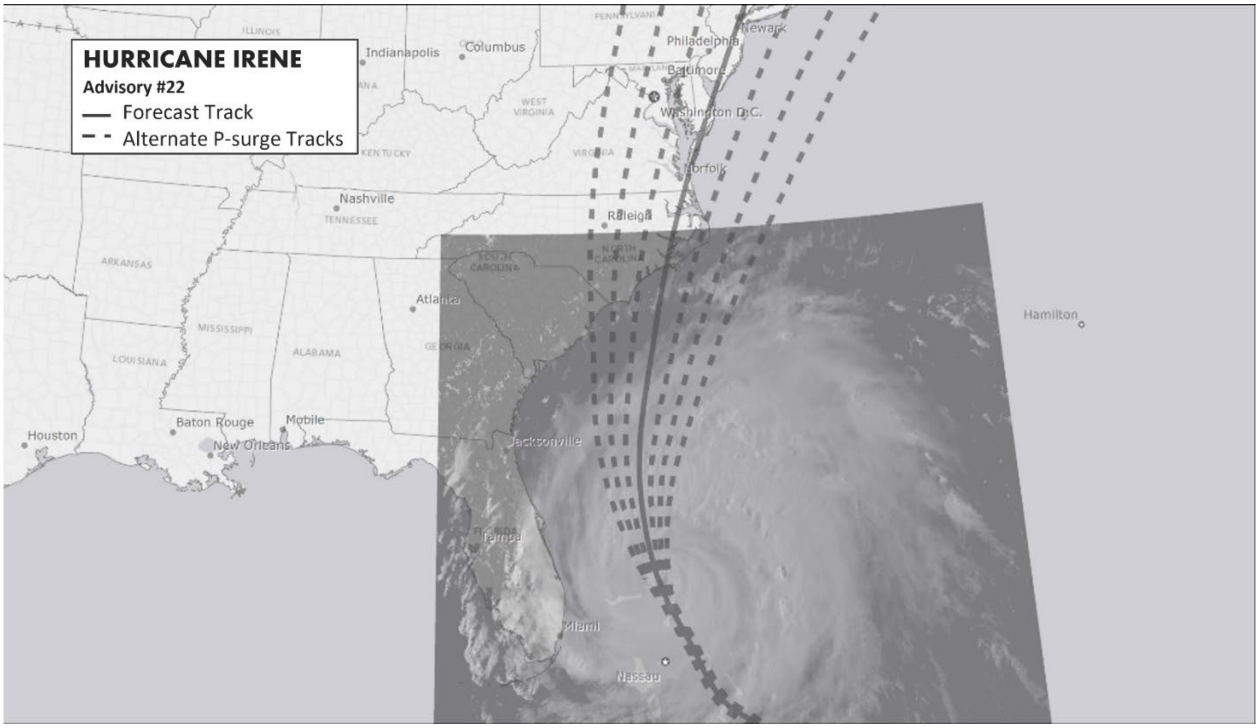
- **Based on NHC official advisory**
  - Uncertainties based on historical errors
- **Accounts for uncertainty in:**
  - Track (landfall location)
  - Size (Radius of Maximum Winds)
  - Forward speed
  - Intensity
- **Accounts for tide**
- **Heights above ground level**



Key Points

- P-surge is the name given to probabilistic storm surge, or the predicted storm surge.
- P-surge has multiple tracks and landfall locations.
- Storm surge probabilities are based on the NHC official advisory and are available approximately 48 hours before the arrival of tropical storm-force winds.
- P-surge accounts for uncertainty by adding variability in:
  - Track and landfall location
  - Size
  - Forward speed
  - Intensity
- Uncertainties are based on historical errors.
- The latest P-surge version accounts for the tide in real time, combining the forecast with the scheduled times for low and high tide.
- Guidance is provided in height above ground level.

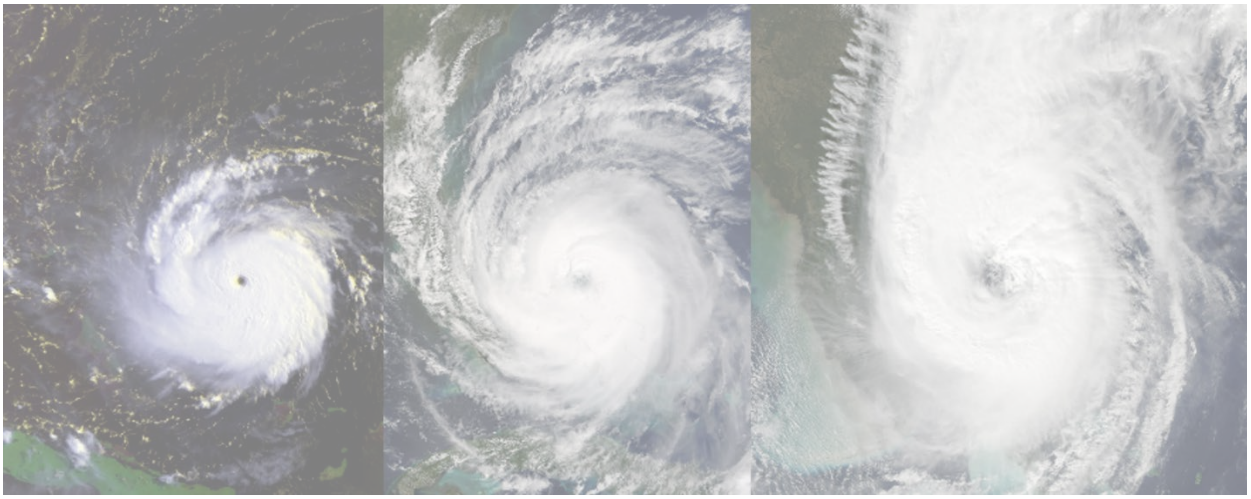
Visual 63: Probabilistic Storm Surge



Key Points

Let's look at an example of Hurricane Irene from 2011 when the storm was east of Florida. As an example, here are some (but not all) of the alternate tracks that are used to create the storm surge probabilities.

Visual 64: Sizes, Intensities, Forward Speeds



Size (RMW): Small, Medium, Large
Forward Speed: Fast, Medium, Slow
Intensity: Strong, Medium, Weak

Key Points

Besides multiple tracks and landfall locations, storm size, storm intensity, and forward speed of the storm are varied in the alternate scenarios that make up P-surge. It is all tied to what was being forecast at that moment.

Visual 65: Web-Based. Timing. Availability.

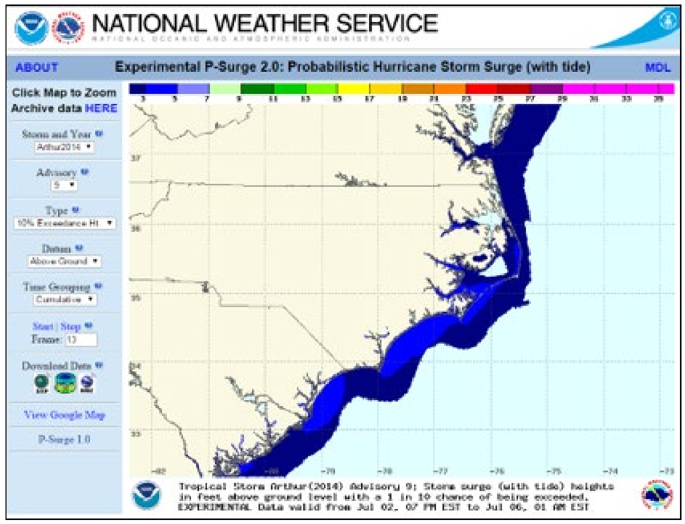
P-SURGE

Typically available with a Hurricane or Storm Surge Watch/Warning

- But can be provided up to 72 hours prior to arrival of TS winds when forecaster confidence is high.

Approx. 1 hour after advisory

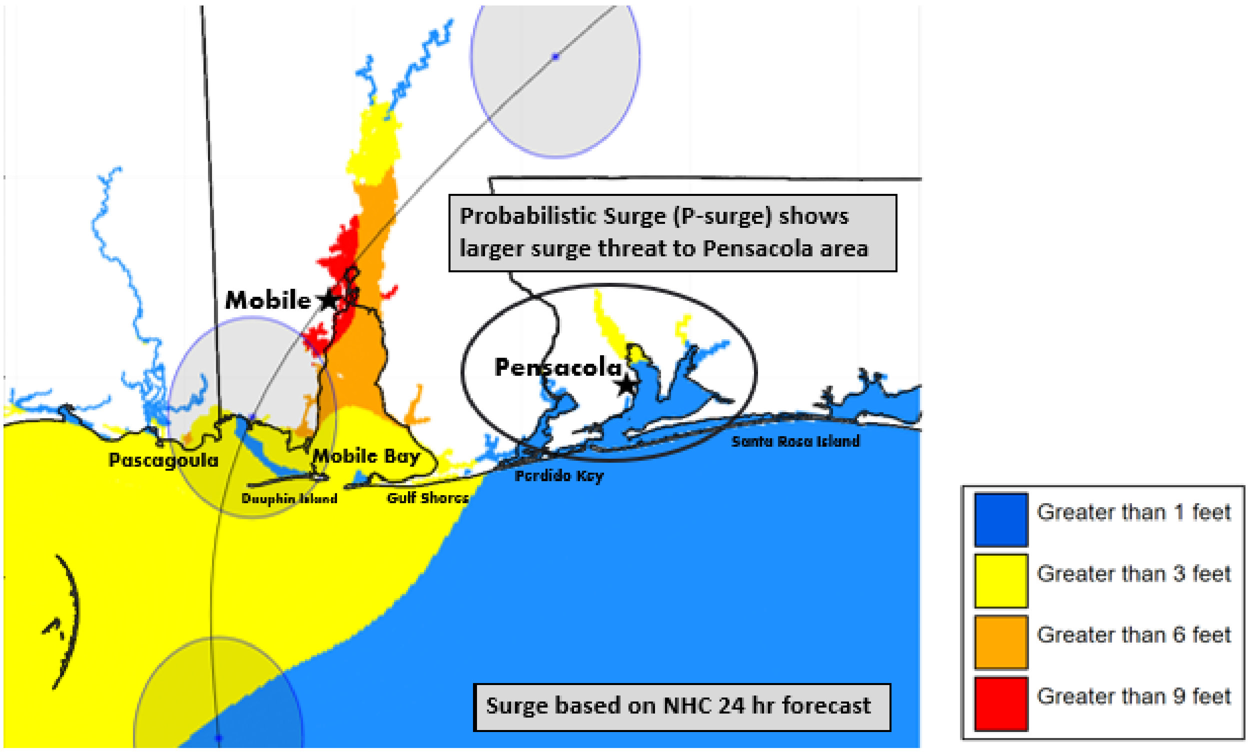
ADV TIME	P-SURGE
• 0500	**0600 EDT**
• 1100	**1200 EDT**
• 1700	**1800 EDT**
• 2300	**0000 EDT**

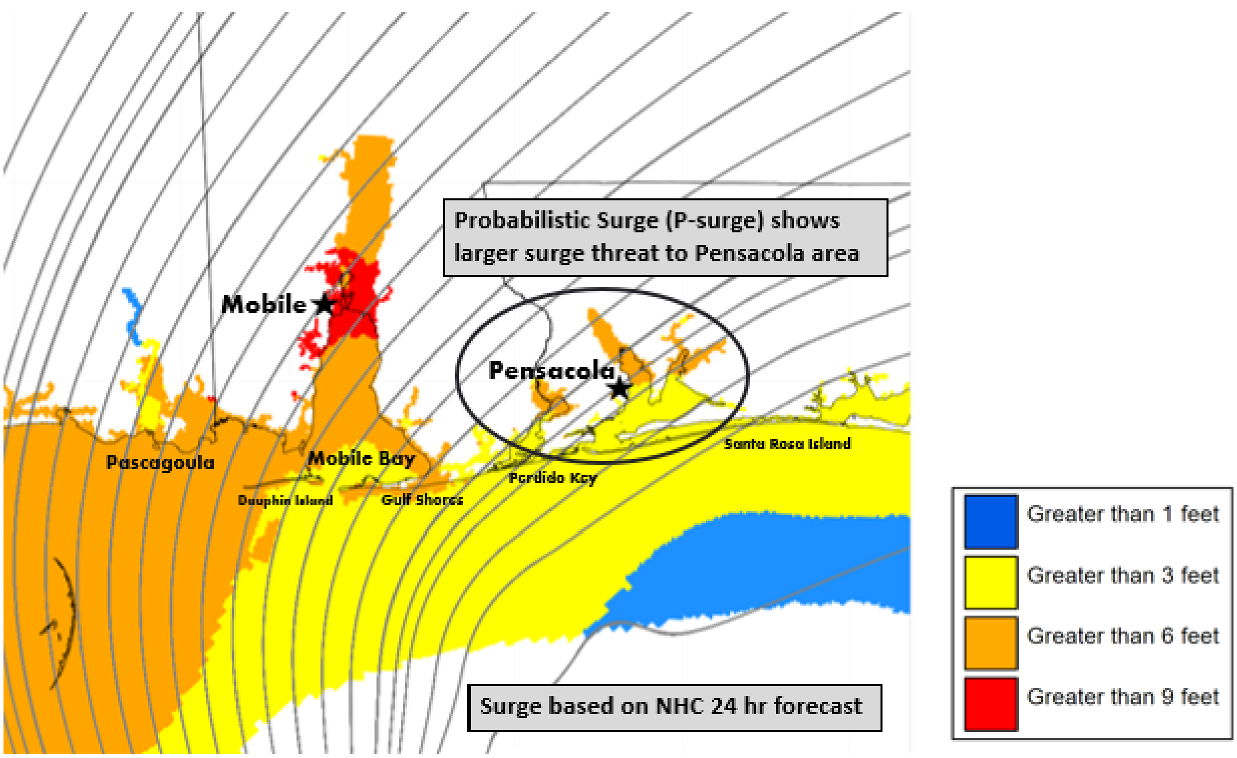


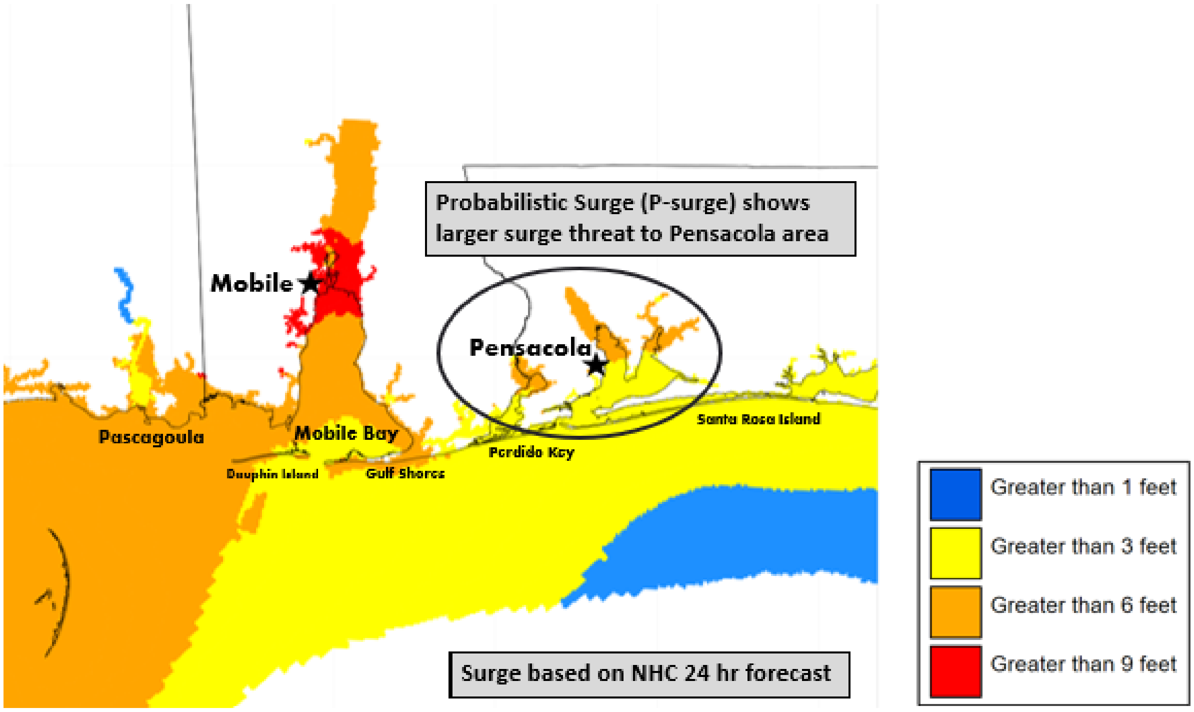
Key Points

P-surge advisories are available whenever a Hurricane Watch or Warning is in effect, which is approximately 48 hours before the arrival of tropical storm-force winds. A new development in 2023 is that this product may be available up to 72 hours before the arrival of storm-force winds when forecaster confidence is high. This is to help decision makers make key evacuation decisions with more time in advance. (May not always be available as some storms might not be defined enough to report on.) P-surge is also available 60–90 minutes after full advisory release time, so if you don't see it right away, do not worry; it typically takes around an hour to be released.

Visual 66: Deterministic vs. Probabilistic







Key Points

Looking back at our Sally case, this is the deterministic forecast of where we expected it to make landfall, just west of Mobile Bay (pushing water up Mobile Bay). During this forecast, it was only predicting a couple of feet of water in the Pensacola area.

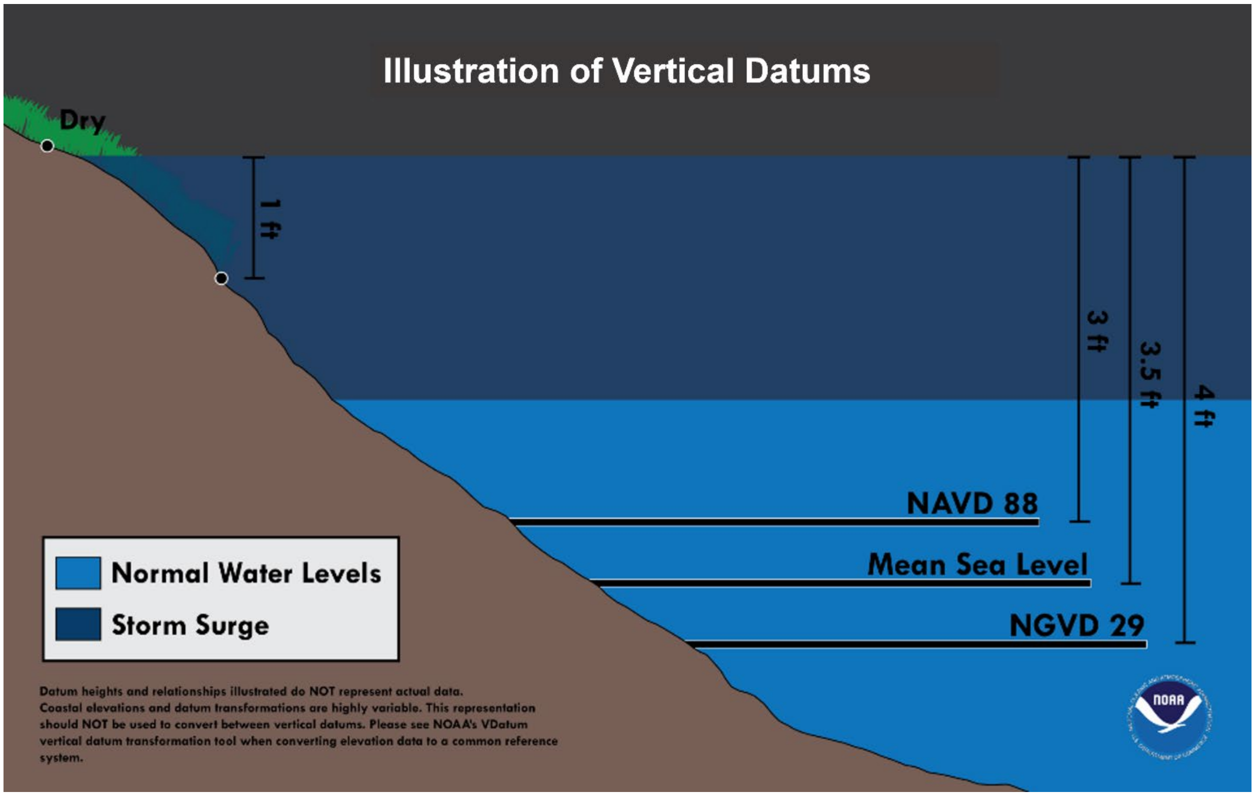
Based on P-surge, there is a reasonable worst-case scenario of greater than 6 feet in parts of Pensacola Bay. This guidance suggests that both Mobile and Pensacola have a significant chance of seeing a lot of storm surge from this storm, which wasn't as obvious in the deterministic forecast.

Visual 67: Vertical Datums – Knowledge Check

In general, NHC operational storm surge products provide water levels above which reference level?

A. Mean Sea Level (MSL)
B. Ground Level (AGL)
C. NAVD88
D. Norman Tidal Levels

Visual 68: Vertical Datums



Key Points

This visual can help you understand the concept of datums and illustrates how using a different datum will give you a different storm-surge-level reading, even when the actual water level is the same. Consider this a list of the different datums used in the illustration. As you can see, each one results in a different measurement for the storm surge.

- NGVD 29 (National Geodetic Vertical Datum from 1929). Using this datum, we could describe the water level as being 4 feet over NGVD 29.
- Mean Sea Level (the sea level halfway between the mean levels of high and low water) - with mean sea level it would be 3½ feet.
- NAVD 88 (North American Vertical Datum of 1988, more accurate than NGVD 29) - this gives us 3 feet.
- Normal Dry Level - this show us how high the water is on a particular point to the beach but gives us a SS of 1 foot. Most products that we build use this level.
- Dry Grass - this shows us that there is no storm surge.

In some of the other decision support we do, the NHC can provide info using other datums. For example, if you as a decision maker need to know if the storm surge will overtake a particular bridge or road, and you know how high that is compared to the other datum sets.

Visual 69: Potential Storm Surge Flooding Map

- **Height above ground that the water <u>could</u> reach.**
  - Reasonable worst-case scenario for any individual location.
  - Values have a 10% chance of being exceeded.
- Not a flooding footprint.
- Issuance and availability are the same as P-surge.

Key Points

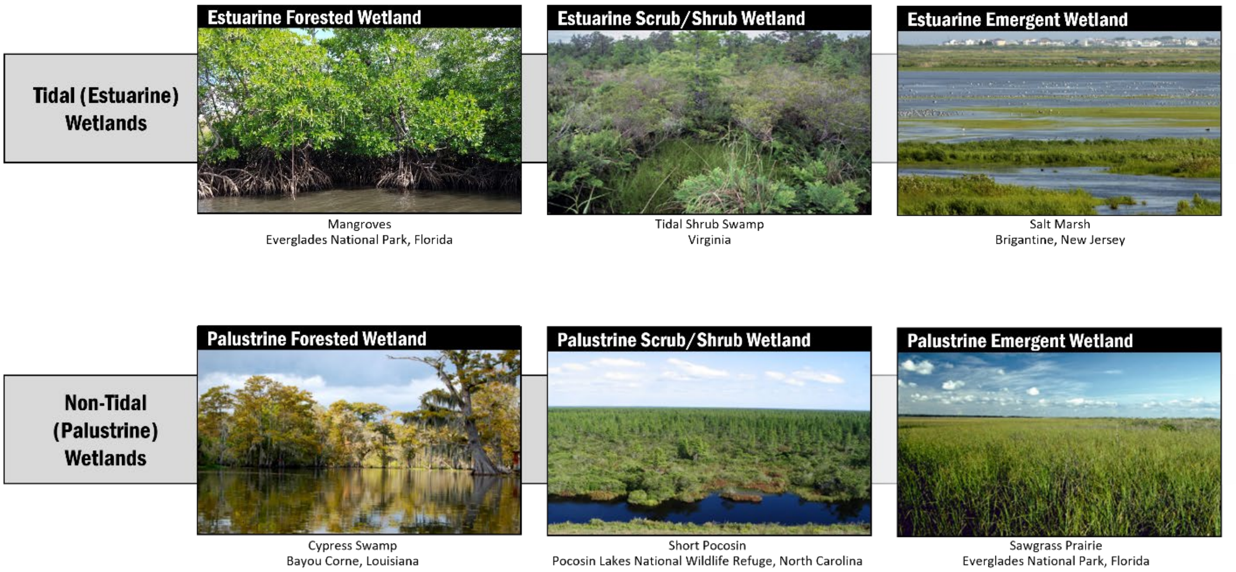
We use the P-surge data to create a potential storm surge flooding map. These color-coded maps show the height above ground that the water could potentially reach.

- Reasonable worst-case scenario for any individual location.
- Shows inundation levels that have a 10% chance of being exceeded.

The first map is issued at the same time as the initial Hurricane Watch, or, in some cases, with a Tropical Storm Watch.

These maps are available about 60 to 90 minutes following the advisory release.

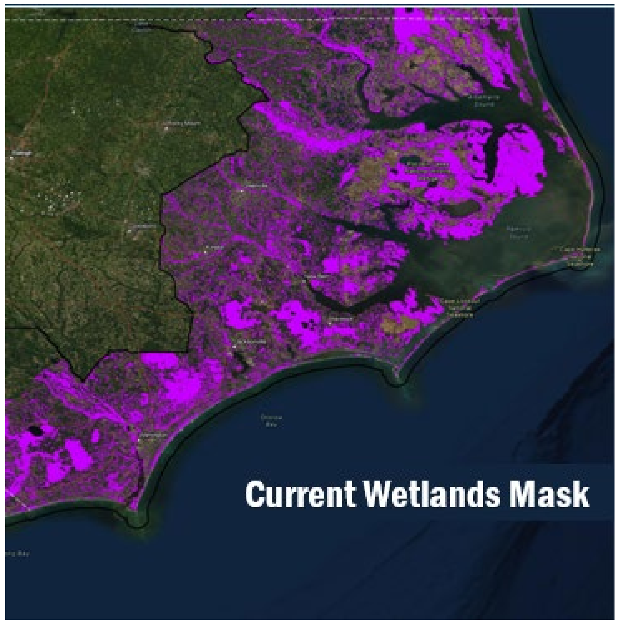
Visual 70: Intertidal/Wetlands



Key Points

On this product, there is an option to toggle on or off the intertidal or wetlands mask. These are areas along the coastline where peoples don't live, that can be submerged by storm surge but are already wet. The first row, tidal wetlands, shows the areas that are already submerged at hightide, so you can focus on areas that aren't submerged at hightide and really matter when there is an incoming storm surge. Starting this year, we are adding a new type of wetland map that occurs further inland than where the saltwater estuaries go. These are freshwater systems like cypress swamps and everglades. These are still connected to the ocean enough to be affected by storm surge. Usually people don't live here, so we wanted to make sure that we mapped those. These layers can be toggled on and off, depending on if you are concerned about these areas or not.

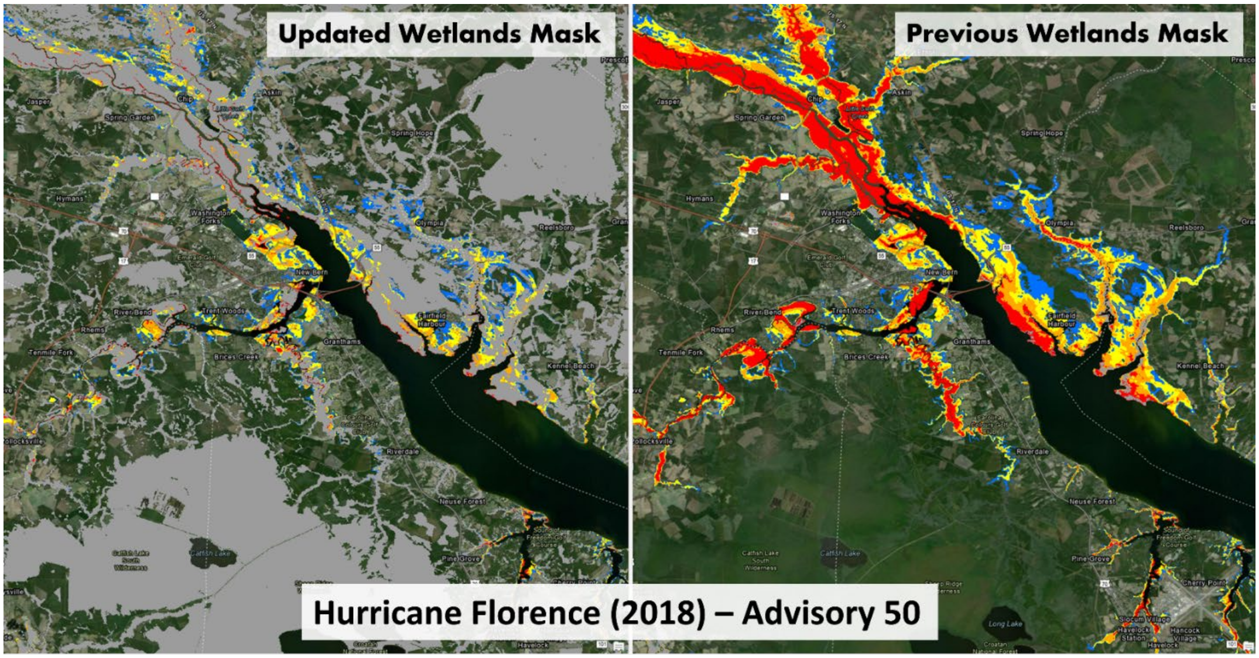
Visual 71: Intertidal/Wetlands Mask



Key Points

This is an example of the current Wetlands Mask that is available when viewing surge modeling. Areas in pink are normally wet at high tide.

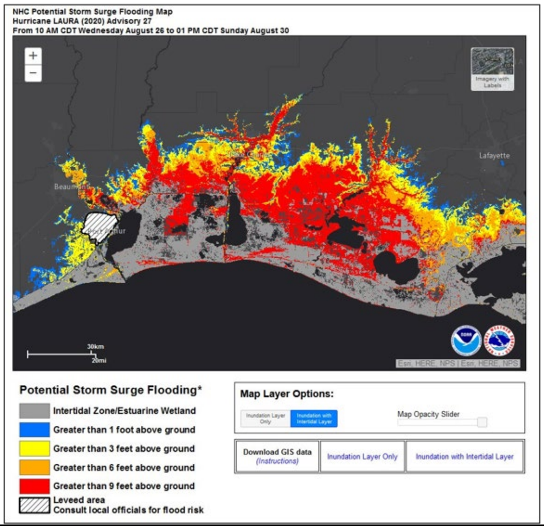
Visual 72: Intertidal/Wetlands Mask 2

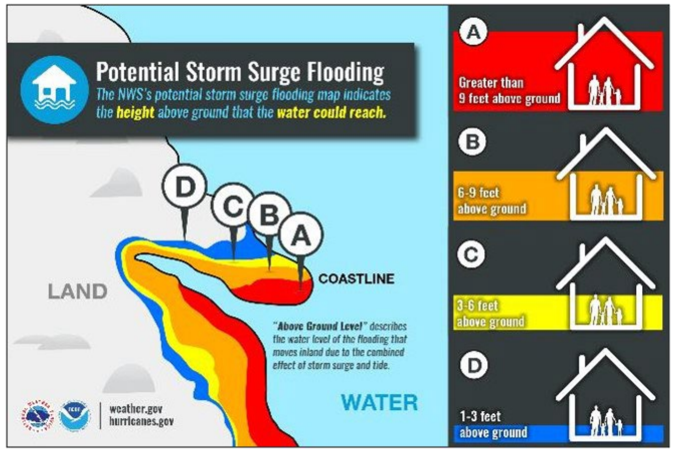


Key Points

This is an example from Hurricane Florence in 2018. On the right side is the potential storm surge flooding map that you would have gotten for Florence, with a lot of surge predicted upriver. It is not that flooding didn't occur there, but people don't live in those locations around the wetlands. On the left side, we see the graphic displayed including the wetlands, focusing our attention on the places where people live.

Visual 73: Messaging P-Surge

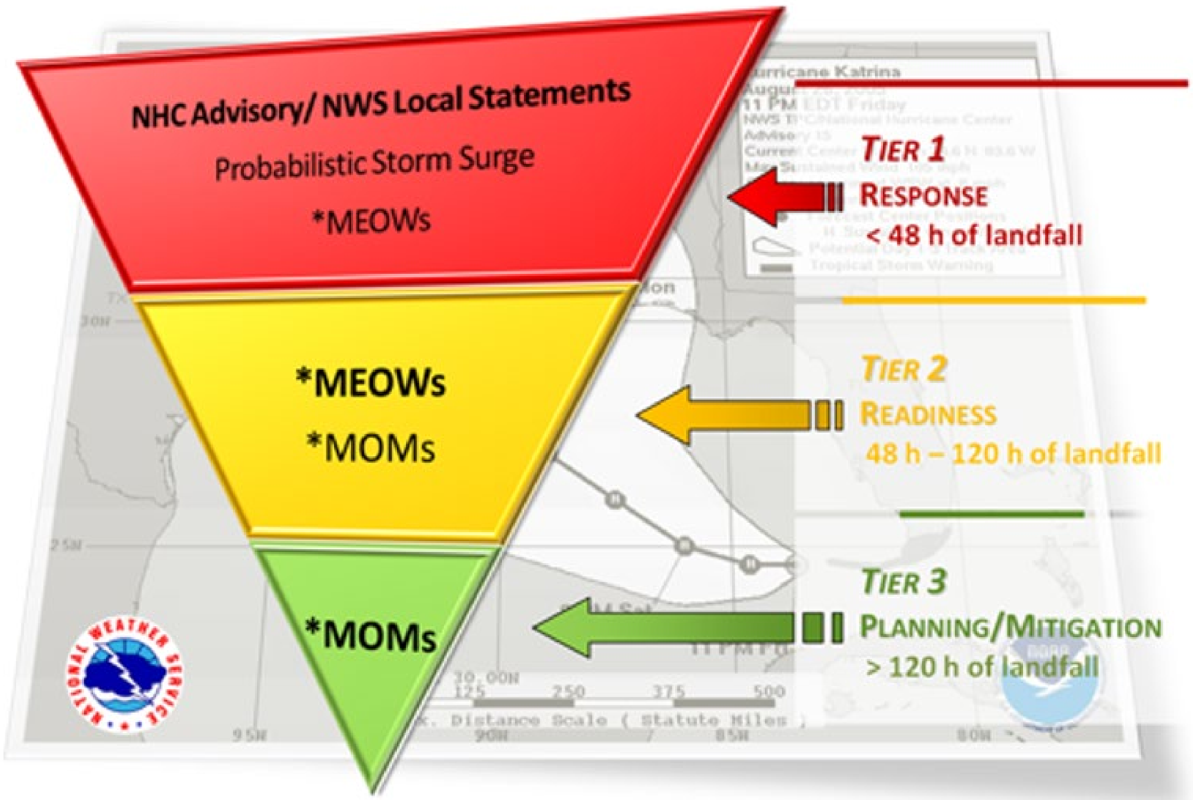




Key Points

Here is a summary of the P-surge flooding map. On the left is an example from Hurricane Laura in 2021, and on the right is an infographic showing what the colors are telling you the heights that the water could reach from Laura's storm surge. If you are in the red zone, it can come up to the roof level on a one-story house. If you're in the orange zone, flooding could potentially be between 6–9 feet, in the yellow zone 3–6 feet, and the blue zone 1–3 feet. Think of P-surge as a reasonable to worst-case scenario.

Visual 74: Decision Support Timeframes



Key Points

To recap everything that we talked about, this graphic is a decision support wedge or timeframe based on how far away we might be from impact during a storm and for releasing storm surge guidance during a tropical cyclone event.

Tier 1

Response: <48 hours before landfall. Watches and Warnings are in effect.

- Use information from
  - NHC Advisory
  - National Weather Service (NWS) Local Statements
- P-surge data starts to become available which comes with a potential storm surge flooding map as well.

Tier 2

Readiness: 48–120 hours before landfall. Now we can start to account for characteristics of the storm.

- MEOWs- add variables. Start to use forecasts.
- MOMs

Tier 3

Planning/Mitigation. Use MOMs

- More than 120 hours before landfall.
- Maybe there isn’t a storm even heading towards our location.
- Generally, what’s used for planning and creating evacuation zones along the coastline.

Visual 75: Questions/Comments?

Unit 4: Making Informed Decisions

Visual 1: Unit 4: Making Informed Decisions

Unit 4:

Making Informed Decisions

Key Points

Unit 4 brings together the previous three units' information in application. This unit is intended to be an activity-driven exploration of how to use the products introduced earlier in the course to prepare for a tropical storm event.

Visual 2: Unit Objectives

At the end of this unit, the participants will be able to:

- Identify the components of the Hurricane Evacuation Study (HES).
- Explain clearance times and their use.
- Identify the capabilities of HURREVAC.

Apply NHP products and services for planning and operational purposes.

Visual 3: What Have We Learned Today?

Key Points

Review from previous units:

- The potential damaging and deadly impacts of hurricane hazards, including Storm Surge, the hazard with the most destructive potential.
- Where you should go to get the best information about the forecast and how to use the products that will help you stay informed.
- How track errors are a fact of life and how we have developed ways to express our uncertainty.

Student Manual	A good understanding of hurricane hazards and forecast products provides the foundation for responding to tropical cyclone incidents. There are additional resources that will be discussed that assess location-specific vulnerability and provide planning factors unique to each jurisdiction.

Visual 4: What are Best Practices?

Key Points

The goal is to use the information learned so far to make good decisions for your community. Decisions like:

- How will you communicate threats to the public?
- How will you protect your community?
- How will you evacuation the population?

These decisions should be based on a plan, using the Planning Process. They should be based on sound research and the specific hazards that you are likely to encounter with a given story.

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Key decisions include protective actions, such as road, bridge, and tunnel closures, along with the timing and scope of evacuation orders. Pre-planned response activities, developed using the best available scientific analysis of hazards and vulnerability, make difficult decisions much easier when hurricanes threaten our communities.

Visual 5: It's Not the Plan. It's the Process.

<table>
<tr>
<td>

- **Step 1**
  - Form a Collaborative Planning Team
- **Step 2**
  - Understand the Situation
- **Step 3**
  - Determine Goals and Objectives
- **Step 4**
  - Plan Development
- **Step 5**
  - Plan Preparation, Review & Approval
- **Step 6**
  - Plan Implementation & Maintenance

</td>
<td></td>
</tr>
</table>

Key Points

- What is a better decision? One made in uncertain conditions, or one made in uncertain conditions that is based on a plan?
- A finished planning product can provide tremendous insight into leadership intent, objectives, roles and responsibilities, lines of effort, etc. The process to develop a plan also lends to better capability, because it synchronizes leadership intent and objectives among all stakeholders and informs planning team members of requirements, gaps, and potential solutions to carry out a hurricane response.
- The Six-Step Planning Process helps to ensure that appropriate stakeholder organizations are represented from the beginning, including during the information-gathering phase.

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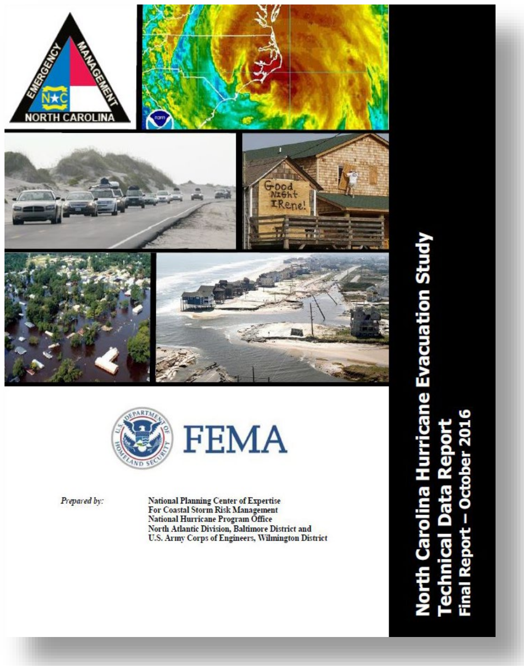
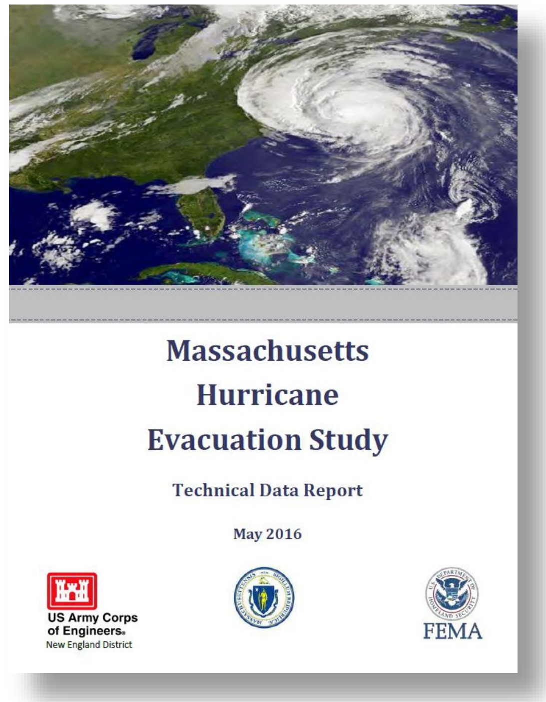
- A Sound Plan is informed, actionable, and socialized, having been developed, tested, and exercised with the buy-in and contributions of every organization with responsibilities to carry it out.
- For more information on the six-step planning process, see Comprehensive Preparedness Guide (CPG) 101 Developing and Maintaining Emergency Operations Plans September 2021, Version 3.0.

Visual 6: Better Information – HES





Key Points

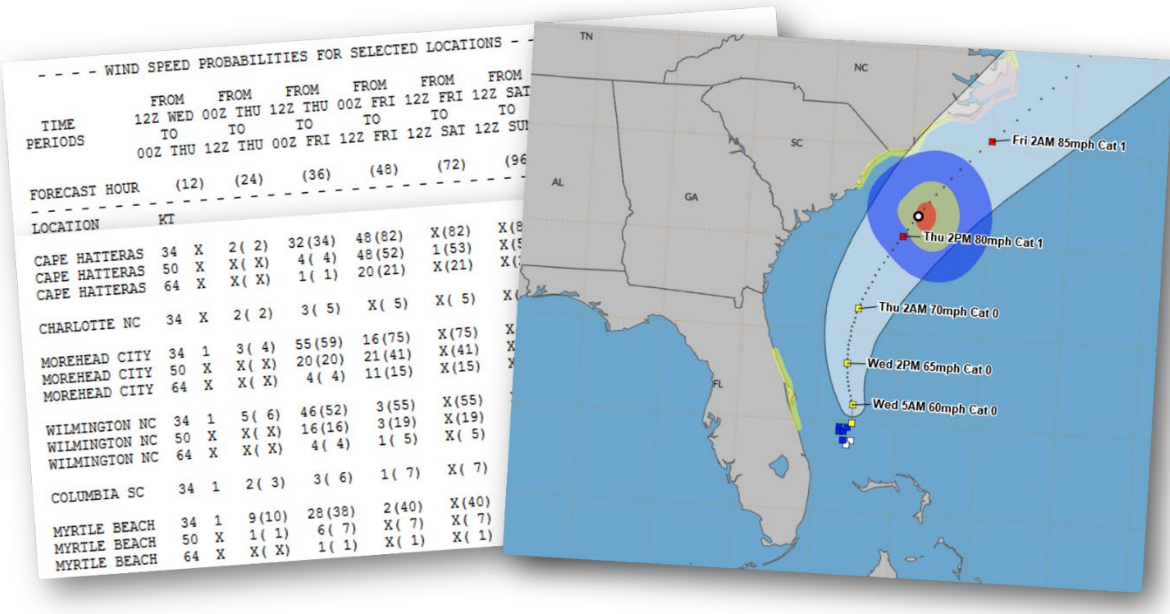
What information would assist you in making a better plan and, ultimately, better decisions?

- How do you know if your community is vulnerable to storm surge?
- Why do we evacuate people?
- What infrastructure is vulnerable?
- How do I know when it's time to call an evacuation?
- How do I visualize the forecast?
- How long would it take for people to get to a point of safety?
- How many shelters does our community need?
- How do I disseminate our message to the public?

Student Manual

The U.S. Army Corps of Engineers act as project managers for Hurricane Evacuation Studies (HES). Some studies cover one state; states with longer coastlines have multiple studies, covering different coastal regions.

Visual 7: Right Tools, Time, and Reason



- - - - WIND SPEED PROBABILITIES FOR SELECTED LOCATIONS - - -

TIME PERIODS		FROM 12Z WED TO 00Z THU	FROM 00Z THU TO 12Z THU	FROM 12Z THU TO 00Z FRI	FROM 00Z FRI TO 12Z FRI	FROM 12Z FRI TO 12Z SAT	FROM 12Z SAT TO 12Z SU
FORECAST HOUR		(12)	(24)	(36)	(48)	(72)	(96
LOCATION	KT						
CAPE HATTERAS	34	X	2(2)	32(34)	48(82)	X(82)	X(8
CAPE HATTERAS	50	X	X(X)	4(4)	48(52)	1(53)	X(5
CAPE HATTERAS	64	X	X(X)	1(1)	20(21)	X(21)	X(
CHARLOTTE NC	34	X	2(2)	3(5)	X(5)	X(5)	X(
MOREHEAD CITY	34	1	3(4)	55(59)	16(75)	X(75)	X
MOREHEAD CITY	50	X	X(X)	20(20)	21(41)	X(41)	X
MOREHEAD CITY	64	X	X(X)	4(4)	11(15)	X(15)	X
WILMINGTON NC	34	1	5(6)	46(52)	3(55)	X(55)	
WILMINGTON NC	50	X	X(X)	16(16)	3(19)	X(19)	
WILMINGTON NC	64	X	X(X)	4(4)	1(5)	X(5)	
COLUMBIA SC	34	1	2(3)	3(6)	1(7)	X(7)	
MYRTLE BEACH	34	1	9(10)	28(38)	2(40)	X(40)	
MYRTLE BEACH	50	X	1(1)	6(7)	X(7)	X(7)	
MYRTLE BEACH	64	X	X(X)	1(1)	X(1)	X(1)	

Key Points

Situational awareness is crucial during all phases of incident response. When decisions must be made for plans to be executed, forecast products provide the best available predictions to execute against.

Visual 8: The Process: Study. Plan. Execute.

Key Points

To make better decisions, we need to follow a three-part process:

1. **Study** - Understand the factors that impact the decisions.
2. **Plan** - Based on the understanding of those factors, prepare ahead of time how you will respond to them.
3. **Execute** - Take action based on your plan, with the confidence that it is based on a solid understanding of the risk factors.


Student Manual

Hurricane Evacuation Studies provide planning factors for deliberate and crisis-action planning. HES products, deliberate plans, and official forecast products provide a basis for risk assessment and operational decision making.

Visual 9: The Process: Study

Key Points

The first part of this process is to study the factors that affect your decisions. In the case of hurricane readiness, this means:

- Identifying storm hazards
- Determining community vulnerability
- Estimating evacuation timing

Hurricane Evacuation Studies determine hurricane vulnerability for coastal jurisdictions, with a final output of the amount of time it takes to complete evacuations under different hurricane scenarios.

Student Manual

Among other planning factors, Hurricane Evacuation Studies produce worst-case storm surge inundation maps, analysis of potential sheltering gaps, and evacuation clearance times.

Visual 10: What is Useful Information?

"We're not that much smarter than we used to be, even though we have ***much more*** information.

...that means the real skill now is learning how to pick out the ***useful*** information..."

The Signal and the Noise

- Nate Silver

Key Points

We can be overloaded with information about the potential impacts if a major hurricane hit. If you have a process by which you identify threats and vulnerabilities, it will help you efficiently evaluate what could happen if a hurricane made landfall in your community.

Student Manual

- Ask: How do you know what information to look for as tropical cyclone threats approach your community?
- Explain that a vast number of information sources are continually within reach.
- After the storm passes and the after-action reviews begin, it's very likely that questions will be asked about how available official information influenced decision-making.

The skill becomes determining - what information would assist you to make a better plan of action and in the end better decisions?

Visual 11: How Do the Hazards Affect You?

RESOURCES

- **Hurricane Evacuation Study (HES)**
- **THIRA** ***Threat and Hazard Identification and Risk Assessment***
- Flood Risk Maps
- Hazus Modeling
- Historical Incidents
- **Local Knowledge**

Key Points

FEMA and NHC provide the following products to help you assess how hurricane hazards can affect your community:

- Hurricane Evacuation Study (HES)
- Threat and Hazard Identification and Risk Assessment (THIRA)
- Flood Risk Maps
- Hazus Modeling
- Historical Incidents
- Local Knowledge

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Review these resources:

Hurricane Evacuation Studies (HES)

THIRA National Risk and Capability Assessment | FEMA.gov

Hazus Hazus | FEMA.gov

Visual 12: HES Components

- **Hazard Analysis**
  - What will be wet and what stays dry?
- **Vulnerability Analysis**
  - Who/what will be affected in your community?
- **Behavioral Analysis**
  - What is the public thinking?
- **Shelter Analysis**
  - What are your shelter needs?
- **Transportation Analysis**
- How long does it take to evacuate?

Key Points

The HES provides several analyses that can help answer questions for your community.

HES provides a critical set of evacuation and response information to hurricane-prone SLTT Emergency Managers to guide their hurricane evacuation planning. An HES has five key components:

- Hazard Analysis
- Vulnerability Analysis
- Behavioral Analysis
- Shelter Analysis
- Transportation Analysis

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Technical Data Reports are the final products of the HES process and contain the findings of the various components of the study.

Visual 13: Frequently Asked Questions 1

FAQs

- What will be wet? Dry?
- How high will the water get?
- How far inland?

Hazard Analysis

Key Points

The first component, Hazard Analysis, helps to assess risk by answering frequently asked questions, such as:

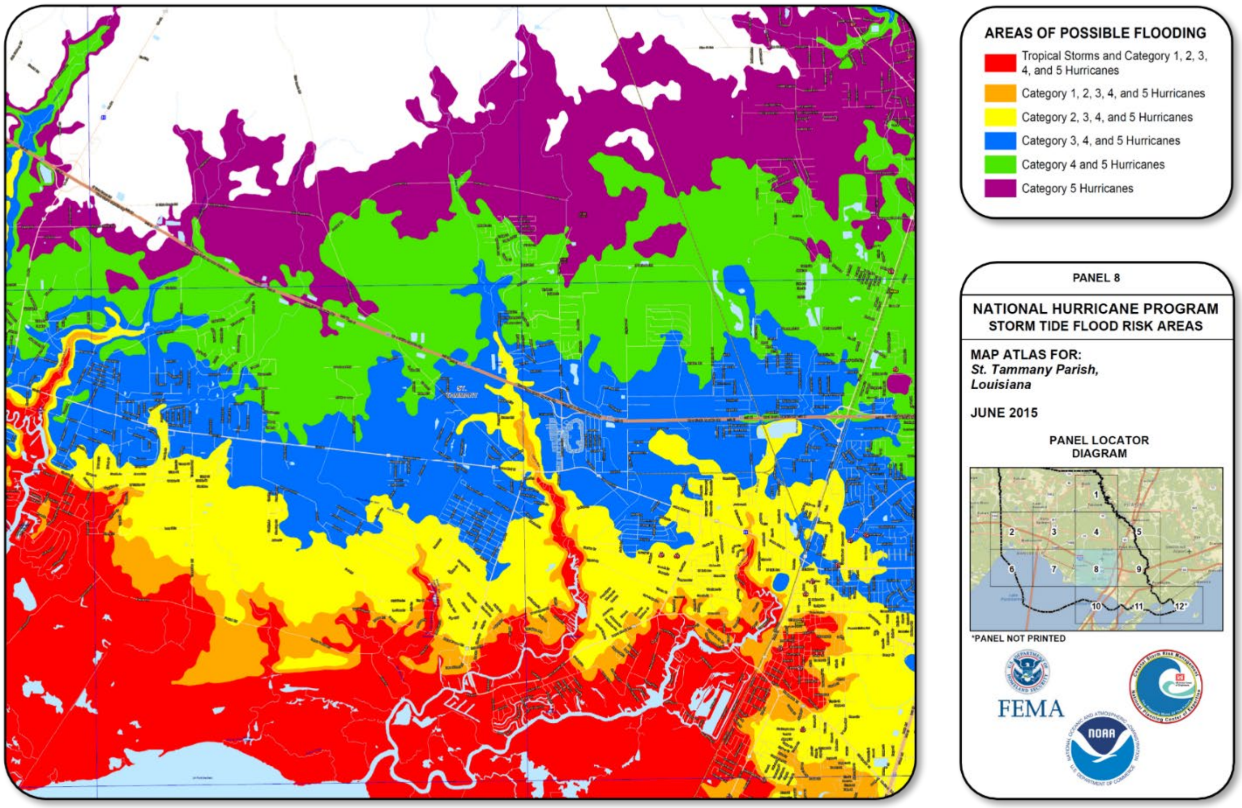
- What areas will be wet? What areas will remain dry?
- How deep will the flooding be?
- How far inland will there be impacts?

By producing GIS data and map atlases of storm surge risk areas for various hurricane scenarios.

Given many storm-related deaths are caused by storm surge and flooding, evacuation decisions are primarily based on storm surge potential.

The hazard analysis will determine the worst-case effects from the various intensities of hurricanes that could strike the region using storm surge modeling.

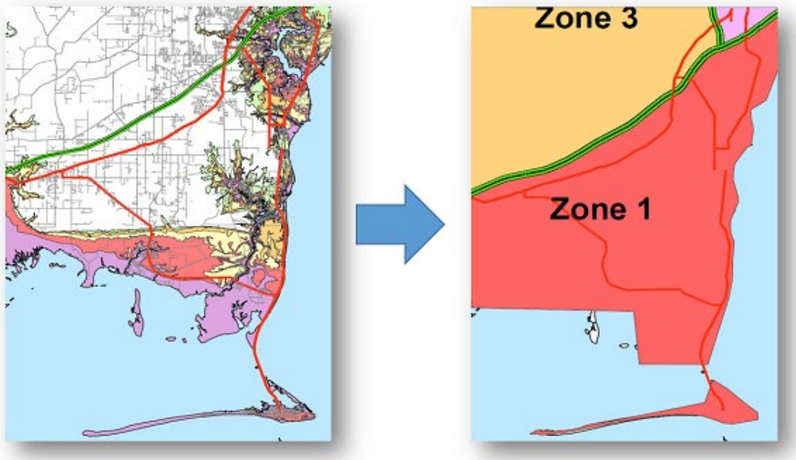
Visual 14: What's Wet and What's Dry?



Key Points

- This map, an example of the output of the hazards analysis, is of a coastal area with the maximum extent of inland storm surge for tropical storms in Red and each category of hurricane.
- This is a useful map for those who are familiar with the geographic area and the maps that depict it.
- The question becomes, how can we be sure that the public understands the risk and what to do in each scenario.
- How does someone find their house on this map, and what actions should they take for an approaching Category 2 or Category 4 storm?

Visual 15: Building Evacuation Zones



Key Points

- The solution to the issue of providing clear instructions to the public is to designate and disseminate official hurricane evacuation zones.
- Evacuation Zones aren't automatically created from Surge Atlases. They must be developed to effectively advocate to the public their vulnerability.
- The above picture depicts a MOM storm surge map.

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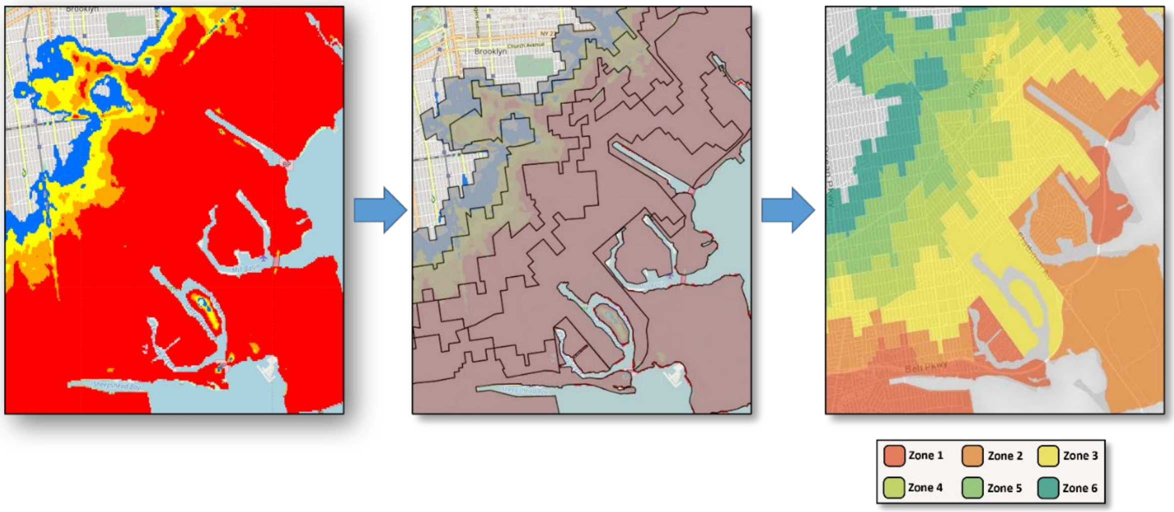
Evacuation zone maps are normally maintained and provided to the public by the jurisdictions that have the statutory authority to order evacuations. Evacuation zones for most of the hurricane-vulnerable areas of the United States are maintained in HURREVAC.

Visual 16: Building Evacuation Zones 2



Key Points

- In many areas of the United States, the Maximum of Maximums or "MOM" is used as the basis for hurricane evacuation zones.
- In many cases, this can lead to more people evacuating than necessary, which is usually an acceptable risk in terms of ensuring public safety.
- In areas of high population density, some jurisdictions have good reasons to limit the number of people under evacuation orders as much as is safely possible. There is a way to safely do this using direction-based or MEOW-based SLOSH Outputs, which some places have referred to as a "Directional Atlas."

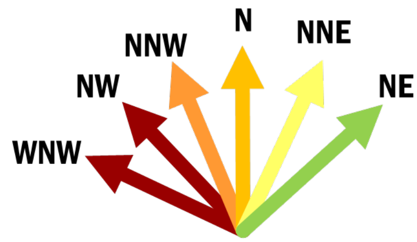
Student Manual

The graphics on this slide depict storm surge vulnerable areas and corresponding hurricane evacuation zones for New York City. Evacuation zones are publicly available on NYC's "Know Your Zone" website: Know Your Zone | NYC Emergency Management

Visual 17: Storm Surge Heights by Direction

New York City Hurricane Evacuation Study – Technical Data Report – 2015

	WNW	NW	NNW	N	NNE	NE
Category 1	12.6	12.1	10.7	8.8	6.6	5
Category 2	20.9	20	20.1	16.5	11.4	8.1
Category 3	26.6	27.6	27.4	23.4	17	11.3
Category 4	32.4	33.9	33.9	30.6	21.7	14.6

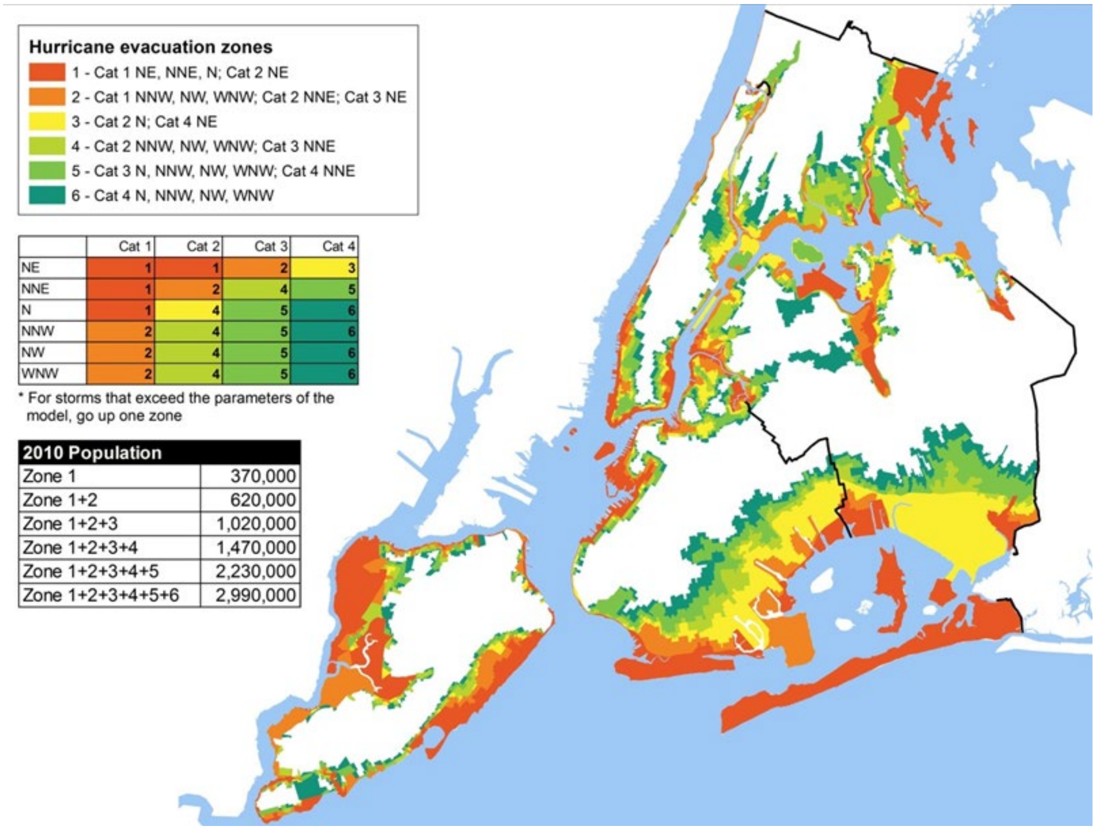


Key Points

- In some coastal areas, a hurricane's direction of approach doesn't have much of an impact on potential storm surge.
- In other areas, the direction the storm is moving has a tremendous impact on how far inland the water can come and how deep the water can be over normally dry ground.
- New York City is one of these areas.
- Shown in the table, a storm moving parallel to the coast has about half of the depth potential as a storm that hits the coast head on.
- In the table, the column of West-Northwest surge depths shows the potential to be more than twice the depth of a storm moving on a Northeast track, which is more parallel to the coastline.
- To determine these different scenarios, the SLOSH Models values for Maximum Envelope of Water, or "MEOWs" are used.
- Remember that MEOWs are the maximum potential storm surge for a tropical cyclone moving a given direction. The MOM or Maximum of Maximums is the worst case of all the MEOWs, considering all directions of approach, and producing the overall worst-case storm surge scenario for each location on the map.

Student Manual	Superstorm Sandy is one example of a rarer storm track that approached the coast moving more to the West Northwest. This resulted in much greater storm surge impacts than more common storms that track parallel to the coastline.

Visual 18: NYC Evacuation Zones



New York City Hurricane Evacuation Study – Technical Data Report – 2015

Key Points

MEOW-based scenarios provide additional evacuation options beyond just the storm’s category by accounting for the direction of approach into account. This reduces the number of zones ordered to evacuation and can substantially reduce the number of evacuees.

Student Manual

Jurisdictions in Florida, Virginia, Delaware, and parts of Massachusetts, Maryland, Louisiana, and Texas use MEOW-based scenarios when planning for evacuations. If your jurisdiction does not, the MEOW blender feature of the Storm Surge (SLOSH) explorer in HURREVAC can be used to easily compare storm surge impacts for different directions of approach.

Visual 19: Frequently Asked Questions 2

FAQs

Who will be affected?

What critical facilities are at risk?

Vulnerability Analysis

Key Points

- The second HES component, Vulnerability Analysis, helps to determine vulnerabilities by answering frequently asked questions, such as:
    - Who is at risk from storm surge?
    - What critical facilities are at risk?
- This analysis develops hurricane evacuation zones for counties/municipalities and identifies the populations and critical infrastructure at risk of storm surge flooding in various hurricane scenarios.
- While the hazards analysis provides information on the areas at risk of the hurricane threats, the vulnerability analysis identifies the impacts of the at-risk areas.
- The data and information from the hazards analysis are used to develop inundation maps; build preliminary evacuation scenarios and evacuation zones; to quantify the population at risk under a range of hurricane conditions; and to identify major medical/institutional and other facilities that are potentially vulnerable to flooding.

Visual 20: Who is at Risk from Storm Surge?

Hancock County, MS

Hancock County, MS						
County Surge Area	**Permanent Residential Structures**	**Non-Permanent Residential Structures**	**Total Residential Structures**	**Commercial Structures**	**Industrial Structures**	**Tourist Structures**
Category 1	2,281	0	2,281	89	0	1
Category 2	5,007	253	5,330	209	4	2
Category 3	9,059	338	9,397	520	7	9
Category 4	9,480	380	9,860	525	7	9
Category 5	10,020	437	10,457	544	7	9
Non-Surge Area	5,518	682	6,200	99	0	1

Table 3-7: Vulnerable Structures by Storm Surge Area
Mississippi Hurricane Evacuation Study - Technical Data Report - 2012

Key Points

- A crucial part of understanding a jurisdiction's vulnerability includes not only knowing which areas are at risk of storm surge flooding, but also knowing who and what are in those areas.
- This slide depicts a sample vulnerability table in the Mississippi coastal counties. These numbers will be used as part of the analysis to determine evacuation clearance times.
- This information can be valuable for planning purposes/pre-season readiness: gives us hard numbers for estimation for operations and response – meals, search and rescue targeting, etc. You can map these populations and also apply them to other analysis to look at how long it will take these populations to evacuate, where they can go, etc., which will be discussed.

Student Manual

Vulnerability analysis information may be found in HES Technical Data Reports available in HURREVAC.

Visual 21: What Facilities are at Risk?

Hancock County, MS

Facility Type	Cat 1	Cat 2	Cat 3	Cat 4	Cat 5	None
Casino	2	-	-	-	-	-
Dam	-	-	-	3	-	19
EOC	-	-	-	-	1	-
Fire	3	2	4	1	1	4
Hazmat	-	4	-	-	-	1
Hospital	-	-	1	-	-	-
Hotels	2	2	5	-	-	1
Police	-	-	4	-	-	-
School	1	3	6	1	-	1
Senior Center	-	-	1	-	-	-
Shelter	-	-	-	-	-	5
TOTAL	7	12	25	6	2	32

Table 3-9: Critical Facilities Summary Table
Mississippi Hurricane Evacuation Study - Technical Data Report - 2012

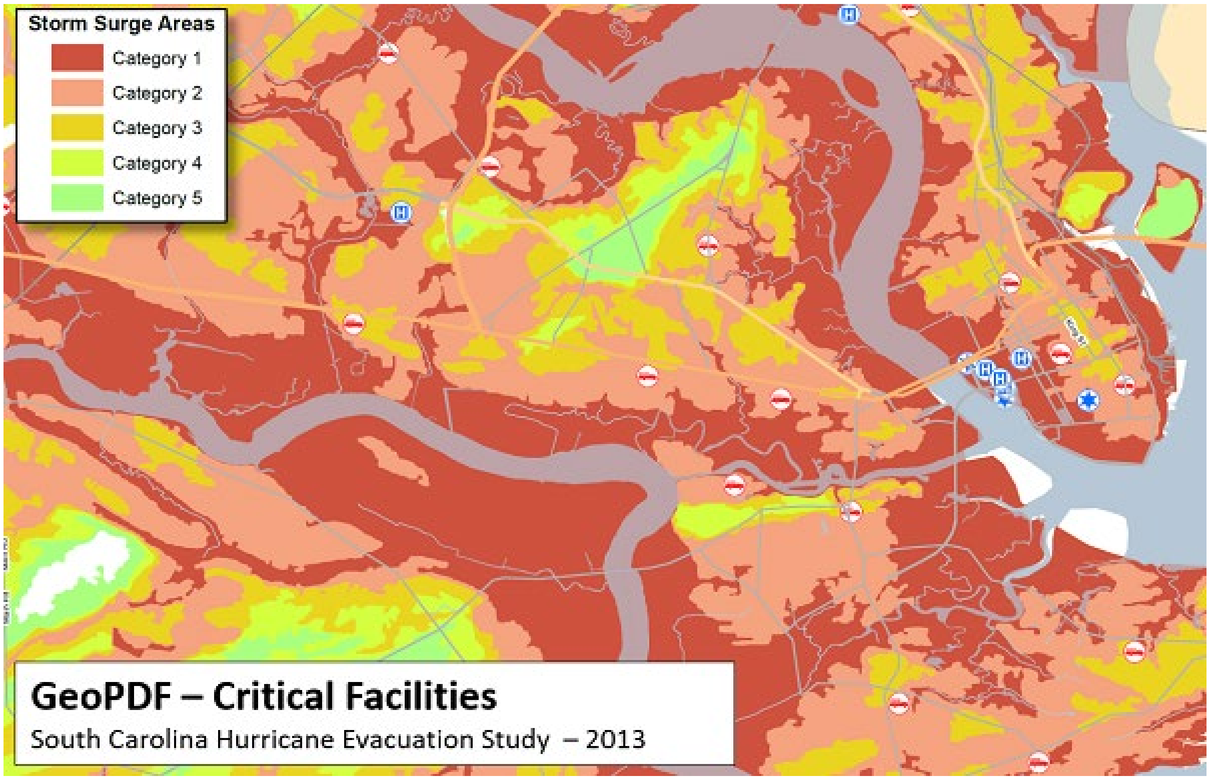
Key Points

- Critical facilities include Emergency Services, other government sites, and key infrastructure such as roadway networks, bridges, and tunnels. They may also include private sector industry that supports Community Lifelines.
- The Vulnerability Analysis also includes particularly vulnerable residential areas, such as Mobile and Manufactured home communities that may provide less protection from wind impacts.
- Shelters in vulnerable areas are another crucial type of site to identify because it helps define the circumstances in which the shelter can safely be used.
- Other sites may be designated by state and local agencies, including those key to economic resilience, perhaps including resorts and casinos.

Student Manual

- Take your identified hazards and cross-reference them with your societal issues, the aspects of your community that may now be vulnerable (people, structures, processes (communication, evac routes), etc.).
- What else would be good to consider? Building codes, gas stations - location and availability, chemical plants, hazardous materials, etc.
- Vulnerability is always changing and, after a storm, it changes again!

Visual 22: What Facilities are at Risk (GIS)?



Key Points

Vulnerability data for critical facilities can be very useful, and representing it geospatially is even more useful for providing a risk snapshot for decision-making. These types of products go a long way toward informing deliberate and crisis action plans.

Visual 23: Frequently Asked Questions 3

FAQs

- Will the public evacuate?
- Where will they go? How? When?
- Do they understand the threat?

Behavioral Analysis

Key Points

- In preparing hurricane evacuation plans, assumptions must be made regarding how the population in and around the vulnerable area will react to the threat.
- These assumptions are necessary for shelter planning, transportation modeling, and guidance in evacuation decision-making and public awareness efforts.

Visual 24: What are People Thinking?

SURVEY RESULTS

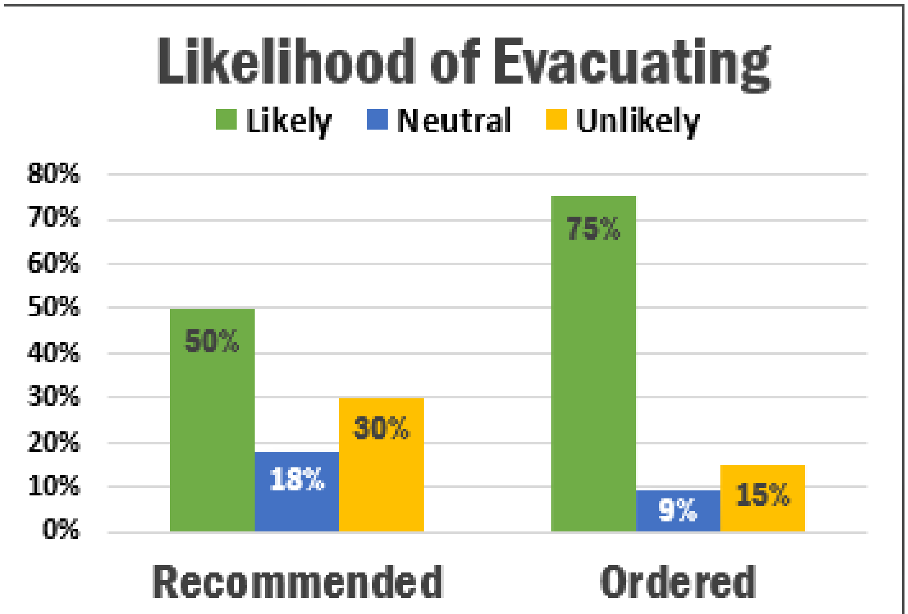
- Serious under-concern about surge
- Evacuation intent often overstated
- Evacuation intent highest for:
  - Major hurricanes
  - Mandatory/ordered evacuations
  - Households with children
  - People with recent real hurricane experience
- Often get a "False Experience" effect

Key Points

- One thing that the Behavioral Analysis has strived to answer is what people are thinking about hurricanes and evacuating. These studies have found that people seriously undervalue the impact of storm surge compared to other hurricane hazards.
- When comparing peoples' survey responses to actual evacuations, the studies found that people usually **stated** that they would evacuate, but when the time came, fewer people followed through with the evacuation. People said they would evacuate for major storms, mandatory evacuations, and if they have a household with children. People also said they would make the decision to evacuate based on their recent hurricane experience.
- Studies also found that people often get a "false experience effect," meaning people say they have been through a storm but were not actually in the brunt of the hazards and did not see how bad it could really be.
- Consistent themes have emerged from Behavioral Analysis across multiple previous hurricane evacuation studies.
- For instance, the public seems to place more emphasis on a storm's category than its storm surge potential.
- Survey respondents tend to overstate evacuation intent, in comparison to actual evacuation order compliance.
- **Evacuation intent highest for** Major Hurricanes, Cat 3 or higher, Mandatory as opposed to recommended Evacuations, and it makes sense that households with children and people with recent real hurricane experience would be more prone to expressing intent to evacuate.

Student Manual		• **False memory** is a phenomenon where someone recalls something that did not happen or recalls it differently from the way it actually happened.

Visual 25: Will the Public Evacuate?

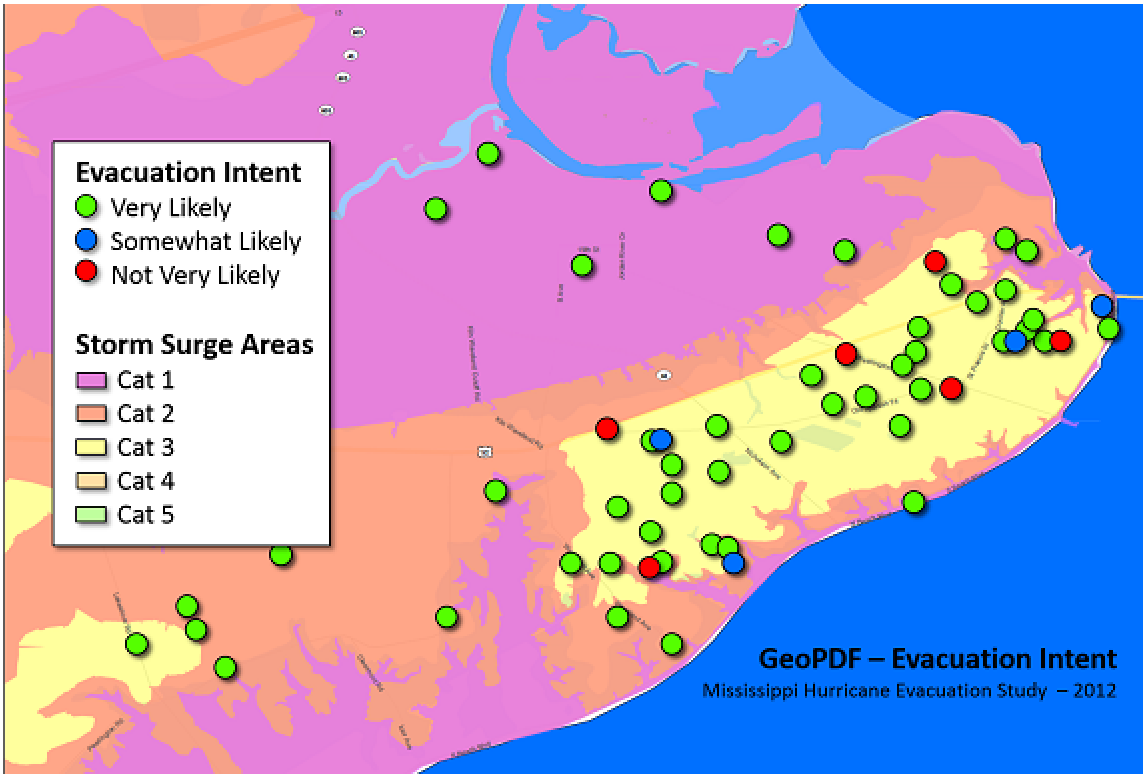


Cat 1-2 Hurricane and Likelihood of Leaving if Recommended or Ordered
South Carolina Hurricane Evacuation Study - Technical Data Report – 2013

Key Points

- One key take-away from this course is the importance of clear evacuation orders.
- Survivors respond at much higher rates when evacuations are ordered, as opposed to recommended.
- We can see from these responses people are more likely to leave when evacuations are "ordered."

Visual 26: Where Should I Focus My Outreach?



Key Points

As with the vulnerability analysis, geospatial representation of the behavioral analysis results can help socialize the results of the study, helping identify areas in need of additional public outreach.

Visual 27: Bottom Line

WHY DO PEOPLE EVACUATE?

- They understand their vulnerability/risk.
- They were told to evacuate.

Key Points

- The best way to reduce the threat to life safety is to help the public help themselves.
- Clear evacuation orders with appropriate instructions and year-round initiatives to socialize risk are critical to successful implementation of protective actions.
- A public that knows their zone, provided clear orders, hearing the same information from multiple reputable sources has the best chance of taking appropriate actions at the right time.

Visual 28: Frequently Asked Questions 4

FAQs

- Who will seek public shelter?
- How many shelter spaces are needed?
- In county? Out-of-county?

Shelter Analysis

Key Points

- We use shelter analysis to answer these questions:
  - Who will seek public shelters?
  - How many shelter spaces are available?
  - Where are the shelters located?
  - Do we have more demand than availability?

Visual 29: Number of Shelters Spaces Needed?

SHELTER ANALYSIS RESULTS	Shelter usage rates (planning purposes)
• **Shelter Locations,** with respect to Evacuation Zones and Storm Surge flood risk areas • **Potential Demand** • **Identification of Deficits**	• 3–8% Coastal • 10% Inland

Key Points

Shelter Analysis is done in collaboration with local emergency management, the American Red Cross (ARC), and other appropriate organizations or agencies.

Most states have a database, and this can be added to the HURREVAC shelter database. The Shelter Analysis helps evaluate the structural integrity of buildings, provide a rating of shelters, and identify official shelters. It can answer the following questions:

- Are the shelters ARC-certified?
- To whom are the shelters available (e.g., county residents only)?
- Where are pet-friendly shelters and shelters for people with special needs?
- Are there vulnerable shelters in your area?

Student Manual	This part of the HES is focused primarily on sheltering from the storm, as opposed to long-term post-landfall sheltering.

Visual 30: What's Available?

Baldwin County, AL

Evacuation Scenario	Evacuating Population LOW OCCUPANCY	Evacuating Population HIGH OCCUPANCY	Shelter Demand LOW OCCUPANCY	Shelter Demand HIGH OCCUPANCY	Sheltering Capacity	Surplus/ Deficit LOW OCCUPANCY	Surplus/ Deficit HIGH OCCUPANCY
Category 1	60,660	101,821	1,576	1,990	8,239	6,663	6,249
Category 2	103,871	151,069	2,909	3,384	7,469	4,560	4,085
Category 3	113,773	162,005	3,567	4,052	7,469	3,902	3,417
Category 4	184,748	234,032	8,528	9,025	2,818	**-5,710**	**-6,207**
Category 5	211,125	260,502	10,898	11,295	0	**-10,898**	**-11,395**

Evacuating Population and Public Sheltering Demand - Baldwin County
Alabama Hurricane Evacuation Study - Technical Data Report - 2012

Key Points

This visual provides an example of a Shelter Analysis. These numbers can then be used as a tool for planning. For example, you can estimate transportation needs (buses) or shelter spaces required. Using this, you can gauge your resources, response, and plan with all functions.

Visual 31: Resources for Evacuating Populations

Shelter Demand	Potential Evacuees	Regular Capacity 7,953 Additional Needed	Emergency Capacity 15,906 Additional Needed	Assessment of Capacity
1%	1,533	0	0	Regular Shelter Capacity Can Support Demand
2%	3,065	0	0	Regular Shelter Capacity Can Support Demand
3%	4,598	0	0	Regular Shelter Capacity Can Support Demand
4%	6,131	0	0	Regular Shelter Capacity Can Support Demand
5%	7,633	0	0	Regular Shelter Capacity Can Support Demand
6%	9,196	1,243	0	Emergency Shelter Capacity Can Support Demand
7%	10,728	2,775	0	Emergency Shelter Capacity Can Support Demand
8%	12,261	4,308	0	Emergency Shelter Capacity Can Support Demand
9%	13,794	5,841	0	Emergency Shelter Capacity Can Support Demand
10%	15,326	7,373	0	Emergency Shelter Capacity Can Support Demand
13%	19,924	11,971	4,018	Over Capacity
15%	22,990	15,037	7,084	Over Capacity
20%	30,653	22,700	14,747	Over Capacity

Table 6: Population Seeking Shelter and Capacity in Zone 1
Puerto Rico Hurricane Evacuation Study – Shelter Analysis Report – 2015

Key Points

This visual provides an example of a Shelter Analysis. These numbers can then be used as a tool for planning. For example, you can estimate transportation needs (buses) or shelter spaces required. Using this, you can gauge your resources, response, and plan with all functions.

Visual 32: Frequently Asked Questions 5

FAQs

- Where will traffic back up?
- What is the road capacity?
- How long will it take to evacuate?

Transportation Analysis

Key Points

- The final component of an HES study is the Transportation Analysis.
- The Transportation Analysis in the HES can help you answer questions such as
  - What route will people use to evacuate?
  - Where will there be traffic congestion?
  - How many people can traverse a road?
  - How long will it take everyone to evacuate?
- Depending on several factors, such as shelter capacity and location, you may have to move those people a few miles or many hundreds of miles inland.
- The transportation analysis calculates public evacuation clearance times for various evacuation scenarios.
- The intent is to ensure evacuations are completed before hazardous conditions arrive.
- These timelines are used to determine when evacuation decisions need to be made and evacuations executed in the operational timeline when a hurricane approaches.
- Other purposes are to define the evacuation roadway network and evaluate traffic control measures and highway modifications for improved traffic flow.

Visual 33: How Long Will It Take to Evacuate?

TRAFFIC MODEL INPUTS

- Demographics
- Behavioral assumptions
- Evacuation routes
- Roadway capacities
- Travel destinations
- Evacuation scenarios

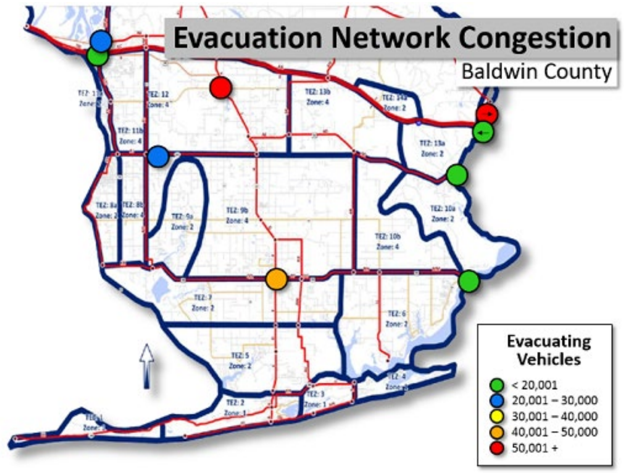
Key Points

- The Transportation Analysis will require input from local emergency management and key traffic law enforcement officials as well as DOT and is designed to provide an understanding of how the roadway network reacts to evacuation decisions made.
- These can be conducted for individual counties or on a regional basis.
- During a hurricane evacuation, an extraordinary number of vehicles must be moved on the road network in a relatively short period of time. Depending on several other factors, such as shelter capacity and location, you may have to move those populations well inland – ex: North Carolina and Georgia. This can cause massive bottlenecks and congestion on the roadways.
- Clearance times anticipate the time required to clear the roadways of all evacuating vehicles. Or the minimum amount of time needed for a safe evacuation prior to the arrival of TS-force winds. Caveat – when the forecast changes, your clearance time may change!

Visual 34: Where Will the Traffic Problems Be?

TRANSPORTATION ANALYSIS

- Traffic Patterns
  - Bottlenecks
  - Evacuating vehicles
- Clearance Times
  - Response rate
  - Seasonal population
  - Evacuation scenarios *One-way or multi-state, etc.*



Key Points

This analysis establishes:

- Evacuation Routes
- Capacity limitations (vehicles per hour)
- Evacuation participation rates
- Evacuees’ destination percentages

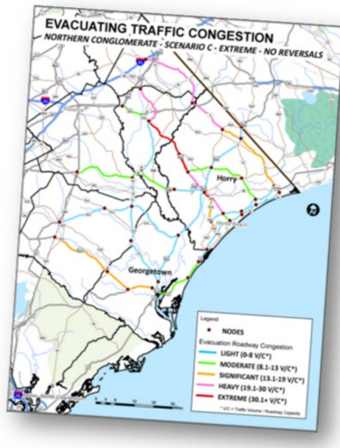
Ultimately this produces the evacuation clearance times.

Visual 35: Modeled on the Road Network

CLEARANCE TIMES

Time for the evacuating population to reach a point of safety

- First evacuating vehicle enters the road network
- Last vehicle reaches an assumed point of safety
- Includes travel time and waiting in congestion
- Doesn't relate to any one particular vehicle
- Driven by bottlenecks



Key Points

Evacuation clearance time is the amount of time it takes for the evacuating population to reach an assumed point of safety. This is usually outside of the county being evacuated. It begins when the first vehicle enters the road network and ends when the last vehicle reaches the assumed point of safety.

Clearance time is determined by several factors, including:

- The number of residents being evacuated
- The expected behavior of those residents
- Roadway network characteristics
- Hurricane shelter availability

Clearance times are based on evacuation zones.

Visual 36: How Long Should Evacuations Take?

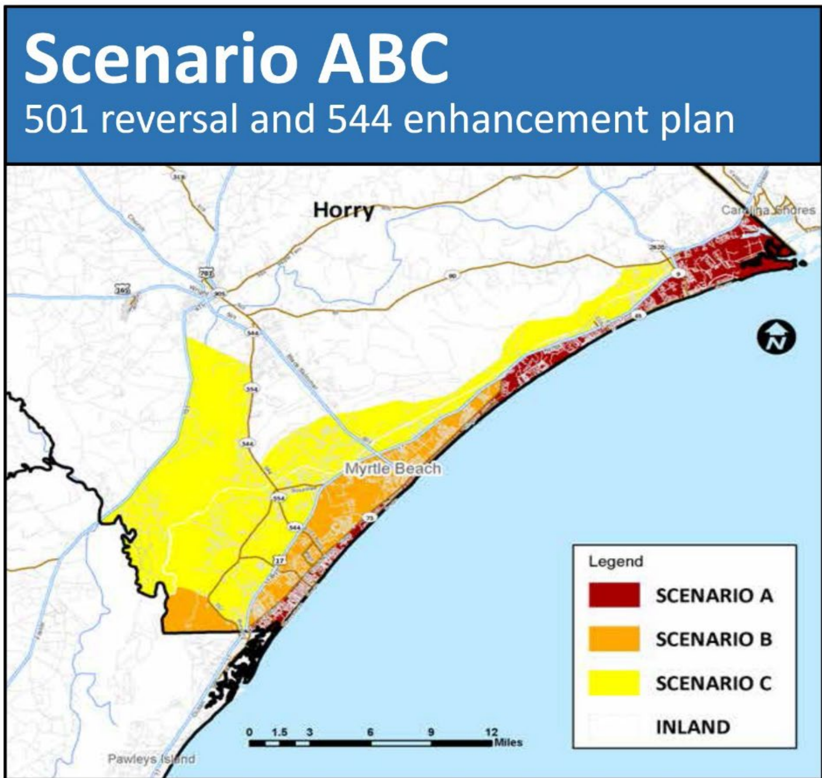


Figure 6-6: Evacuation Zones

South Carolina Hurricane Evacuation Study – Technical Data Report – 2013

Horry County, SC
Scenario ABC *(501 reversal and 544 enhancement plan)*

Response	Low Occupancy	Med Occupancy	High Occupancy	Extreme Occupancy
SLOW	22	26	29	31
MEDIUM	20	24	27	29
FAST	19	23	26	28
IMMEDIATE	18	22	25	27

Evacuation Clearance Times - Scenario ABC
South Carolina Hurricane Evacuation Study - Technical Data Report - 2013

Key Points

- This is an example of a standard clearance time scenario with varying rates of occupancy and response rates.
- Clearance times can be created/adapted to fit several scenarios for your jurisdictions. For example, they can include one-way/reverse lanes/contra flow operations.

Student Manual

The most recent hurricane evacuation clearance times for coastal jurisdictions are maintained in HURREVAC.

Visual 37: The Process: Plan

Key Points

The second phase of making better decisions is to make a plan. This should occur long before there is a tropical cyclone threat. Your plan should be based on the risks and hazards that you identified in the Study phase. This phase involves:

- Informing hazards and risk
- Developing response timelines
- Identifying hazard triggers

Visual 38: Trust the Process

• **Step 1**
  ○ Form a Collaborative Planning Team
• **Step 2**
  ○ Understand the Situation
• **Step 3**
  ○ Determine Goals and Objectives
• **Step 4**
  ○ Plan Development
• **Step 5**
  ○ Plan Preparation, Review & Approval
• **Step 6**
  ○ Plan Implementation & Maintenance
	

Key Points

The planning process brings together leadership and partners to gain buy-in to the "bones" of the plan and what is to be accomplished. As outlined in CPG 101 (Comprehensive *Preparedness Guide - Developing and Maintaining Emergency Operations Plans*), the six-step process is a great way to tackle planning for hurricane events. After forming a team (Step 1), you have to understand the situation. What does a hurricane do to your community? What will it look like when the dust settles? It can be hard to imagine that scenario.

You can view the Comprehensive Preparedness Guide at [Comprehensive Preparedness Guide (CPG) 101 Planning steps].

Visual 39: Frequently Asked Questions 6

FAQs

- What forces us to react?
- What is acceptable risk?
- What assumptions can I make?

Identify Hazard Triggers

Key Points

Emergency management is risk management. How much risk are you willing to accept? What will force your hand every time? The actions you take and when you take them will depend on how risk averse you are.

Visual 40: What Forces You to Act?

Lane Reversal Decision Factors

Decision Factor	Indicator
The storm's current/projected intensity and the public perception of the threat to their safety.	**Category 3 or greater storm** portrayed through the media as a significant threat will probably require the use of lane reversal.
Tourism occupancy: High tourist occupancy greatly increases evacuating population and thereby increases traffic congestion.	**For a Category 1 or 2 storms**, monitor traffic flow and have lane reversal ready. **A Category 3 or greater storm** will indicate the need for reversal. (Note: Beaufort County requires Highway 278 reversal during tourist season at 85% tourist occupancy)

Key Points

Planning factors and triggers vary significantly, based upon local factors.

- Geography, infrastructure, and vulnerability play tremendous roles in what jurisdictions must plan for.
- Local first responders and Emergency Managers know the important activities that must be completed, probably have a good idea about how long it takes to complete them, and understand what triggers those activities.
- Capturing those decision points and triggers in deliberate plans helps reduce decision-making on the fly during the response phase.

Visual 41: Storm Category vs. Evac Actions

Storm Category \ Evacuation Actions	Tropical Storm Force Wind Arrival	RECOMMENDED South & East of Abercom/US-204	EARLY South & East of Abercom/US-204; MANDATORY Islands & Low-lying Areas	MANDATORY South & East of Abercom/US-204; MANDATORY Islands & Low-lying Areas	MANDATORY South & East of Abercom/US-204	RECOMMENDED Remainder of County; MANDATORY East of I-95	MANDATORY Entire County	MANDATORY Entire County	MANDATORY Entire County
Cat 5									30+48NH
Cat 4								30+48NH	
Cat 3							30+48NH		
Cat 2						24+30NH			
Cat 1 Direct					24+30NH				
Cat 1 Parallel to Coast				18+24NH					
Tropical Storm Direct			18+24NH						
Tropical Storm Parallel Coast		12							
Arrival Tropical Storm									

Islands and Low-lying Area Early Evacuations are 6 to 12 hours prior to Mandatory Evacuations
Hours for Evacuation + Added Hours for Nursing Home (NH) and Special Needs Evacuations

Chatham County Evacuation Guidelines (Not Current)

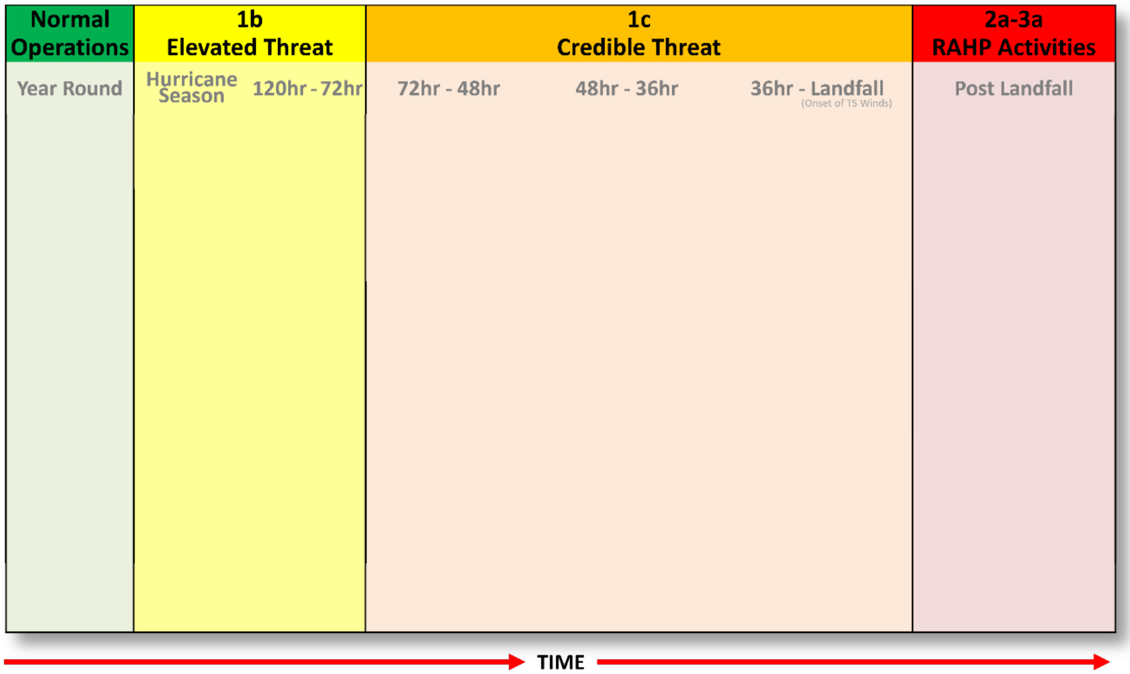
Evacuation Actions

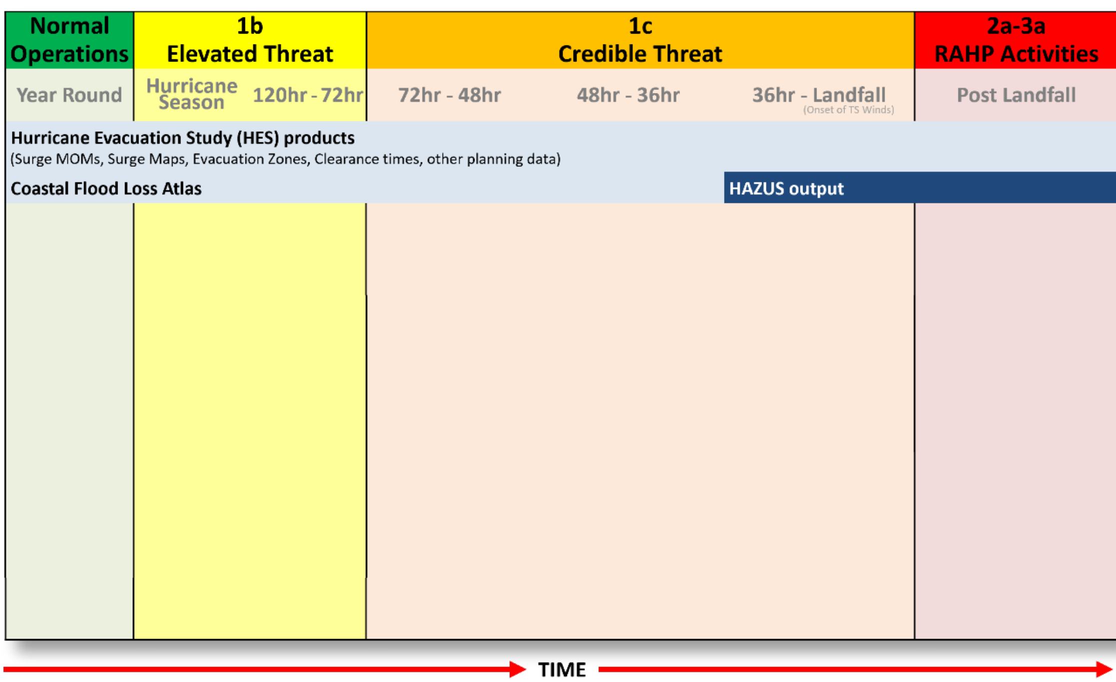
Islands and Low-Lying Area Early Evacuations are 6 to 12 hours prior to Mandatory Evacuation. Hours for Evacuation + Added Hours for Nursing Home (NH) and Special Needs Evacuation.

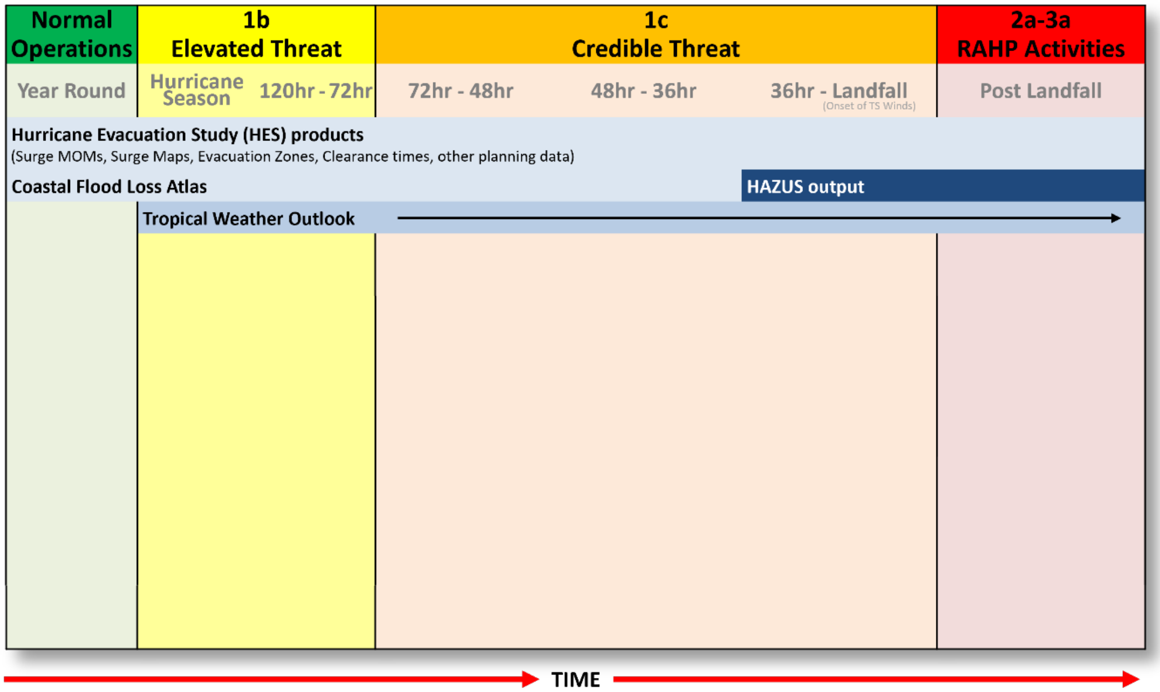
Key Points

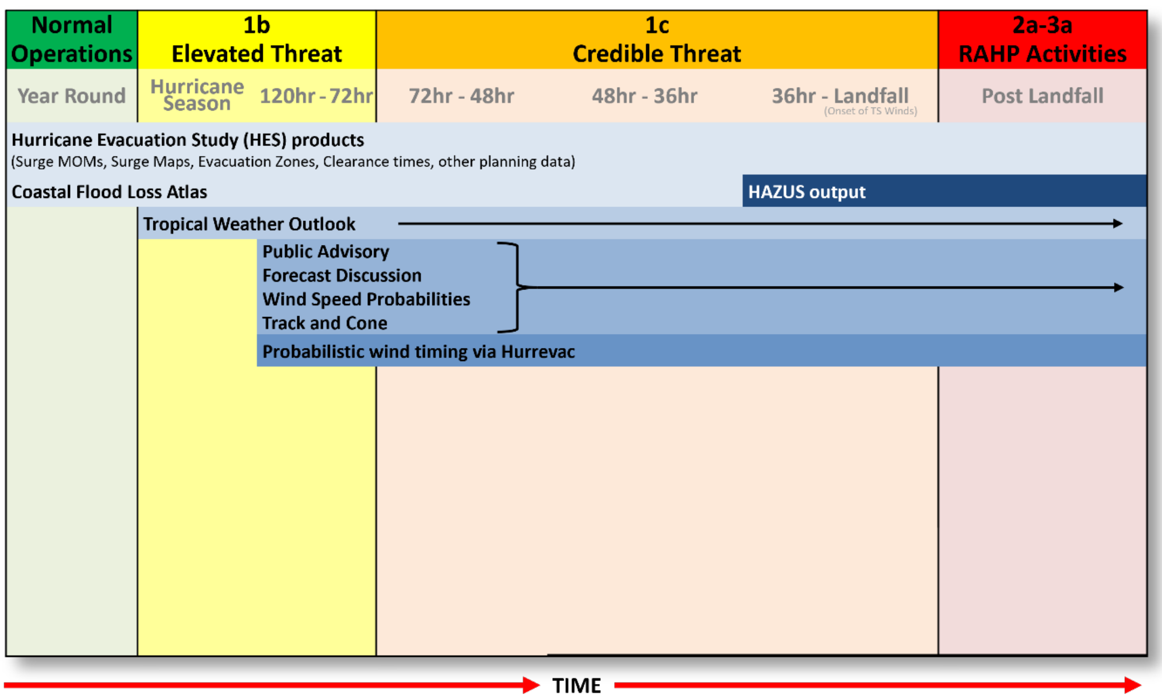
One way to guide your decisions is to create a matrix that determines evacuation actions based on the storm category. The example above shows evacuation actions that should be taken in response to different levels of tropical cyclone, including how far in advance of the storm to make the determination. Note that there are triggers based on the storm's category and its direction.

Visual 42: When is Key Information Available?






Normal Operations
1b Elevated Threat
1c Credible Threat
2a-3a RAHP Activities
Year Round
Hurricane Season
120hr - 72hr
72hr - 48hr
48hr - 36hr
36hr - Landfall
(Onset of TS Winds)
Post Landfall
Hurricane Evacuation Study (HES) products
(Surge MOMs, Surge Maps, Evacuation Zones, Clearance times, other planning data)
Coastal Flood Loss Atlas
HAZUS output
Tropical Weather Outlook
TIME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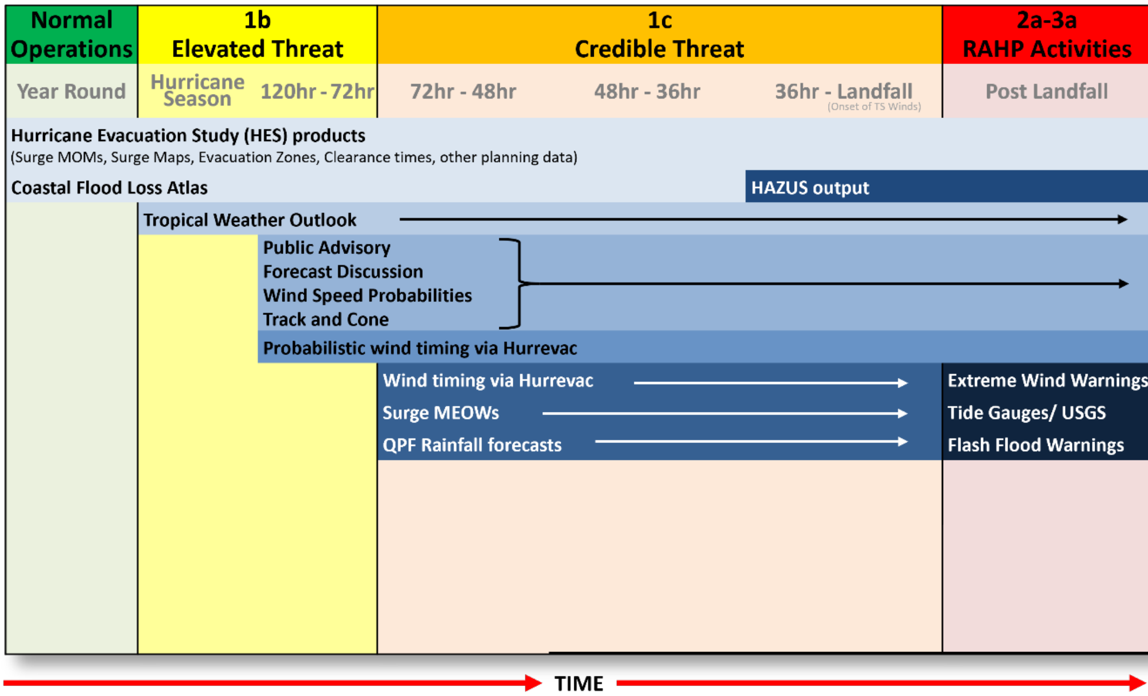
Coastal Flood Loss Atlas
HAZUS output
Tropical Weather Outlook
Public Advisory
Forecast Discussion
Wind Speed Probabilities
Track and Cone
Probabilistic wind timing via Hurrevac
TIME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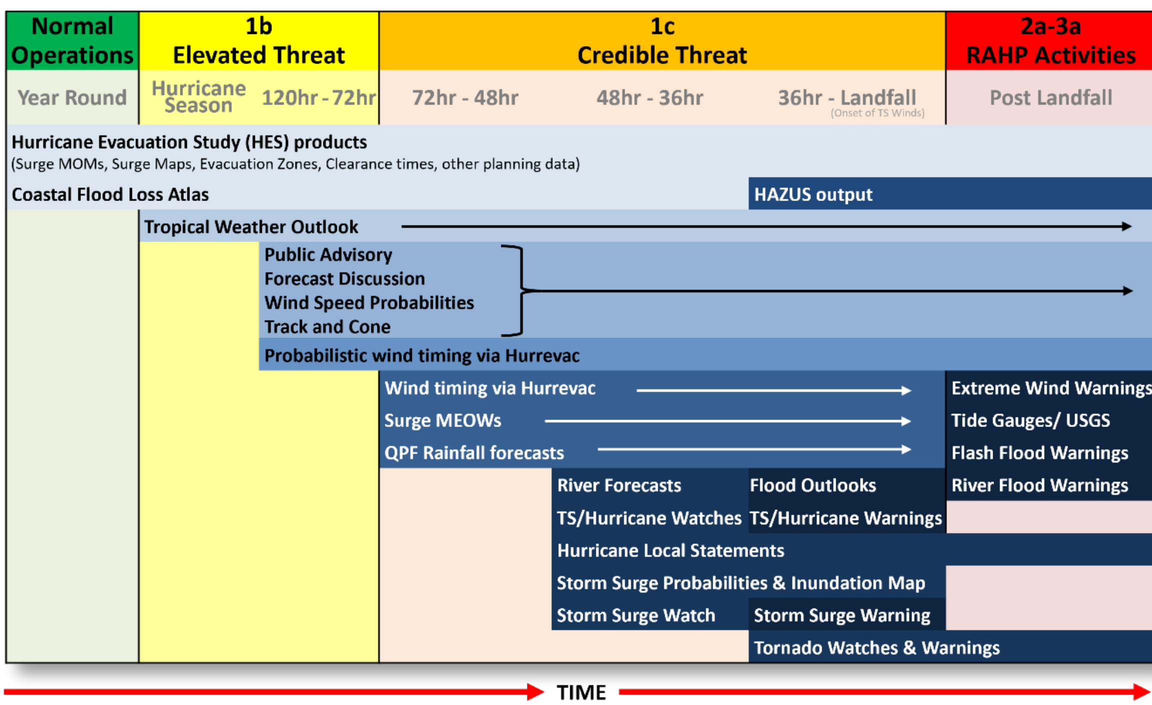
120hr - 72hr
72hr - 48hr
48hr - 36hr
36hr - Landfall
(Onset of TS Winds)
Post Landfall
Hurricane Evacuation Study (HES) products
(Surge MOMs, Surge Maps, Evacuation Zones, Clearance times, other planning data)
Coastal Flood Loss Atlas
HAZUS output
Tropical Weather Outlook
Public Advisory
Forecast Discussion
Wind Speed Probabilities
Track and Cone
Probabilistic wind timing via Hurrevac
Wind timing via Hurrevac
Surge MEOWs
QPF Rainfall forecasts
Extreme Wind Warnings
Tide Gauges/ USGS
Flash Flood Warnings
TIME


Normal Operations
1b Elevated Threat
1c Credible Threat
2a-3a RAHP Activities
Year Round
Hurricane Season
120hr - 72hr
72hr - 48hr
48hr - 36hr
36hr - Landfall
(Onset of TS Winds)
Post Landfall
Hurricane Evacuation Study (HES) products
(Surge MOMs, Surge Maps, Evacuation Zones, Clearance times, other planning data)
Coastal Flood Loss Atlas
HAZUS output
Tropical Weather Outlook
Public Advisory
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Wind Speed Probabilities
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Probabilistic wind timing via Hurrevac
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Surge MEOWs
QPF Rainfall forecasts
Extreme Wind Warnings
Tide Gauges/ USGS
Flash Flood Warnings
River Forecasts
Flood Outlooks
River Flood Warnings
TS/Hurricane Watches
TS/Hurricane Warnings
Hurricane Local Statements
Storm Surge Probabilities & Inundation Map
Storm Surge Watch
Storm Surge Warning
Tornado Watches & Warnings
TIME

Key Points

- NHC has a variety of tropical cyclone products that they develop. These products are delivered on a schedule in relation to the arrival of the storm. The example above shows at which point the different products are delivered. We will step through each of these.
- Prior to the identification of a potential threat, Deliberate Planning increases preparedness and augments collaborative capabilities. When a threat is identified, and forecasts begin to replace scenario assumptions, Crisis-Action Planning begins.
- It is valuable to look at how the availability of information products are laid out in the planning timeframes and how they are related to one another.

This timeline shows incident phases, as defined in FEMA plans.

- Phase 1 is pre-incident operations.
- Normal, steady-state operations transition when a potential hurricane threat is identified.
- 120 hours is the standard timeline because NHC forecast advisories extend to a 5-day period.
- Of course, that does not mean that jurisdictions will always have 5 days of notice before being impacted by hurricane hazards.
- When impacts are more certain, response operations transition to the Credible Threat phase.
- Phase 2 is post-incident operations, and it begins with the arrival of hurricane hazards.
- The arrival of tropical storm-force winds is normally used as the forecast planning factor, but keep in mind that there are cases in which storm surge can arrive before the onset of winds.

First image overlay

- The first three columns are before the storm. The last column is after the storm makes landfall.
- Products that are available year-round include HES products, the Coastal Flood Loss Atlas, and scenarios can be run in Hazus, to produce a picture of potential losses.
- Hazus can be more useful in the Credible Threat phase, as the forecast actual scenario becomes clearer.

Second image overlay

- The NHC's Tropical Weather Outlook comes available when there is the potential for tropical cyclone formation.
- It covers disturbances with the potential to become tropical cyclones, in addition to any active storms for which the NHC is issuing advisories.

Third image overlay

- When the NHC initiates advisories on tropical cyclones and potential tropical cyclones.
- This provides the full suite of NHC forecast products, including their widely recognized forecast graphics and the forecaster's insight provided by the Forecast Discussion.
- An active forecast also turns on the functionality for probabilistic wind timing in HURREVAC.

Fourth image overlay

- When a location is within the 3-day error cone, deterministic wind timing in HURREVAC can start to narrow down the timeframe for the potential onset of hazardous conditions.
- Around this time, more forecast certainty can make SLOSH MEOWs useful for planning along with Quantitative Precipitation Forecasts from the Weather Prediction Center.

Final image overlay

- Getting closer to the onset of hazards, Watches and Warnings, along with local forecast products, narrow the picture for likely potential conditions.

Visual 43: Frequently Asked Questions 7

FAQs

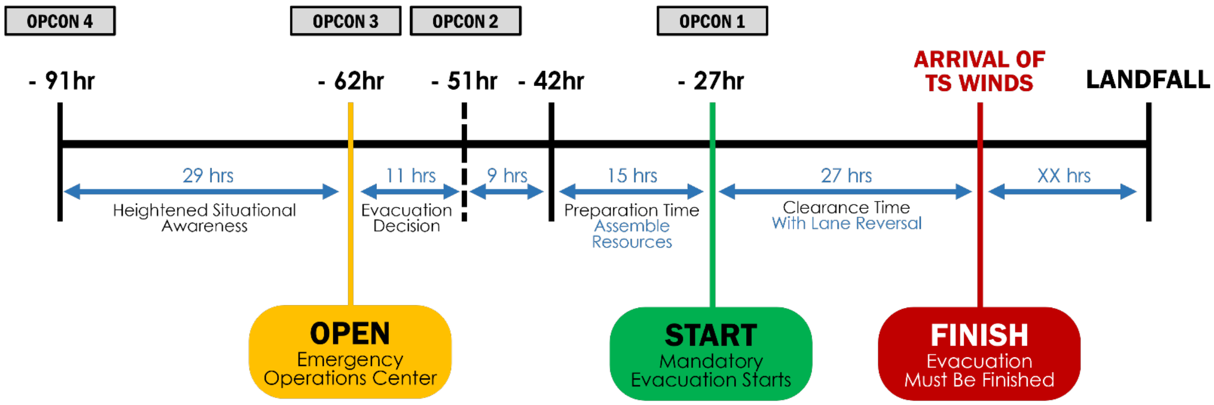
- When do we open shelters?
- When do we need to deploy?
- How do we stay synchronized?

Decision Timelines

Key Points

When a hurricane threatens your area, you need to know how long you have to make decisions. By developing Decision Timelines ahead of the storm, you will be able to answer questions like these.

Visual 44: Evacuation Scenario Decision Timeline



Horry County Evacuation Timeline for ABC Scenario

Key Points

- This is an example of a decision timeline. Notice that the times occur in relation to the arrival of tropical storm-force winds.
- The next type of planning product relies on Hurricane Evacuation Studies, and Deliberate Planning.
- If you take the planning factor from the HES, in this case the Evacuation Clearance Time, you know the amount of time it takes to complete the evacuation under different scenarios.
- In this plan, the county provides 24 hours from their decision time to "calling" for an evacuation. It isn't just flipping the switch and it happens.

Visual 45: Hurricane Readiness Checklist

Hurricane Preparedness – prior to June 1	PRIORITY LEVEL	PERSONNEL RESPONSIBLE	STATUS OF TASK	DATE/TIME COMPLETED
Hurricane Planning				
• Update local hurricane operation, evacuation plans and resource files.				
• Revise Standard Operating Procedures (SOPs).				
• Review local emergency management ordinances and update.				
• Test HURREVAC and/or other hurricane tracking software.				
• Review Stafford Act Policies with State Emergency Management.				
• Determine evacuation decision making authority w/ line of succession.				
Emergency Operations Center (EOC)				
• Replenish supplies and check equipment.				
• Test communication lines.				
• Update activation plans and train staff.				
• Update HURREVAC to latest version.				

Key Points

This is an example. Each jurisdiction will have different actions based on local operations. You can assign Priority levels, Personnel responsible, Status of the task, and when it was completed. It may seem laborious, but well worth the while during a frantic emergency.

- A Hurricane Readiness Checklist can help you identify tasks that need to occur both before and during a tropical cyclone event. This checklist identifies the priority level of each task, who is responsible for the task, the status of the task, and the date and time that the task was completed.
- When you have up-to-date HES data for evacuation clearance times, you can begin the deliberate planning process to determine how long other essential response activities take to carry out. Armed with this knowledge, you can create a pre-landfall execution checklist and have it validated by stakeholders prior to hurricane season.
- This type of checklist keeps pre-landfall response activities on schedule and reduces the number of surprises, especially if it is well-socialized, exercised, and regularly updated.

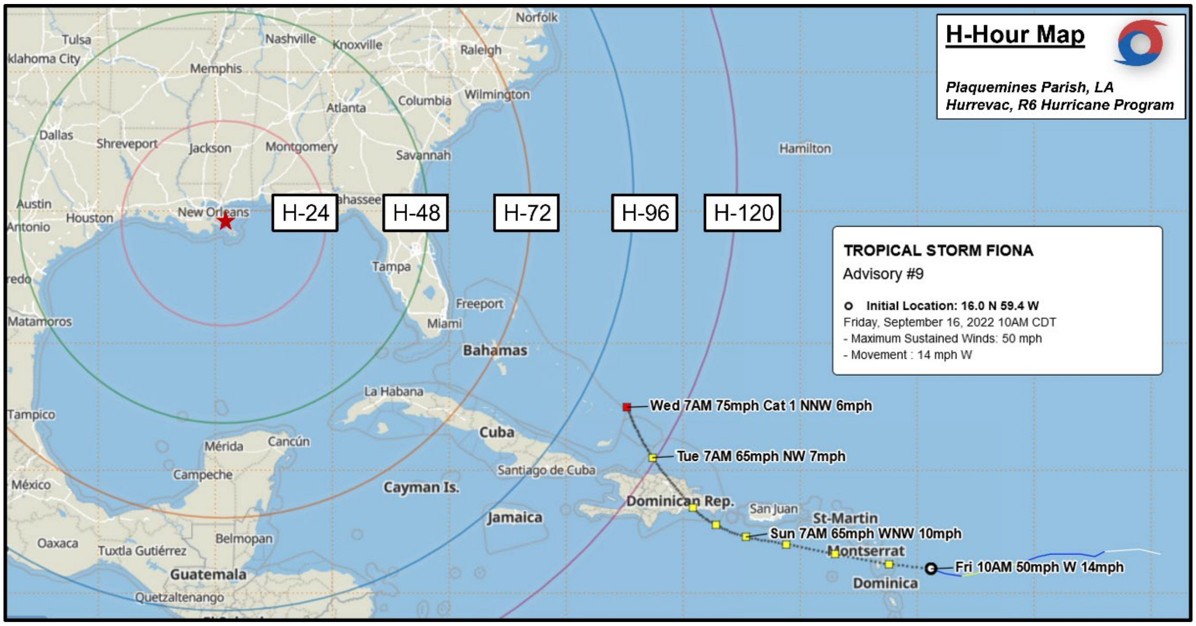
Visual 46: Hurricane Readiness Checklist 2

Storm Impacts Imminent (~36 hours) Hurricane Watches and Warnings Issued	PRIORITY LEVEL	PERSONNEL RESPONSIBLE	STATUS OF TASK	DATE/TIME COMPLETED
Storm Watch				
• Conference calls with NOAA local WFO/RFC/SPC.				
• Continue to monitor HURREVAC and other systems.				
• Monitor storm track and provide local government officials updates.				
• Anticipate the possible arrival of rainfall and tornadoes.				
• Monitor river stages and rainfall forecast.				
Emergency Operations Center (EOC)				
• Activate EOC (partial or full based on clearance times and threat).				
• Request primary ESF support agencies provide EOC briefings.				
• Complete and distribute EOC situation reports, as applicable.				
• Prepare EOC facility-Mitigate for Winds, Water, etc.				

Key Points

This checklist can include pre-season, steady-state activities along with essential response tasks in the lead-up to hazardous conditions and beyond. Effective plans need to be socialized and tested.

Visual 47: Time-Based Planning Assumptions



Key Points

- A region may use a chart to guide what levels of activation or preparedness they may be using.
- Depending on the level of government you support, your activities may ramp up early, when a tropical cyclone threat is more than several days away. If you support a state, the level of certainty that your state may be impacted is different than that of a city or county jurisdiction.
- A phased ramp-up of operational levels ensures that your jurisdictions are putting capabilities and response actions in play as the probability increases that your area of responsibility could be impacted.

Visual 48: The Process: Execute

Key Points

The final stage of making better decisions is to execute your plan and put your decisions into action. This phase occurs once there is a hurricane threat. During this phase, you need to:

- Continuously monitor the threat as it occurs.
- Assess the risk.
- Take action based on the assessed risk and your plan.

Visual 49: Frequently Asked Questions 8

FAQs

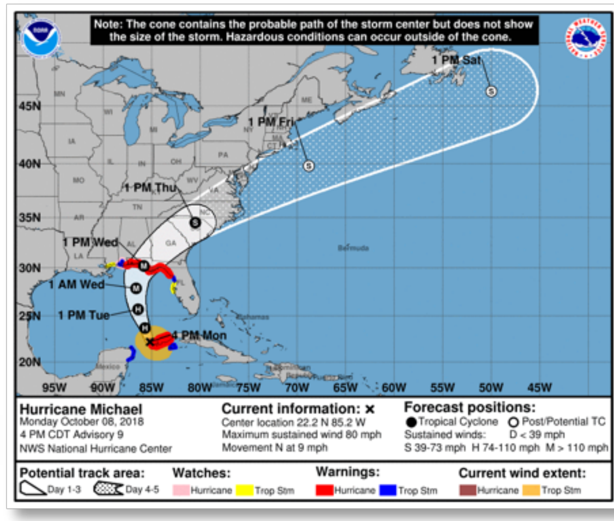
- What is the forecast?
- A threat to my community?
- When are hazards expected?

NHC Forecasts

Key Points

The NHC and Weather Forecast Office (WFO) forecasts can help you answer these questions.

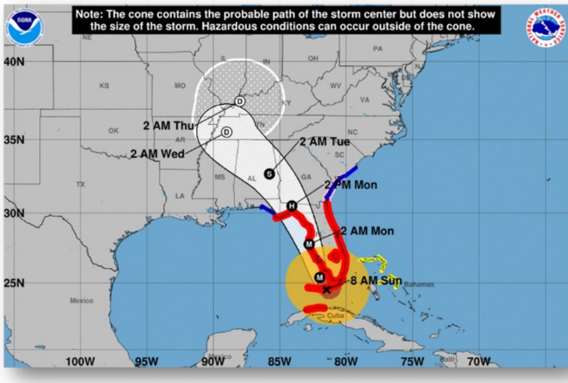
Visual 50: What NHC Forecasts?

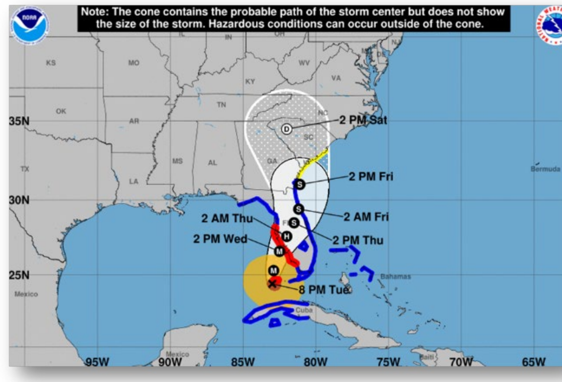


Key Points

The Track Forecast and Cone products can help you determine where the storm is heading. However, they will not tell you the entire story.

Visual 51: Storm Characteristics





Key Points

Forecast graphics can tell you about the storm's size, approach angle, and forward speed. These are important factors to consider for what you are planning.

Visual 52: Where is the Storm Going?

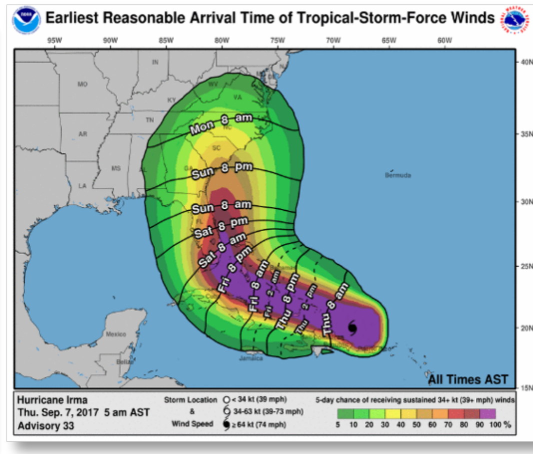
NATIONAL HURRICANE CENTER

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

TROPICAL STORM ISAAC WIND SPEED PROBABILITIES NUMBER 21
NWS NATIONAL HURRICANE CENTER MIAMI FL AL092012
0900 UTC SUN AUG 26 2012

- - - - WIND SPEED PROBABILITIES FOR SELECTED LOCATIONS - - - -

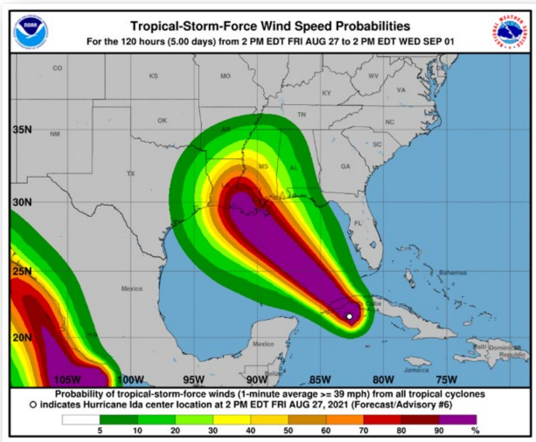
TIME PERIODS		FROM 12Z WED TO 00Z THU	FROM 00Z THU TO 12Z THU	FROM 12Z THU TO 00Z FRI	FROM 00Z FRI TO 12Z FRI	FROM 12Z FRI TO 12Z SAT	FROM 12Z SAT TO 12Z SUN	FROM 12Z SUN TO 12Z MON
FORECAST HOUR		(12)	(24)	(36)	(48)	(72)	(96)	(120)
LOCATION	KT							
PANAMA CITY FL	34	X	3(3)	22(25)	30(55)	16(71)	2(73)	1(74)
PANAMA CITY FL	50	X	X(X)	1(1)	13(14)	15(29)	2(31)	1(32)
PANAMA CITY FL	64	X	X(X)	X(X)	3(3)	6(9)	2(11)	1(12)
PENSACOLA FL	34	X	X(X)	10(10)	32(42)	31(73)	5(78)	X(78)
PENSACOLA FL	50	X	X(X)	X(X)	6(6)	28(34)	5(39)	1(40)
PENSACOLA FL	64	X	X(X)	X(X)	1(1)	14(15)	3(18)	X(18)
MOBILE AL	34	X	X(X)	5(5)	24(29)	35(64)	8(72)	1(73)
MOBILE AL	50	X	X(X)	X(X)	3(3)	22(25)	8(33)	1(34)
MOBILE AL	64	X	X(X)	X(X)	1(1)	8(9)	4(13)	1(14)

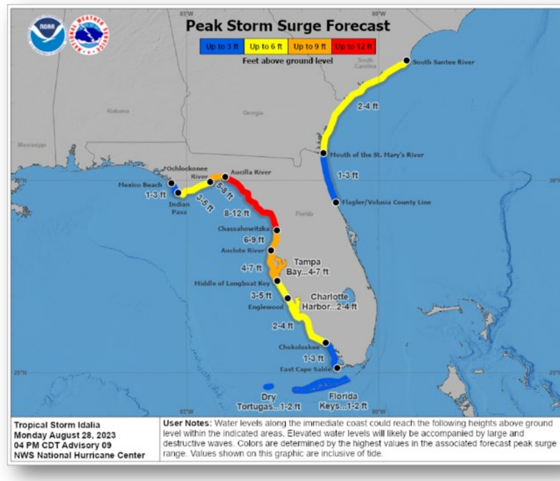


Key Points

Time of arrival graphics help you establish a timeline regarding evacuations. Wind speed probabilities help you see your level of risk with regards to wind. Monitor changes in the probabilities to see if your risk is increasing or decreasing.

Visual 53: Evaluate the Storm Threat





Key Points

NHC provides products that allow an Emergency Manager to see wind and surge risk from a specific storm.

Visual 54: Frequently Asked Questions 9

FAQs

- What is the forecast?
- Evacuation start times?

HURREVAC

Key Points

HURREVAC is a hurricane tracking decision-support tool available for free to Federal Government employees. It is a valuable resource for Emergency Managers during evacuation.

Visual 55: HURREVAC - Knowledge Check

POLL QUESTION

Do you have a HURREVAC account?

A. Yes, and I use it regularly.
B. Yes, but I am unfamiliar with how to use it.
C. I just registered for an account.
D. I do not have an account.

Visual 56: HURREVAC 1

HURREVAC

- **Hurricane tracking and decision support tool**
  - Uses NHC forecast data
  - Calculates evacuation start times
- **A resource for EMs during evacuations**
  - Common forecast picture
- **Reports**
  - Wind timing
  - Evacuation timing
  - Storm summary

Key Points

HURREVAC is a hurricane tracking and decision support tool that accesses and displays NHC data, such as MEOWs, MOMs, storm forecasts, and other products. HURREVAC uses this data and Hurricane Evacuation Studies to calculate evacuation times and to issue reports on wind time arrivals, evacuation timing, storm summaries, and other information. While primarily used in coastal decision making, HURREVAC has many useful resources for inland Emergency Managers.

Hurrevac.com allows you to register with a government email address. The site has webinar training materials and user guides as well as user support.

Visual 57: HURREVAC 2

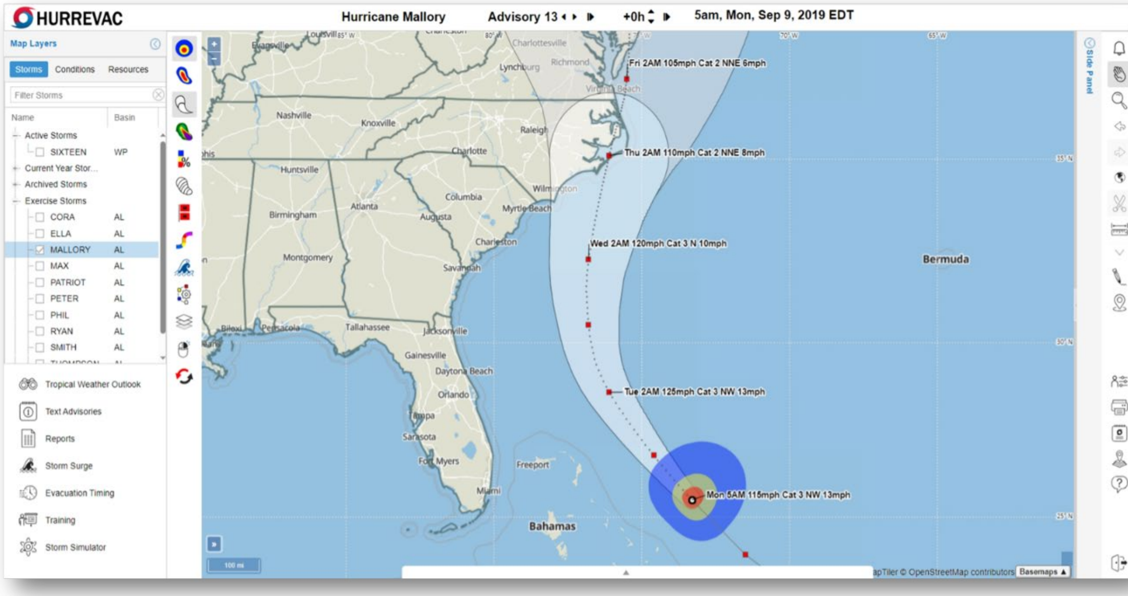
HURREVAC

- **Web-based**
  - No downloads or software to install.
  - Use your computer, tablet or phone.
  - Access your profile/preferences anywhere.
- **SLOSH Display**
  - MOMs & MEOWs
  - MEOW mixer
- **Register online** https://register.HURREVAC.com/

Key Points

Hurrevac.com allows you to register with a government email address. The site has webinar training materials and user guides as well as user support.

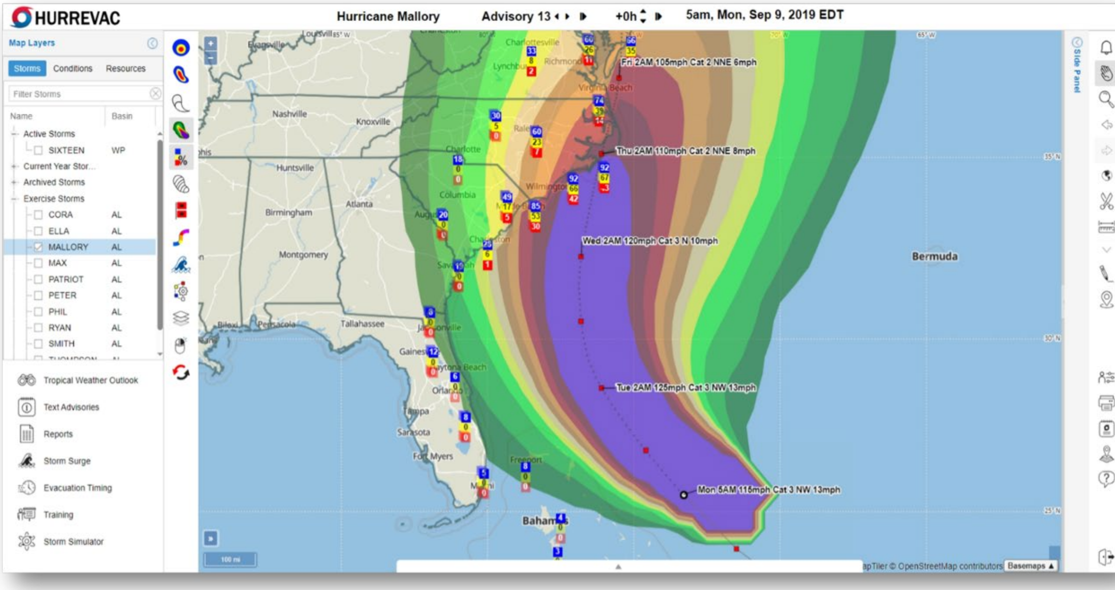
Visual 58: Forecast Track



Key Points

HURREVAC graphics mirror the official NHC forecast products, and provide additional information, such as the radius of strong tropical storm-force winds and detailed forecast labels. The capability to customize the map display with these forecast products makes HURREVAC a useful tool for storm and forecast tracking.

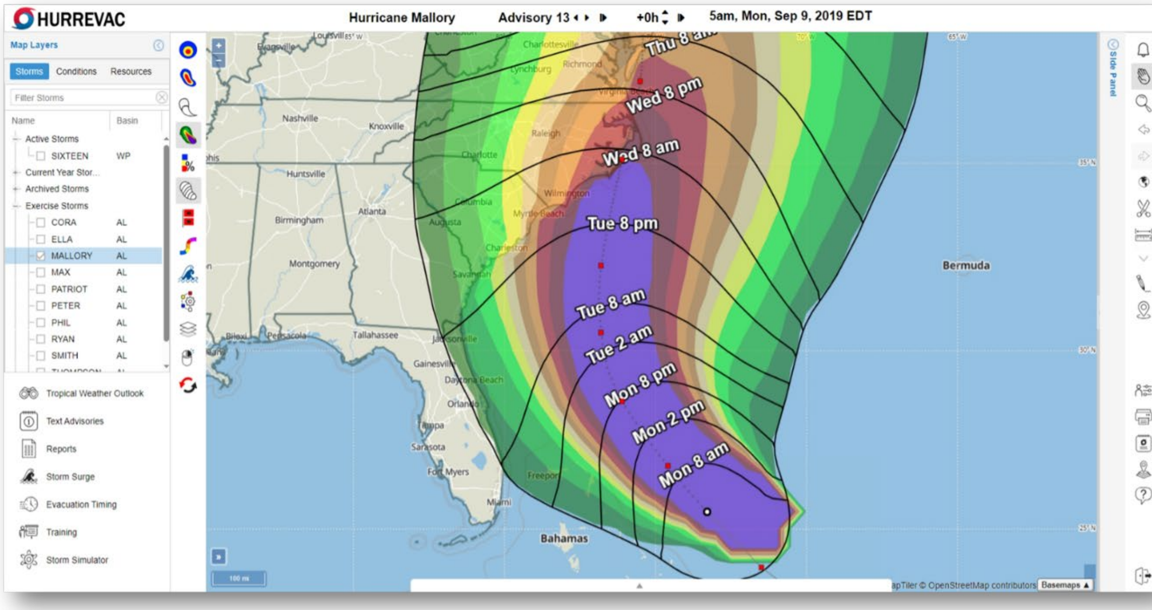
Visual 59: Wind Threat - Probabilities



Key Points

Wind speed probability information that is provided in NHC text products can be displayed graphically in HURREVAC. These numbers across the map correspond to the probabilities of TS, Strong TS, and Hurricane-force winds at each of these locations.

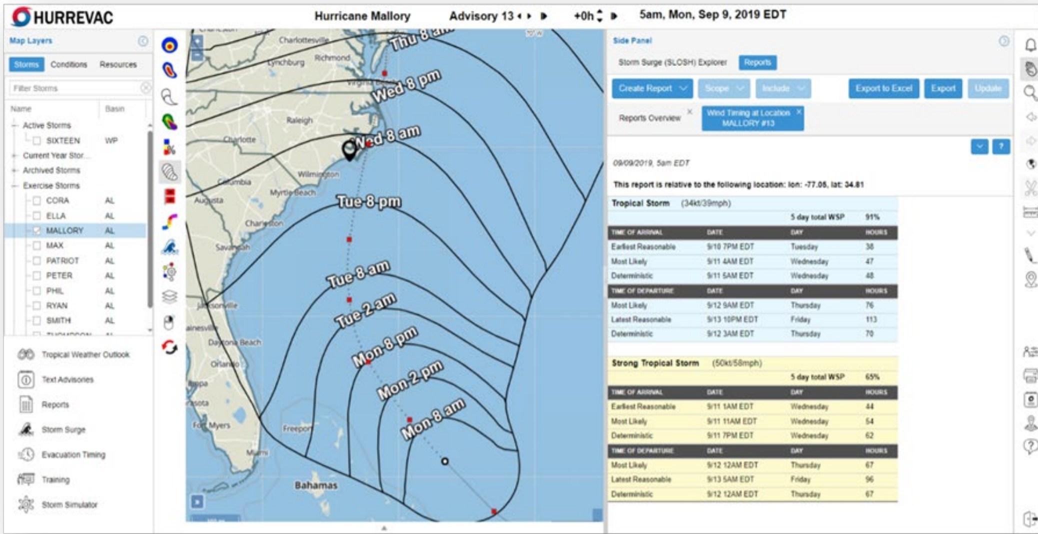
Visual 60: Wind Threat – Time of Arrival



Key Points

Wind timing graphics in HURREVAC mirror those available from the NHC.

Visual 61: Wind Timing – Report



Reports Overview ×

Wind Timing at Location MALLORY #13 ×

09/09/2019, 5am EDT

This report is relative to the following location: lon: -77.05, lat: 34.81

Tropical Storm (34kt/39mph)

		5 day total WSP	91%
TIME OF ARRIVAL	**DATE**	**DAY**	**HOURS**
Earliest Reasonable	9/10 7PM EDT	Tuesday	38
Most Likely	9/11 4AM EDT	Wednesday	47
Deterministic	9/11 5AM EDT	Wednesday	48
TIME OF DEPARTURE	**DATE**	**DAY**	**HOURS**
Most Likely	9/12 9AM EDT	Thursday	76
Latest Reasonable	9/13 10PM EDT	Friday	113
Deterministic	9/12 3AM EDT	Thursday	70

Key Points

You can right-click on a location in HURREVAC and get time of arrival and time of departure for winds. A demo will demonstrate this capability.

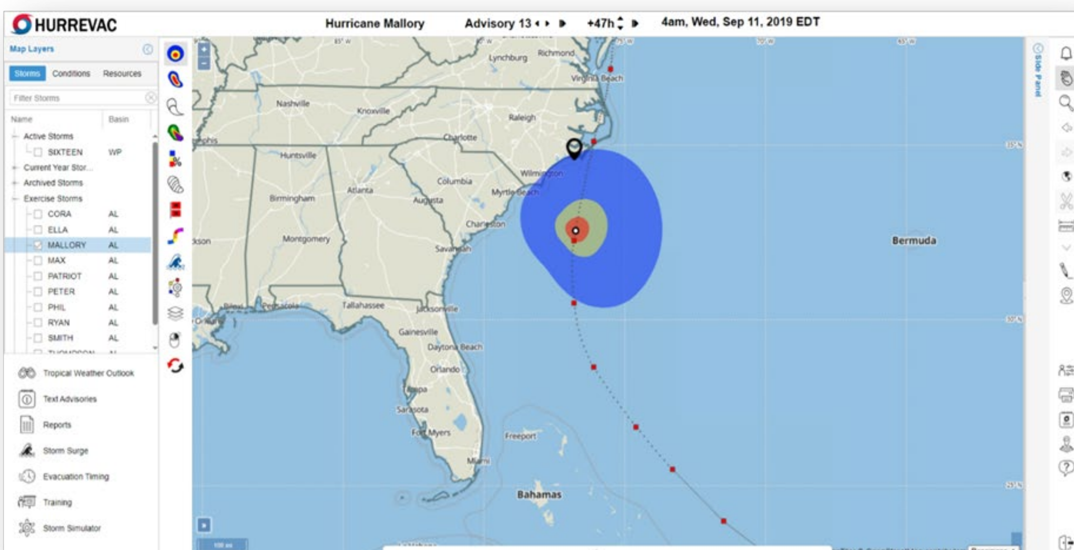
Visual 62: Wind Timing – All Affected Areas

Wind Timing
MALLORY #13

The purpose of the wind timing table is to show when specific wind thresholds are expected to be exceeded at a particular location.

Displaying data in NC for: Counties

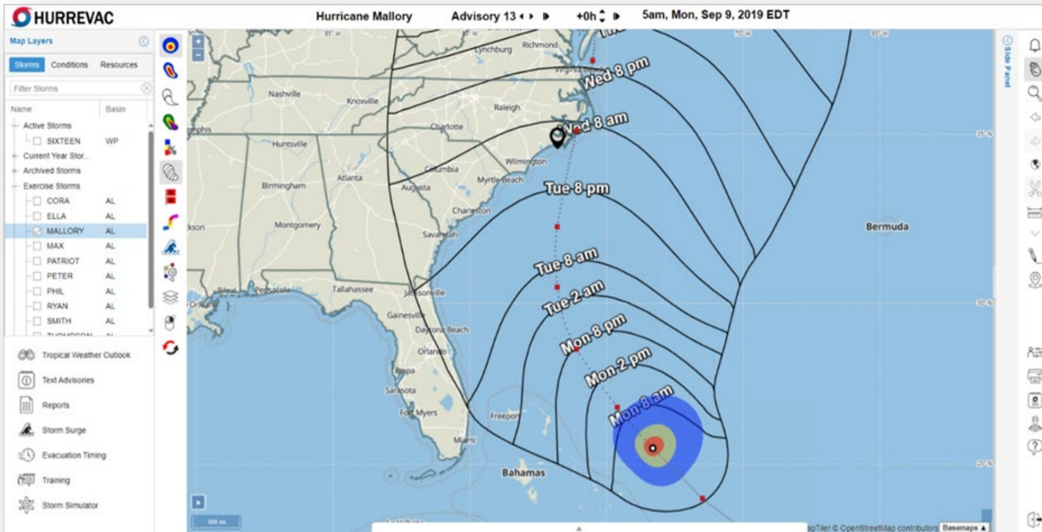
State	County	34kt Start	50kt Start	64kt Start	64kt End	50kt End	34kt End
NC	Carteret	09/11 3am	09/11 1pm	09/11 5pm	09/12 3am	09/12 3am	09/12 3am
NC	New Hanover	09/11 3am					09/12 3am
NC	Brunswick	09/11 3am					09/12 3am
NC	Onslow	09/11 4am	09/11 6pm			09/11 10pm	09/12 3am
NC	Jones	09/11 5am	09/11 7pm			09/12 12am	09/12 3am
NC	Craven	09/11 5am	09/11 5pm			09/12 3am	09/12 3am
NC	Pender	09/11 5am					09/12 3am
NC	Hyde	09/11 6am	09/11 4pm	09/11 9pm	09/12 3am	09/12 3am	09/12 3am
NC	Dare	09/11 6am	09/11 5pm	09/11 11pm	09/12 3am	09/12 3am	09/12 3am
NC	Pamlico	09/11 6am	09/11 6pm	09/12 12am	09/12 3am	09/12 3am	09/12 3am
NC	Beaufort	09/11 7am	09/11 8pm			09/12 3am	09/12 3am
NC	Duplin	09/11 8am					09/12 3am



Key Points

- Wind timing reports provide insight into the deterministic forecast for the onset of hazardous conditions in threatened areas. The report shows county-by-county timing information for when all pre-storm preparations should be completed, along with the timing for different wind intensities.
- Because these forecasts are deterministic, there is a high likelihood of the forecast changing with each new advisory. Thus, the specificity of the timing in these reports can sometimes imply a level of precision that the forecast does not have. The accuracy of these reports improves as the storm approaches and forecast certainty increases.

Visual 63: Evacuation Start Times



Evacuation Timing
MALLORY #13

09/09/2019, 5:00 am

The purpose of the evacuations timing table is to show, for each location, when the onset of tropical-storm-force winds is expected and provide the earliest and latest times for making evacuation decisions based on the range of evacuation scenarios and settings that the user has selected.

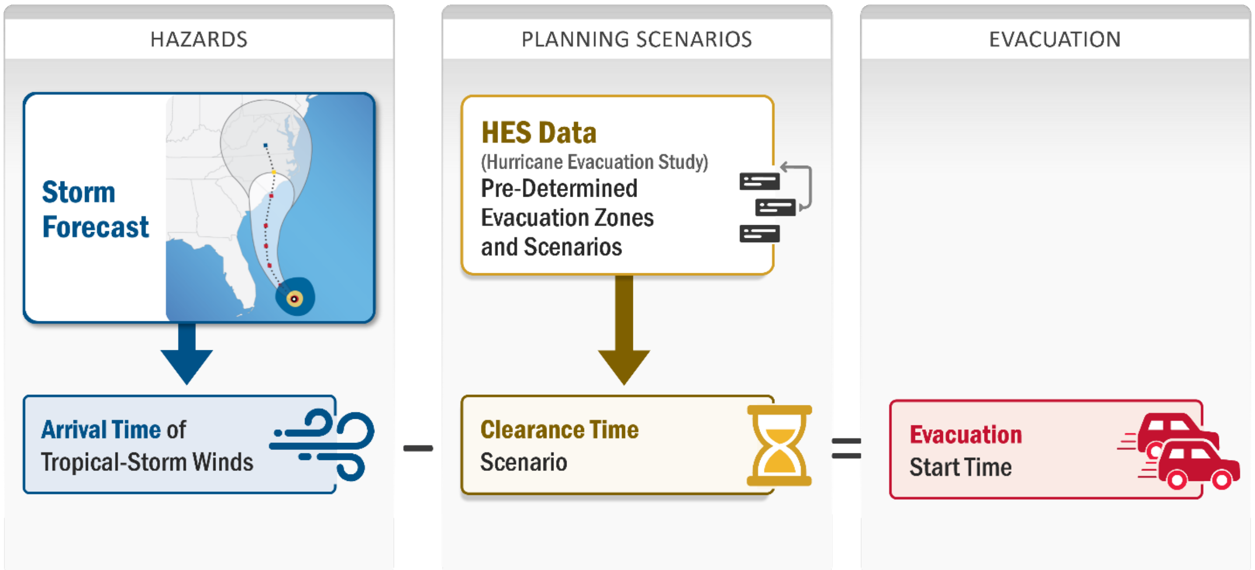
This report uses your saved Evacuation Scenarios and Timeline actions.

State	County	Scenario	Earliest-Reasonable TS Onset Time	Most-Likely TS Onset Time	Clearance Time	Earliest Evac Start Time	Latest Evac Start Time	TS WSP (%)
NC	Carteret	B/Slow/Worst/County	Tue 07 PM	Wed 04 AM	39 hrs	Mon 04 AM	Mon 01 PM	93
NC	Carteret	B/Mod/Med SP/County	Tue 07 PM	Wed 04 AM	35 hrs	Mon 08 AM	Mon 05 PM	93
NC	Carteret	B/Fast/High SP/County	Tue 07 PM	Wed 04 AM	34 hrs	Mon 09 AM	Mon 06 PM	93
NC	Carteret	B/Imm/Low SP/County	Tue 07 PM	Wed 04 AM	30 hrs	Mon 01 PM	Mon 10 PM	93

Key Points

There may be many scenario options to choose from to mirror the actual forecast and provide a tailored evacuation clearance time for incoming threats, depending on the complexity of a jurisdiction's evacuation scenarios.

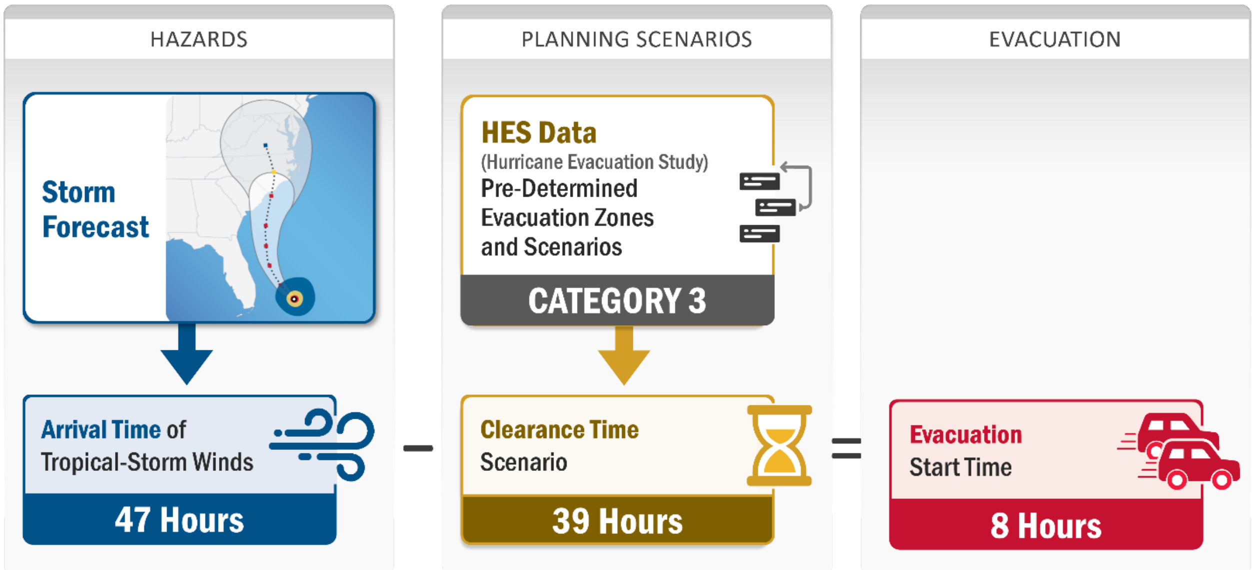
Visual 64: Calculating Evacuation Start Time



Key Points

- HURREVAC can also help you calculate evacuation start time. This is the time that you should begin an evacuation to have it completed by the time tropical storm-force winds arrive in your area.
- Evacuation start time is calculated by subtracting the clearance time from the time that tropical storm-force winds are expected to arrive.
- Clearance time is the amount of time it takes to complete an evacuation, from the time the first car enters the roadway to the time the last car gets to a point of assumed safety. This includes adjustments for increased traffic volume. HURREVAC gives you this information based on the data from your area's HES.

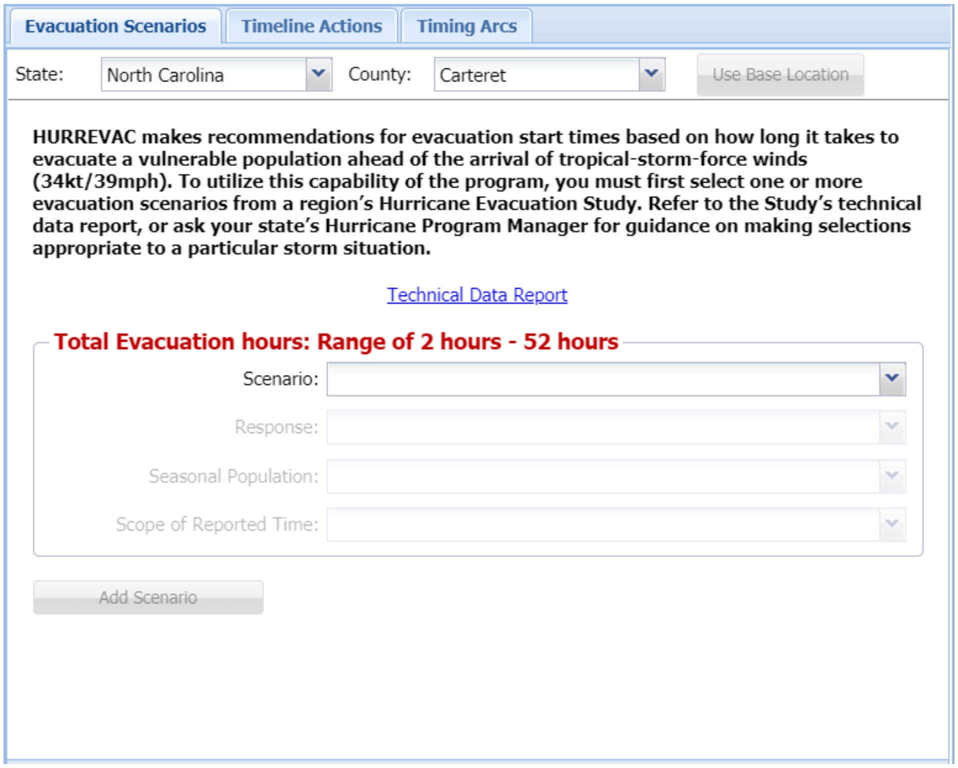
Visual 65: Calculating Evacuation Start Time 2

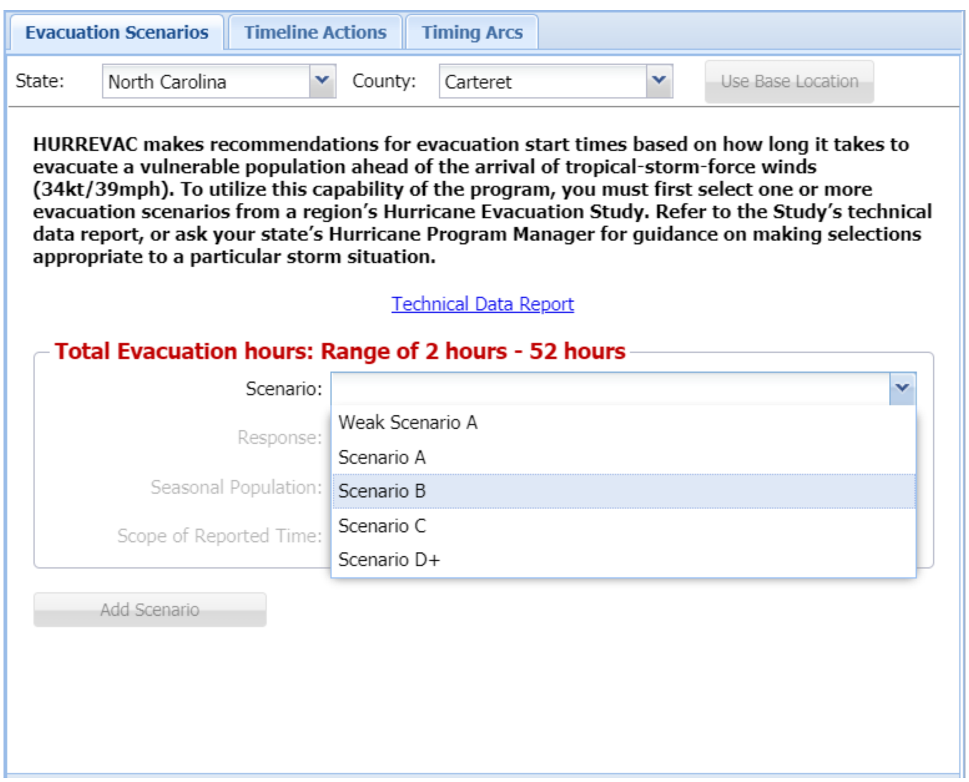


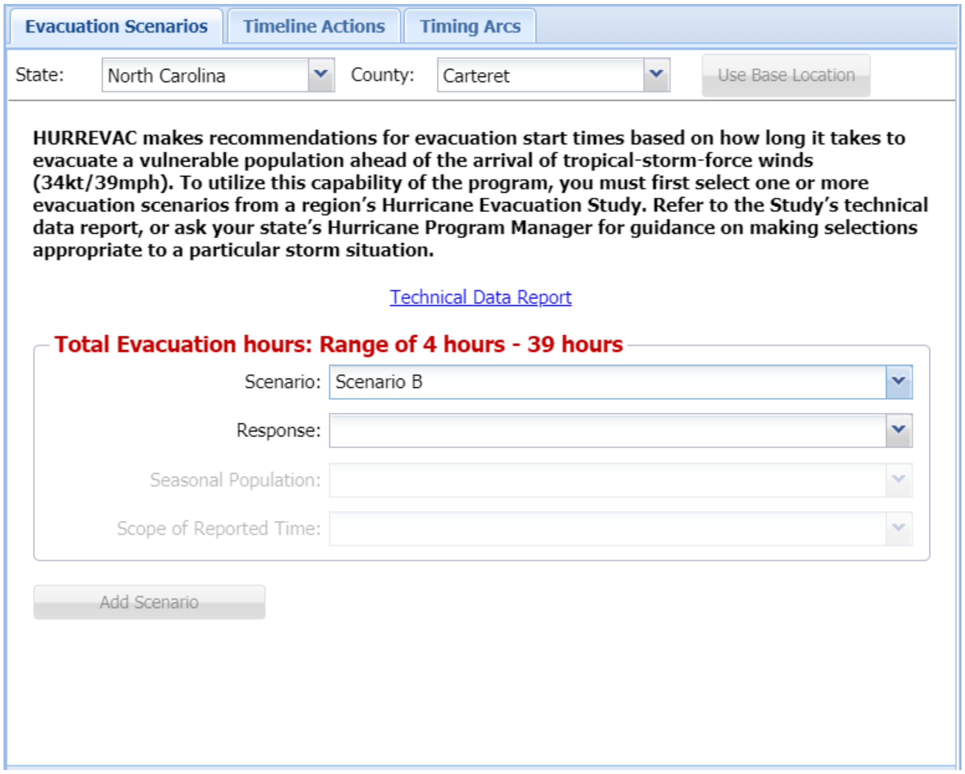
Key Points

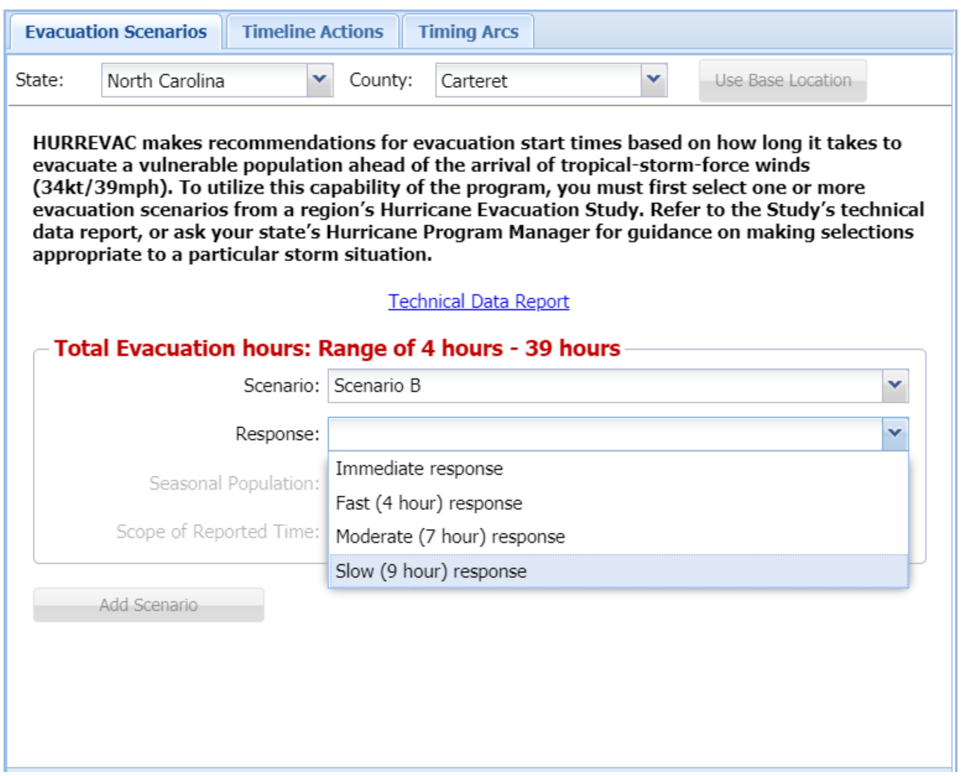
The key functionality of HURREVAC is to ingest the official NHC forecast for arrival of hazardous conditions while accounting for the appropriate clearance time from hurricane evacuation studies. This gives Emergency Managers the critical planning factor of the deadline to begin evacuations to ensure enough time for the threatened population to reach safe locations.

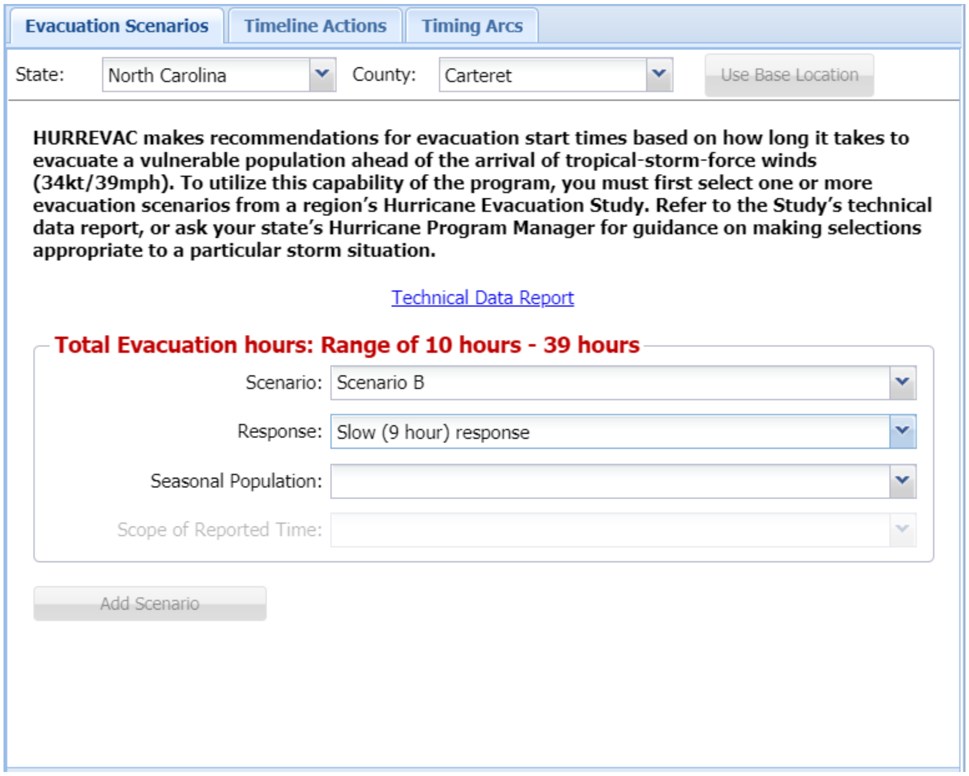
Visual 66: Evacuation Scenarios

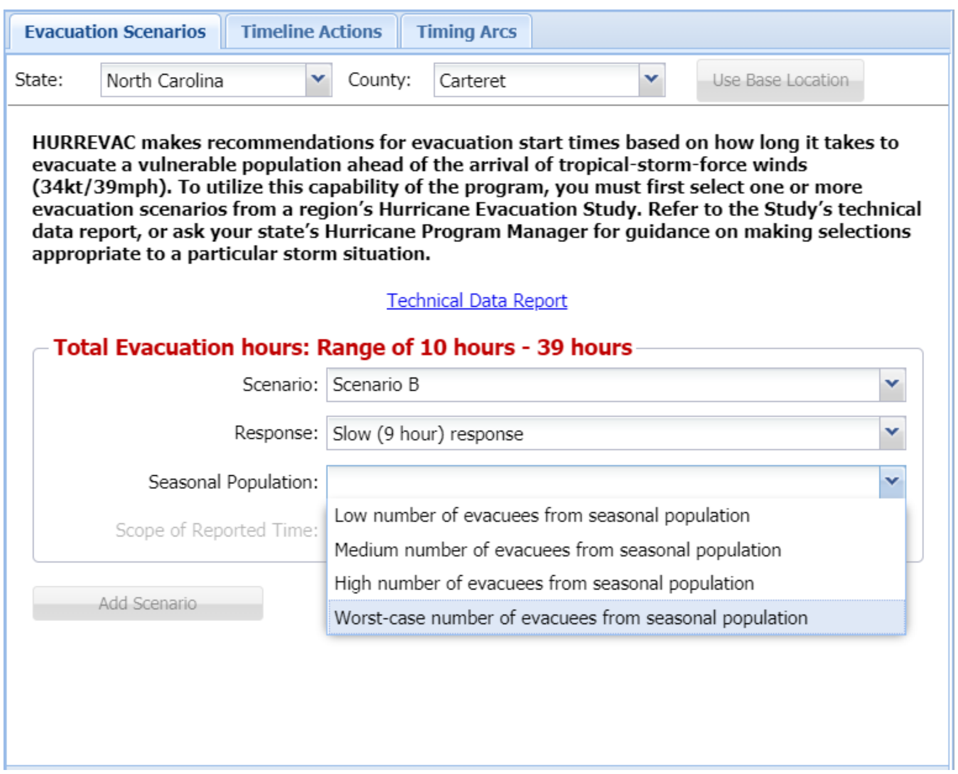


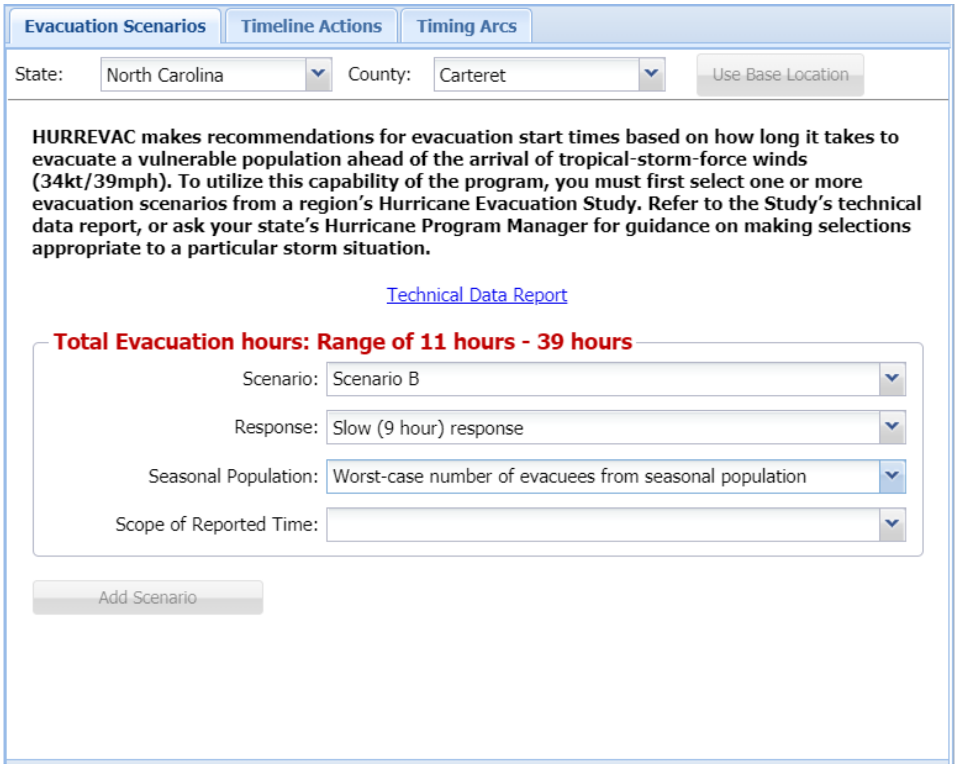


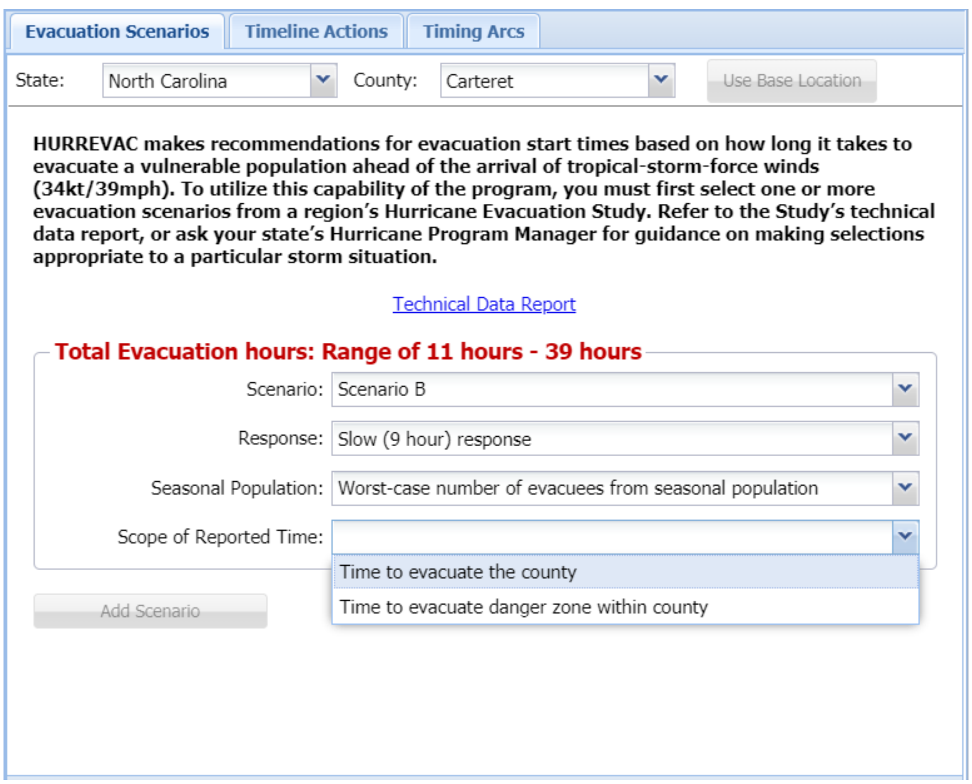

Evacuation Scenarios
Timeline Actions
Timing Arcs
State: North Carolina
County: Carteret
Use Base Location
HURREVAC makes recommendations for evacuation start times based on how long it takes to evacuate a vulnerable population ahead of the arrival of tropical-storm-force winds (34kt/39mph). To utilize this capability of the program, you must first select one or more evacuation scenarios from a region's Hurricane Evacuation Study. Refer to the Study's technical data report, or ask your state's Hurricane Program Manager for guidance on making selections appropriate to a particular storm situation.
Technical Data Report
Total Evacuation hours: Range of 4 hours - 39 hours
Scenario: Scenario B
Response:
Seasonal Population:
Scope of Reported Time:
Add Scenario

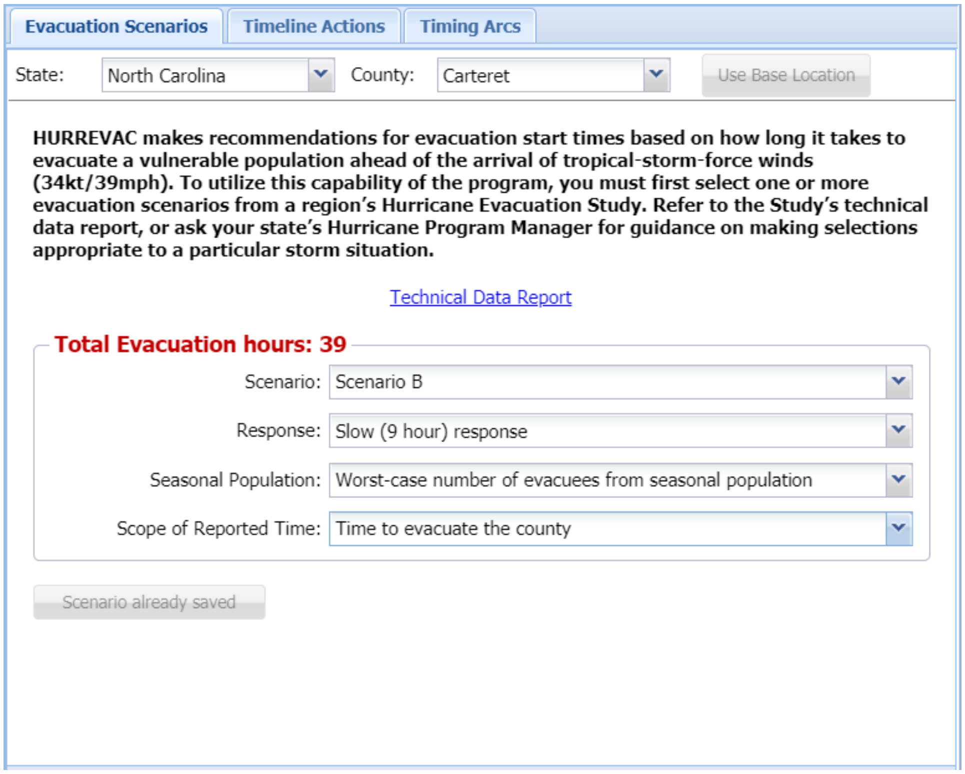

Evacuation Scenarios
Timeline Actions
Timing Arcs
State: North Carolina
County: Carteret
Use Base Location
HURREVAC makes recommendations for evacuation start times based on how long it takes to evacuate a vulnerable population ahead of the arrival of tropical-storm-force winds (34kt/39mph). To utilize this capability of the program, you must first select one or more evacuation scenarios from a region's Hurricane Evacuation Study. Refer to the Study's technical data report, or ask your state's Hurricane Program Manager for guidance on making selections appropriate to a particular storm situation.
Technical Data Report
Total Evacuation hours: Range of 4 hours - 39 hours
Scenario: Scenario B
Response:
Immediate response
Fast (4 hour) response
Moderate (7 hour) response
Slow (9 hour) response
Seasonal Population:
Scope of Reported Time:
Add Scenario


Evacuation Scenarios
Timeline Actions
Timing Arcs
State:
North Carolina
County:
Carteret
Use Base Location
HURREVAC makes recommendations for evacuation start times based on how long it takes to evacuate a vulnerable population ahead of the arrival of tropical-storm-force winds (34kt/39mph). To utilize this capability of the program, you must first select one or more evacuation scenarios from a region's Hurricane Evacuation Study. Refer to the Study's technical data report, or ask your state's Hurricane Program Manager for guidance on making selections appropriate to a particular storm situation.
Technical Data Report
Total Evacuation hours: Range of 10 hours - 39 hours
Scenario:
Scenario B
Response:
Slow (9 hour) response
Seasonal Population:
Scope of Reported Time:
Add Scenario


Evacuation Scenarios
Timeline Actions
Timing Arcs
State:
North Carolina
County:
Carteret
Use Base Location
HURREVAC makes recommendations for evacuation start times based on how long it takes to evacuate a vulnerable population ahead of the arrival of tropical-storm-force winds (34kt/39mph). To utilize this capability of the program, you must first select one or more evacuation scenarios from a region's Hurricane Evacuation Study. Refer to the Study's technical data report, or ask your state's Hurricane Program Manager for guidance on making selections appropriate to a particular storm situation.
Technical Data Report
Total Evacuation hours: Range of 10 hours - 39 hours
Scenario:
Scenario B
Response:
Slow (9 hour) response
Seasonal Population:
Low number of evacuees from seasonal population
Medium number of evacuees from seasonal population
High number of evacuees from seasonal population
Worst-case number of evacuees from seasonal population
Scope of Reported Time:
Add Scenario


Evacuation Scenarios
Timeline Actions
Timing Arcs
State:
North Carolina
County:
Carteret
Use Base Location
HURREVAC makes recommendations for evacuation start times based on how long it takes to evacuate a vulnerable population ahead of the arrival of tropical-storm-force winds (34kt/39mph). To utilize this capability of the program, you must first select one or more evacuation scenarios from a region's Hurricane Evacuation Study. Refer to the Study's technical data report, or ask your state's Hurricane Program Manager for guidance on making selections appropriate to a particular storm situation.
Technical Data Report
Total Evacuation hours: Range of 11 hours - 39 hours
Scenario:
Scenario B
Response:
Slow (9 hour) response
Seasonal Population:
Worst-case number of evacuees from seasonal population
Scope of Reported Time:
Add Scenario


Evacuation Scenarios
Timeline Actions
Timing Arcs
State:
North Carolina
County:
Carteret
Use Base Location
HURREVAC makes recommendations for evacuation start times based on how long it takes to evacuate a vulnerable population ahead of the arrival of tropical-storm-force winds (34kt/39mph). To utilize this capability of the program, you must first select one or more evacuation scenarios from a region's Hurricane Evacuation Study. Refer to the Study's technical data report, or ask your state's Hurricane Program Manager for guidance on making selections appropriate to a particular storm situation.
Technical Data Report
Total Evacuation hours: Range of 11 hours - 39 hours
Scenario:
Scenario B
Response:
Slow (9 hour) response
Seasonal Population:
Worst-case number of evacuees from seasonal population
Scope of Reported Time:
Time to evacuate the county
Time to evacuate danger zone within county
Add Scenario



Key Points

HURREVAC allows the user to tailor the evacuation scenario from the HES to the most applicable real-world scenario. It includes the impacts that the public response rate and seasonal or tourism population might have on the timing of completing the evacuation.

Visual 67: Evacuation Start Times (cont.)

Evacuation Timing
MALLORY #13

09/09/2019, 5:00 am

The purpose of the evacuations timing table is to show, for each location, when the onset of tropical-storm-force winds is expected and provide the earliest and latest times for making evacuation decisions based on the range of evacuation scenarios and settings that the user has selected.

This report uses your saved Evacuation Scenarios and Timeline actions.

State	County	Scenario	Earliest-Reasonable TS Onset Time	Most-Likely TS Onset Time	Clearance Time	Earliest Evac Start Time	Latest Evac Start Time	TS WSP (%)
NC	Carteret	B/Slow/Worst/County	Tue 07 PM	Wed 04 AM	39 hrs	Mon 04 AM	Mon 01 PM	93
NC	Carteret	B/Mod/Med SP/County	Tue 07 PM	Wed 04 AM	35 hrs	Mon 08 AM	Mon 05 PM	93
NC	Carteret	B/Fast/High SP/County	Tue 07 PM	Wed 04 AM	34 hrs	Mon 09 AM	Mon 06 PM	93
NC	Carteret	B/Imm/Low SP/County	Tue 07 PM	Wed 04 AM	30 hrs	Mon 01 PM	Mon 10 PM	93

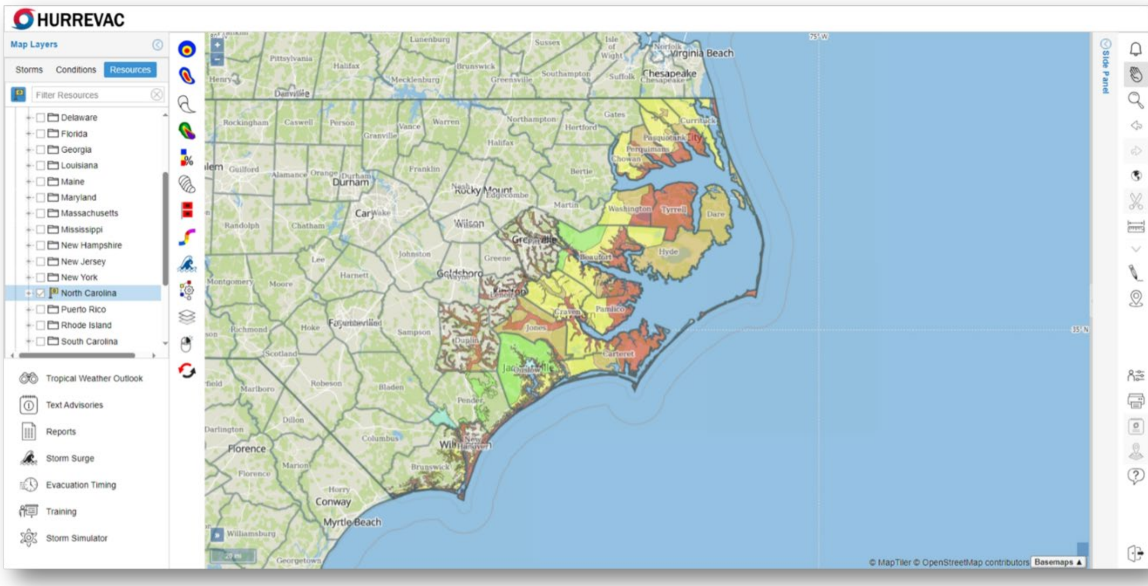
Key Points

HURREVAC has the functionality to not only pair evacuation clearance times with the official forecast, but users may also add activities from their response timeline to make sure that their pre-landfall checklist is on schedule as the forecast changes.

Student Manual

Evacuation clearance times are for public, self-evacuation. Using the timeline feature, Emergency Managers can add in other critical protective actions from their deliberate plans.

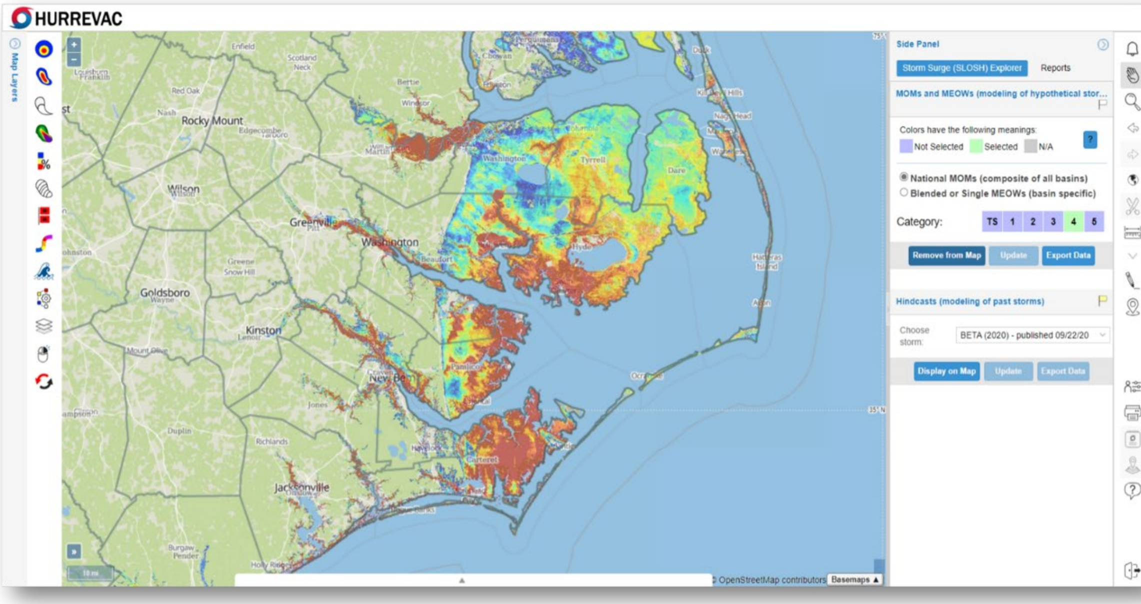
Visual 68: Evacuation Zones



Key Points

Hurricane Evacuation Zones are captured by state and county under the "Resources" tab in HURREVAC.

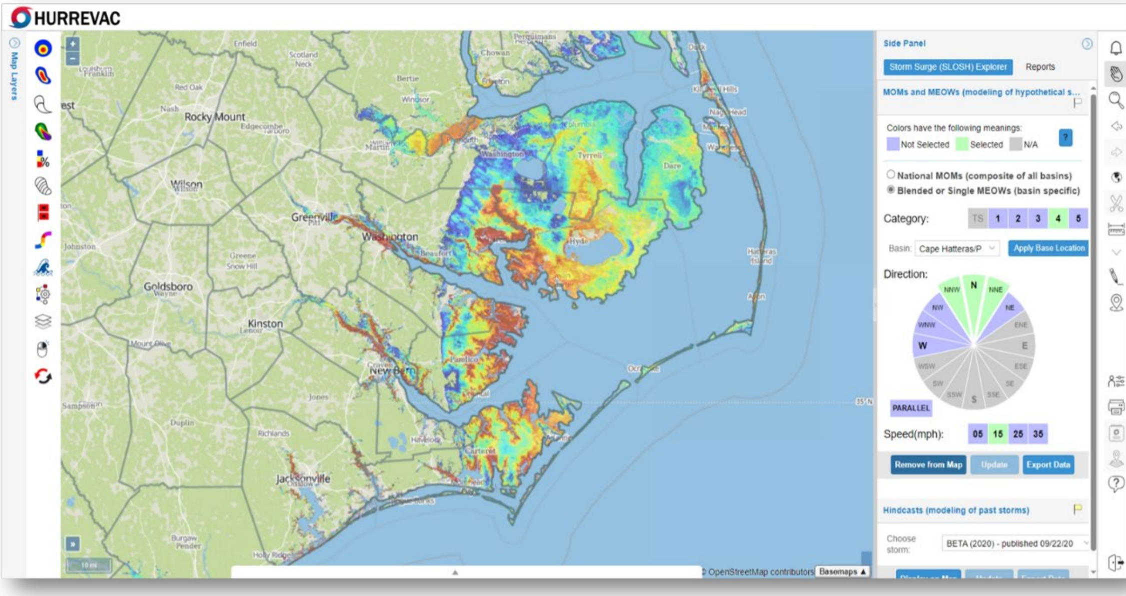
Visual 69: Surge Threat – SLOSH MOMs



Key Points

- The Storm Surge explorer allows users to see MEOWs and MOMs for all active SLOSH basins.
- The MEOW blender allows users to combine the maximum results for multiple MEOWs at once, and determine relative vulnerabilities based on the storm's direction of approach.

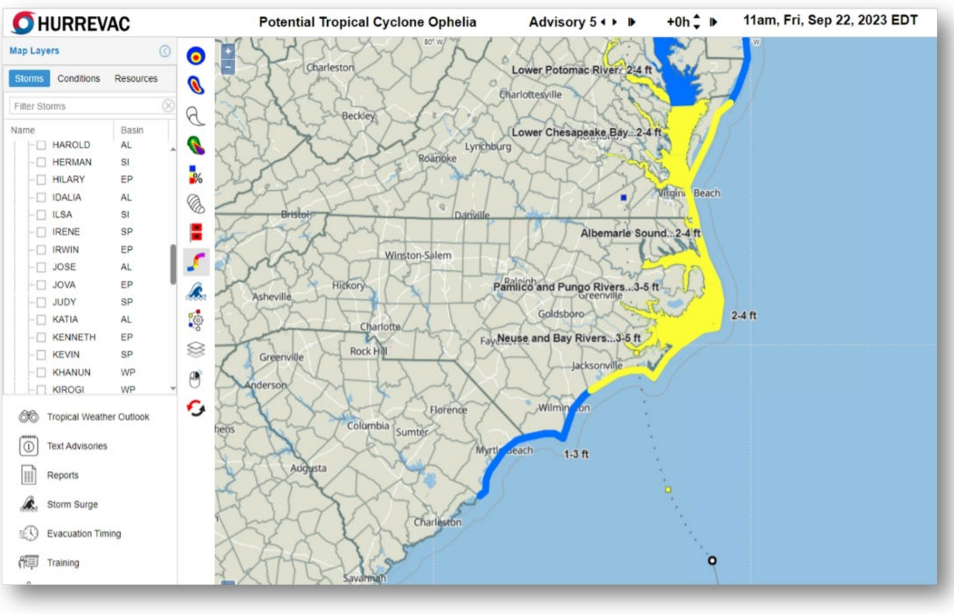
Visual 70: Surge Threat – SLOSH MEOWs



Key Points

- This visual shows three directional MEOWs have been selected on the circle, assuming a Category 3, at high tide with a 15 mph forward speed.
- What's displayed on the map is the worst case for each location from all three of these scenarios. This is very useful as the storm approaches and users can begin narrowing down the anticipated impacts as forecast certainty improves.

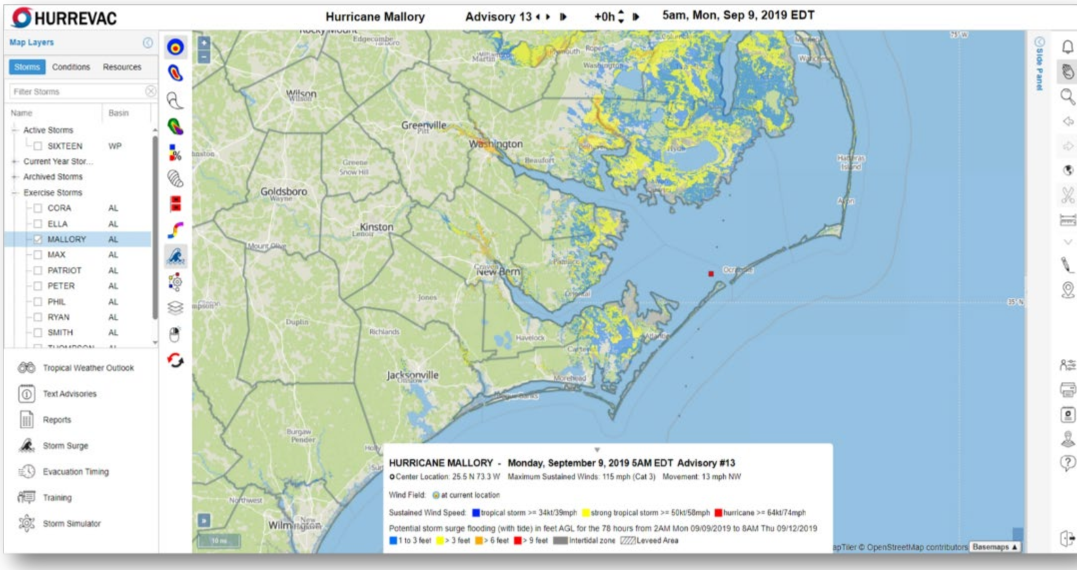
Visual 71: Surge Threat – Peak Storm Surge



Key Points

- This visual shows the NHC Peak Storm Surge Forecast but viewed from within HURREVAC.

Visual 72: Surge Threat – Potential Inundation



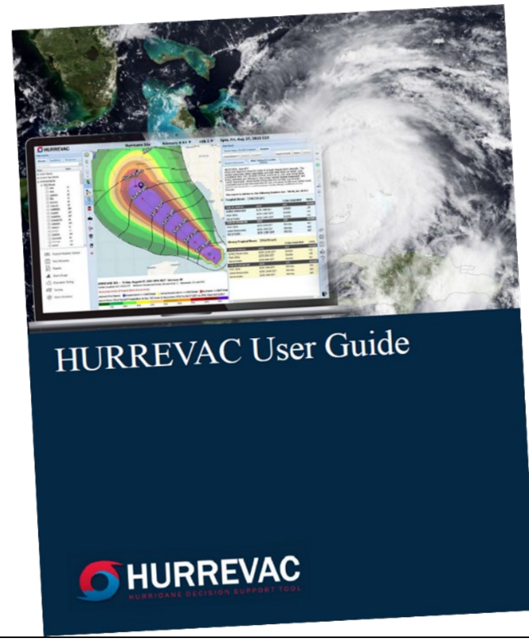
Key Points

- This visual shows the NHC Potential Storm Surge Flooding layer but viewed within HURREVAC.
- This is the 10% exceedance output from P-surge.
- In HURREVAC, you can zoom in closer than on the NHC website, and you can put on different map layers.
- Try turning on the evacuation zone layer to see what areas are at risk.

Visual 73: HURREVAC Account Registration

HURREVAC's Registration Site.

https://register.hurrevac.com



Key Points

- Download HURREVAC from the HURREVAC website.
- Register using the button on the top-right of the screen.
- It is available for free to Federal Government employees and those involved in the U.S. Government's preparation and responses to hurricanes.
- There are great resources for training and technical help on the left side of the page.

Visual 74: Frequently Asked Questions 10

FAQs

- Confidence? Contingencies?
- What is the forecast/evacuation timing?
- Can we get a briefing?

Hurricane Liaison Team

Key Points

The Hurricane Liaison Team helps EMs answer questions on events through information sharing, interpretation, contextualization, and other support.

Visual 75: Background

HLT Background

- Initial idea arose in the early 1990s.
- Proven during response to the 1995 Hurricane Season.
    - Erin and Opal
- Formalized in 1996.
    - Request from Governor of Florida to FEMA and NHC Director
    - Full-time positions at NHC.

Key Points

In addition to the Local NWS, the HLT can help facilitate communications and forecast information.

Initial idea arose in early 1990's.

Successfully proven during response to the 1995 Hurricane Season.

Became formal in 1996 by FEMA Director upon request of the Governor of Florida and the Director of National Hurricane Center.

The HLT is a partnership between the National Weather Service and the Federal Emergency Management Agency. It is made up of liaisons at the National Hurricane Center, Regional Hurricane Program Managers, Reservists, and NWS meteorologists and hydrologists.

Visual 76: Mission

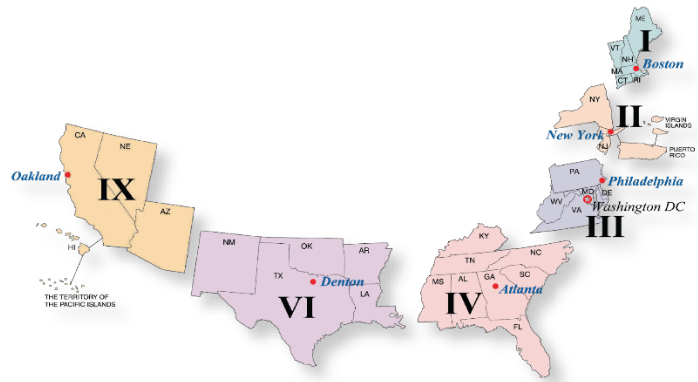
"The Hurricane Liaison Team's mission is to improve our Nation's capability to respond to hurricanes through the rapid exchange of critical information between the National Hurricane Center and Federal, State, Local, Tribal and Territorial Emergency Managers."

Key Points

"The Hurricane Liaison Team's mission is to **improve our Nation's capability to respond to hurricanes through the rapid exchange of critical information** between the National Hurricane Center and Federal, State, Local, Tribal and Territorial Emergency Managers."

Visual 77: Regional Program Managers

- Technical Knowledge
- State/Local Relationships
- Deploy to NHC



Key Points

Each hurricane-prone FEMA Region has a Regional Hurricane Program Manager. These technical experts are familiar with their specific region's work in blue skies to build relationships and deploy to the Hurricane Center during incidents that threaten their Region to provide support.

Visual 78: Responsibilities

Real-time interpretation, assessment, and guidance

- Apply NHC forecasts with Regional, State, and local response evacuation plans.

Forum for EMs to ask questions.

- Reinforce decisions.
- Assist with the use of NHC forecasts and predictive modeling.

Provide NHC visibility on EM protective actions.

- Improve messaging.

Key Points

This is a review of what the Hurricane Liaison Team does during events. A full suite of telecommunications equipment is located in the HLT office to communicate with FEMA HQ. The HLT FEMA members are not making forecasts but are serving as liaisons to the NHC meteorologists.

Visual 79: Unit Review

- Identify the components of the Hurricane Evacuation Study (HES).
- Explain clearance times and their use.
- Identify the capabilities of **HURREVAC.**
- Apply NHP products and services for planning and operational purposes.

Key Points

This is a review of Unit 4

Visual 80: Questions/Comments?

Visual 81: Course Review 1

- **Unit 1:** Explain the hurricane life cycle, climatology, and associated hazards to coastal communities.
- **Unit 2:** Describe when NHC products are available for tropical cyclone events and how to use them to determine threats from an approaching storm.

Key Points

This is a review of the course, Units 1 and 2

Visual 82: Course Review 2

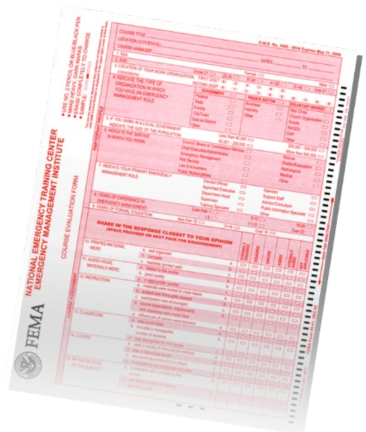
- **Unit 3:** Explain the uncertainties of NHC forecasts that must be considered in emergency management decision making.
    - Describe the storm surge threat and how to assess potential impacts.
- **Unit 4:** Explain the components of Hurricane Evacuation Studies (HES) and how they can inform planning for hurricanes.
    - Identify the resources available for evacuation planning and response and how to use them.

Key Points

This is a review of the course, Units 3 and 4.

Visual 83: EMI Evaluation Form

- **Please complete.**
- **Rate topics and instructors from Scale of 1 (lowest) - 5 (highest).**
- **Write in comments to improve the training!**



Key Points

Please fill out the evaluation form and turn it into the instructors.