L0310: Hurricane Readiness for Inland Communities

Student Manual

Date Released: 11/2023

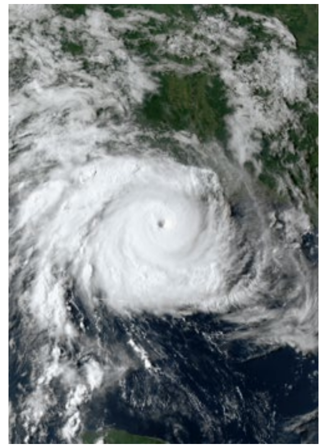
FEMA

Contents

Unit 0: Course Overview

Visual 1: Hurricane Readiness for Inland Communities

L0310: Hurricane Readiness for Inland Communities



Key Points

Welcome to the L0310 Hurricane Readiness for Inland Communities training course. This 1-day course is intended to help you make 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

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. Consult the agenda for more details.
- Parking Area (s) – park only in designated areas.
- Smoking Policy – no smoking in the building.
- 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 cell 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.
    - Students Identification (SID) Number is required.
- 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

Training Application

- EMI now uses an Online Training Application.
  - National Training Center – General Admissions Application
  - Students must submit their online application within 14 days of class completion to get EMI credit.
  - https://training.fema.gov/generaladmissionsapplication/
- Student Identification (SID) Number is required to register for this training and any FEMA course.
  - https://cdp.dhs.gov/femasid

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 (https://training.fema.gov/generaladmissionsapplication/staticforms/startapplication.aspx).
- 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

Evaluations

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

Key Points

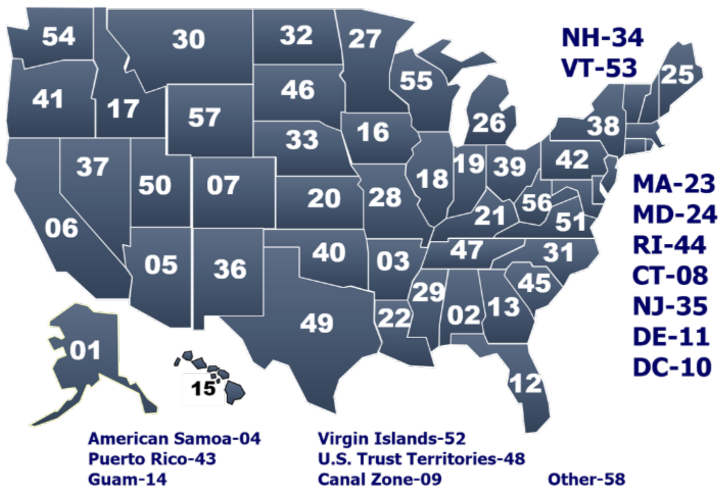
The EMI Course Evaluation Form will be used to document participant feedback at the end of the course on overall quality of content, instruction, and facilities.

- 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: Block #3 – 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 state 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 Partners

FEMA

NATIONAL HURRICANE PROGRAM

three federal partners, one mission to save lives

Key Points

This course is presented by the National Hurricane Program (NHP) (https://www.fema.gov/emergency-managers/risk-management/hurricanes), an interagency partnership administered by the Federal Emergency Management Agency 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

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.

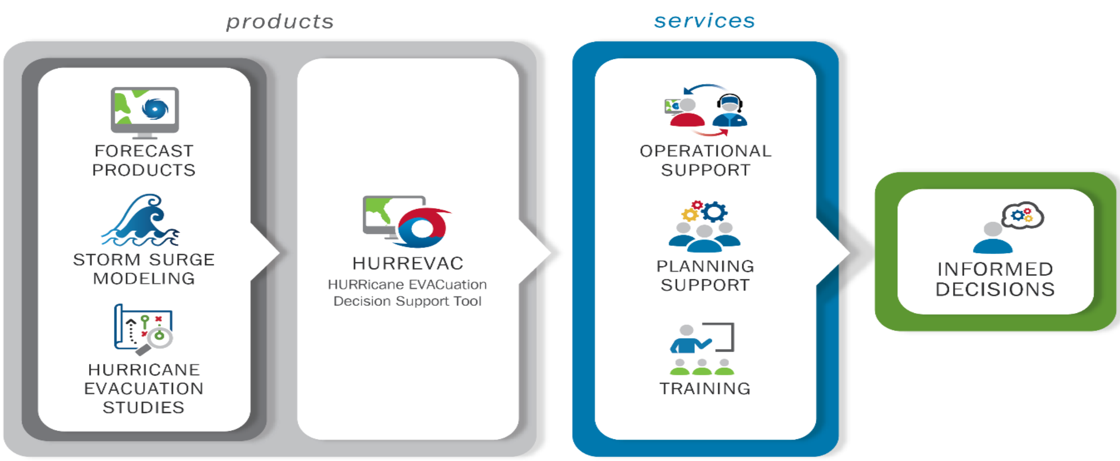
The NHP has established three central goals designed to fulfill its mission:

1. Provide OPERATIONAL tools, information, and technical assistance to 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 Emergency Managers (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 (https://www.fema.gov/emergency-managers/risk-management/hurricanes).

Visual 10: NHP Products and Services

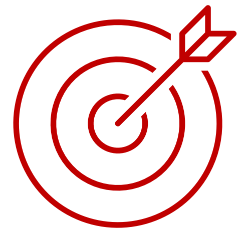


Key Points

- **Column 1 of the graphic:** The NHP provides products and services to SLTT Emergency Managers. The NHC issues forecast products when there is storm threat. Through the partnership with the NHP, the 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. USACE leads the coordination of Hurricane Evacuation Studies (HES) in partnership with FEMA and the states.
- **Column 2 of the graphic:** These products (forecast wind speed data, storm surge risk products, and evacuation zones and clearance times from an 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 Emergency Managers (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 those from the National Weather Service (NWS).



Visual 12: Course Objectives

After completing this course, you should be able to:

- Explain the hurricane life cycle, climatology, and associated hazards to inland communities.
- Describe when NWS products are available for tropical cyclone events and how to use them to determine threats from an approaching storm.
- Explain the uncertainties of NWS forecasts that must be considered in emergency management decision making.
- Explain the factors that influence tropical cyclone rainfall and the forecast products available, including their inherent uncertainty.
- Identify the resources available for inland evacuation planning and response and how to use them.

Visual 13: Course Agenda

COURSE AGENDA – In Person	Length
Unit 0: Course Overview	15 minutes
Unit 1: Tropical Cyclone Basics	120 minutes
Unit 2: National Weather Service (NWS) Products	90 minutes
LUNCH	
Unit 3: Understanding Forecast Uncertainty	75 minutes
Unit 4: Inland Hurricane Preparation in Practice	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
- L0310 Student Manual
- Handouts

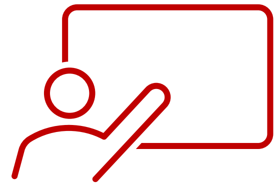
NHC Outreach Materials

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

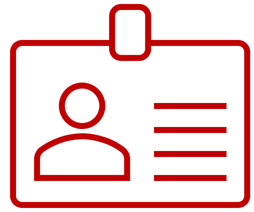
- Name
- Position
- Synopsis of hurricane experience



Visual 16: Student Introductions

Please introduce yourself:

- Name
- Title
- Agency/Organization



Visual 17: Questions/Comments

Unit 1: Tropical Cyclone Basics

Visual 1: Tropical Cyclone Basics

Unit 1:

Tropical Cyclone Basics

Key Points

Welcome to Unit 1: Tropical Cyclone Basics. This unit introduces the basics of tropical cyclones, including what defines a tropical cyclone vs. subtropical and extratropical cyclones, the climatology of tropical cyclones, cyclone formation, and hazards and threats from tropical cyclones.

Visual 2: Unit 1 Objectives

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

1. Explain the characteristics of tropical cyclones, including life cycle, factors influencing intensity, and categorization scale.
2. Describe the hazards of tropical cyclones and their impacts.
3. Explain the inland flood threat posed by tropical cyclones, including influencing factors.

Visual 3: 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

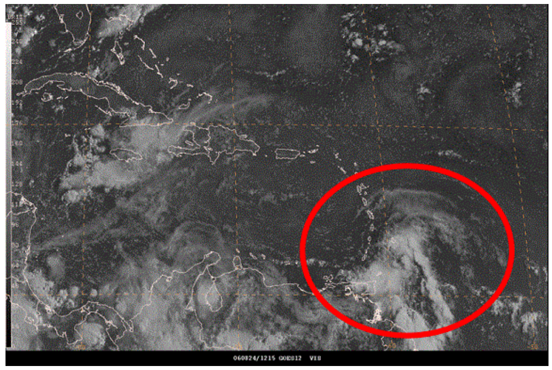
Key Points

There are several types of tropical cyclones. Wind speed is the metric used to categorize them. Tropical cyclones 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)

Visual 4: Tropical Cyclone: Surface Circulation? Organized?



Key Points

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

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

Visual 5: Tropical Cyclones Defined

Characteristics of Tropical Cyclones

- Hurricane, Tropical Storm, Tropical Depression
- 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

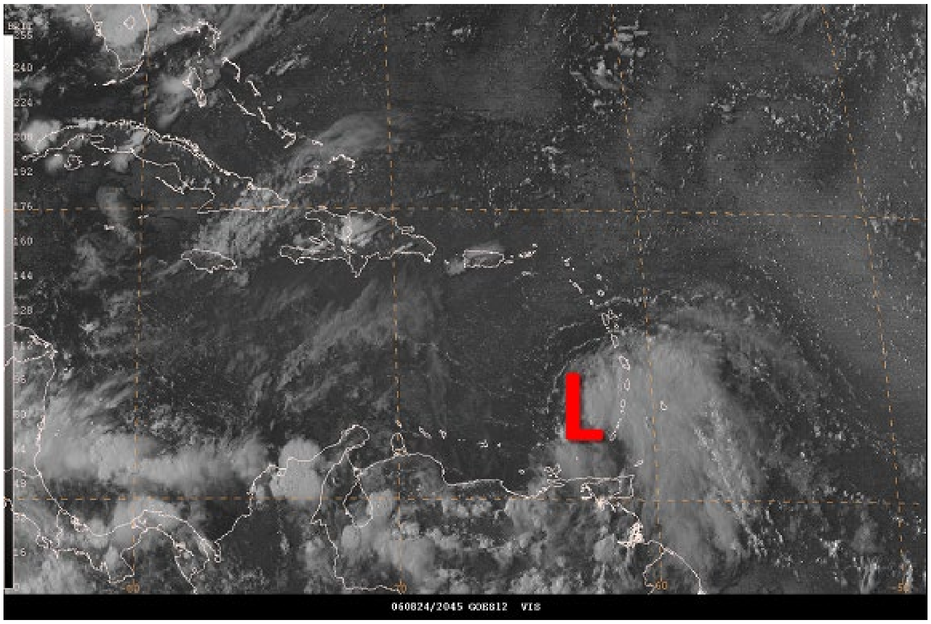
Key Points

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. 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 6: Ernesto 2006

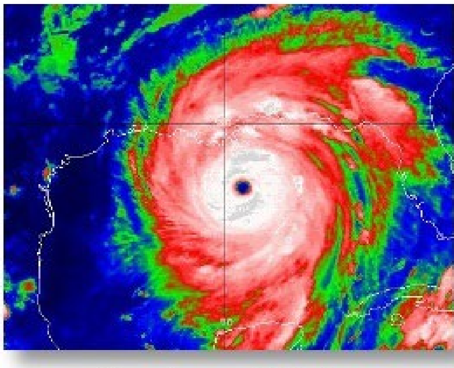


Advisory 1 issued based on aircraft data

Key Points

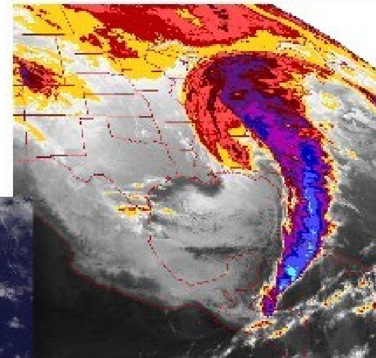
This depression later grew into Hurricane Ernesto (2006).

Visual 7: Tropical, Subtropical, & Extratropical Cyclones



Hurricane Katrina
2005

Subtropical Storm Ana
2015



March Superstorm
1993

Key Points

Coastal storms include both tropical and non-tropical cyclones. 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 difference 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 "nor'easters," originate in the non-tropical middle-latitudes of the earth. Temperatures here are not as consistently warm.

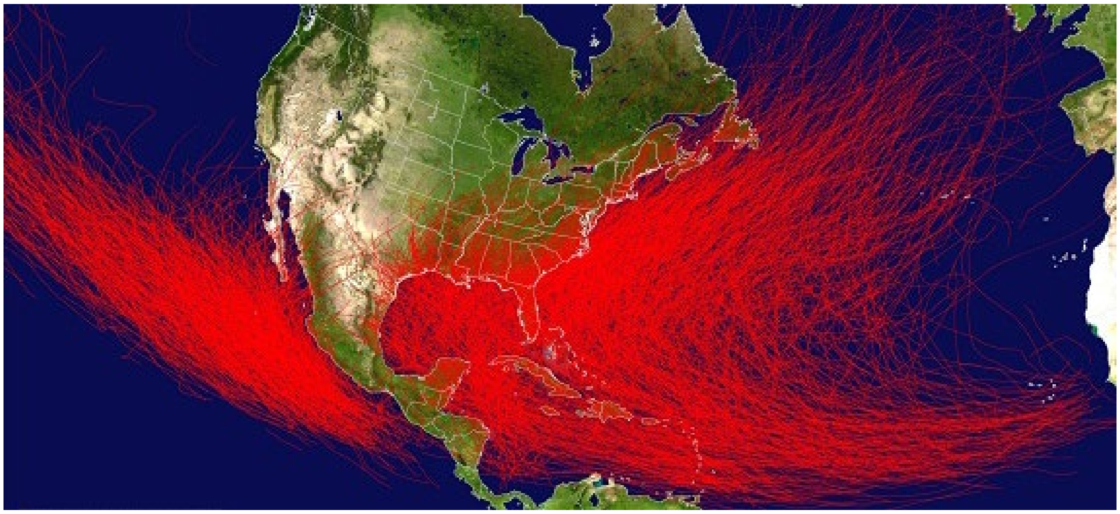
Whereas the energy for a tropical cyclone comes from the warmth, the primary energy source for an extratropical storm is the result of the temperature contrast between warm and cold air masses. Therefore, the two types of storms, although similar in many ways, behave differently and have different characteristics.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

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. This leads to a comma-like shape.

It is possible for a tropical cyclone to become extratropical and vice versa as the storm moves northward into the mid-latitudes (although the former is more typical).

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 temperature differences 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

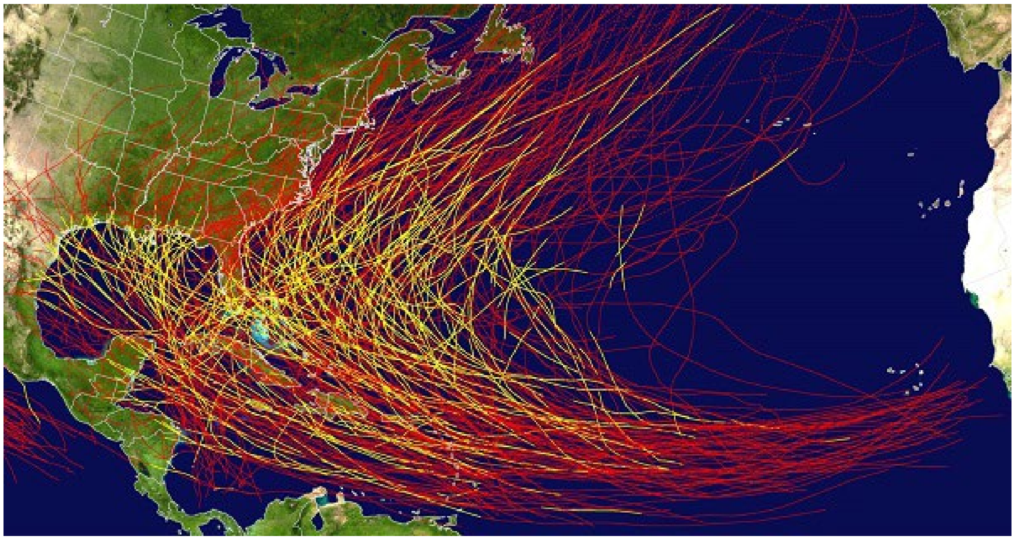


Data since 1949 in Pacific, 1851 in Atlantic

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 1851

Key Points

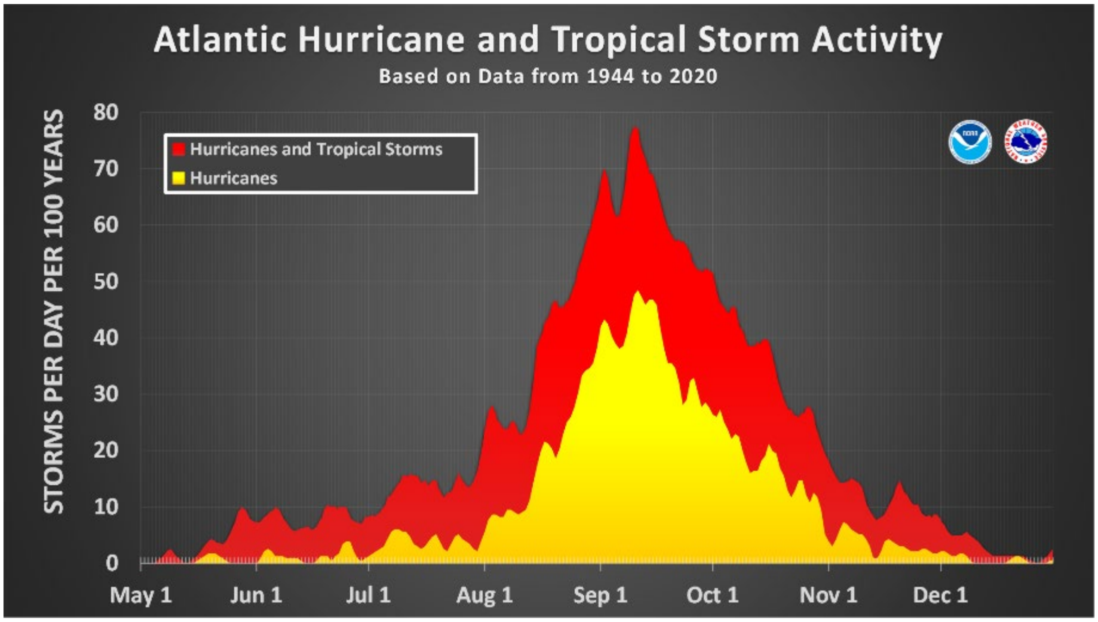
This map shows all of the tropical cyclones strong enough to be classified as hurricanes (red lines) and major hurricanes (yellow lines) during the same time period. Remember, a major hurricane has wind speeds of 111 mph or greater.

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



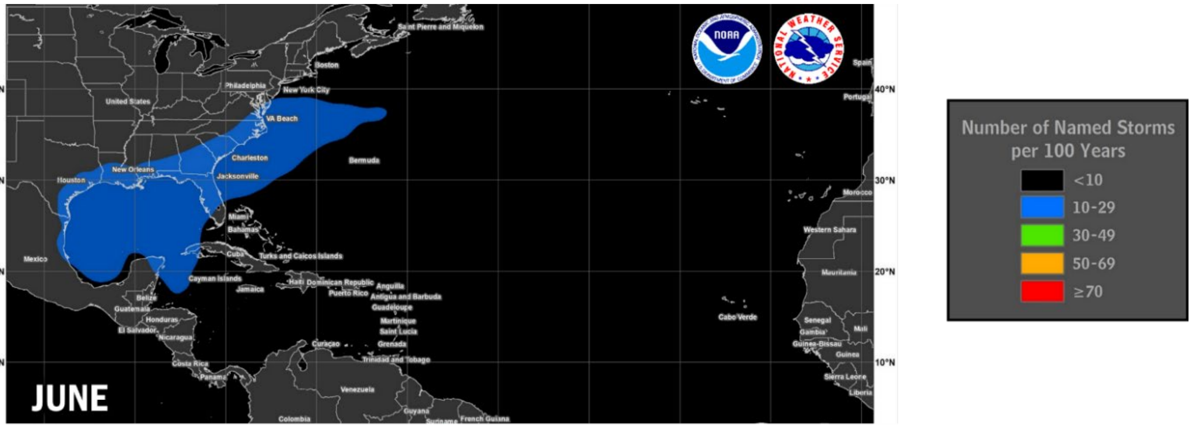
Key Points

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 (https://www.nhc.noaa.gov/climo) from hurricanes.gov.

Visual 12: June Areas of Occurrence



- 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.

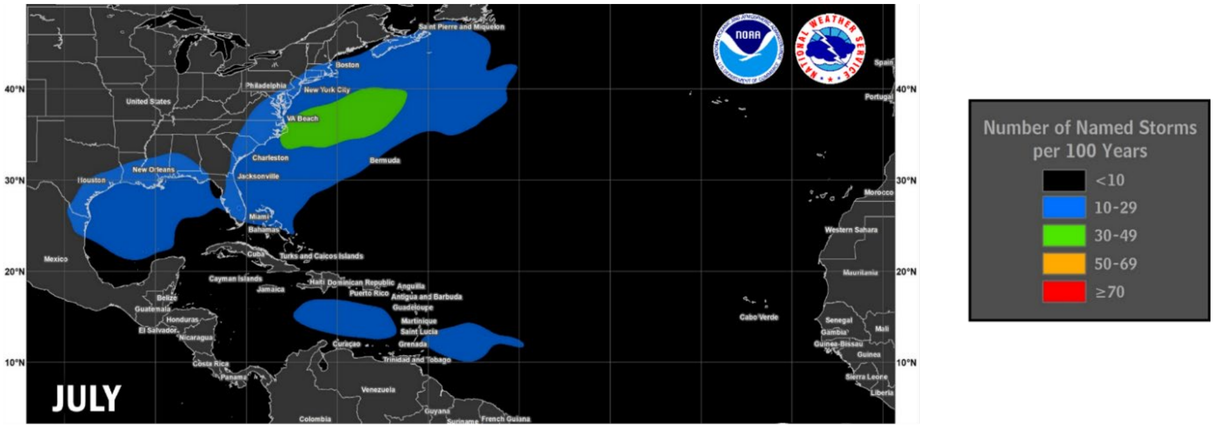
These visuals show likely occurrence areas for tropical storms and hurricanes in June. In June, there is, on average, about one storm every year. Most tropical cyclones in June occur in the Northwest Caribbean Sea, the Gulf of Mexico, or off the Southeast U.S. coast.

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. Also, don’t let your guard down during the early parts of the season. Hurricane Agnes – one of the most impactful tropical systems in American history – occurred in late June 1972. While it was barely a Category 1 hurricane when it made landfall along the Gulf Coast, it caused unprecedented and historic inland flooding through several Mid-Atlantic states.

Visual 13: July Areas of Occurrence

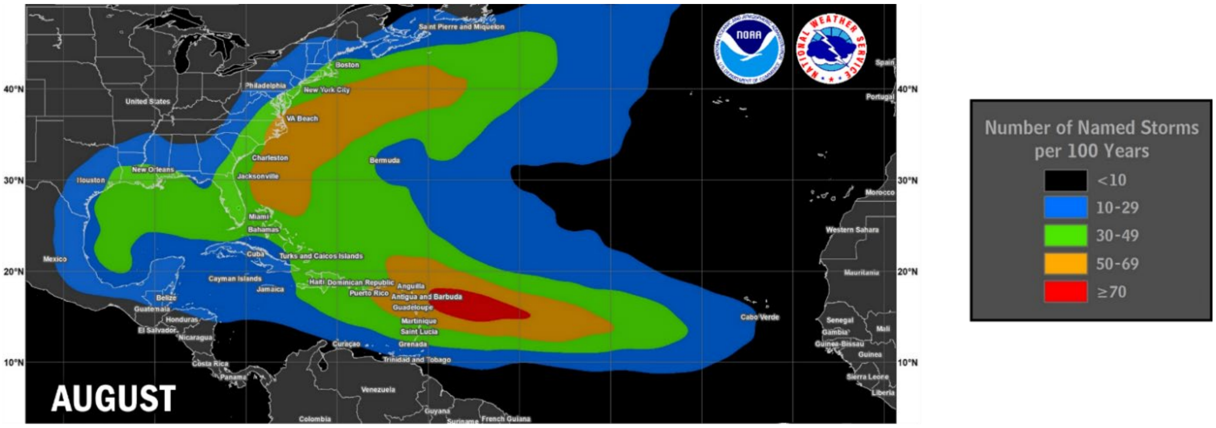


- On average, one to two named storms every year
- July occurrence areas spread east and cover the western Atlantic, Caribbean, and Gulf of Mexico.

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 Areas of Occurrence



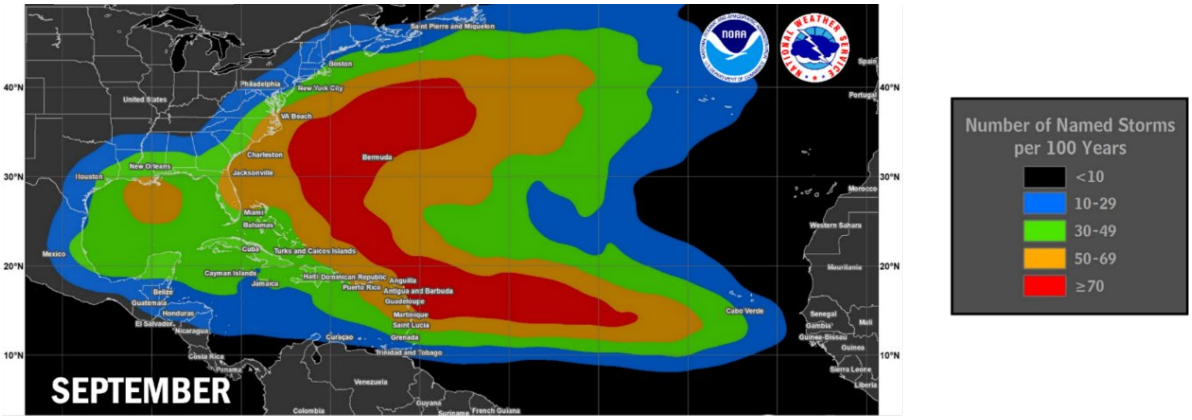
- On average, about three to four storms each year.
- The Cape Verde season usually begins in August.

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 Cabo Verde islands, near where they form off the West 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 Areas of Occurrence

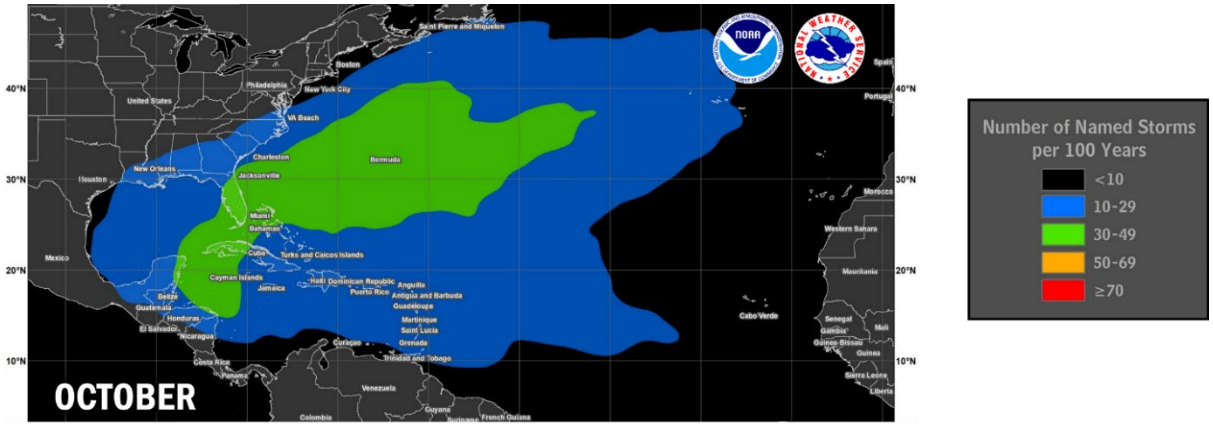


- Climatological peak of the season; on average, four to five storms every year.
- Storms can form nearly anywhere in the basin; Long-track Cape Verde storms are more likely.

Key Points

September is the climatological peak of the tropical cyclone season. Storms can form nearly anywhere in the basin. The risk for powerful, long-track Cape Verde hurricanes is greatest in September. (The average is around two per year.)

Visual 16: October Areas of Occurrence

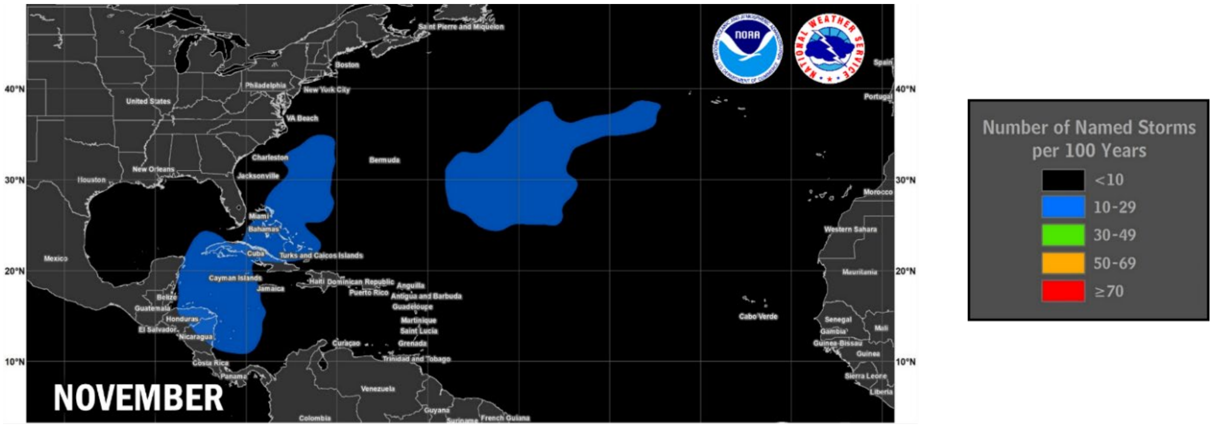


- On average, two to three named storms each year.
- Cape Verde season ends, and activity shifts to the Gulf of Mexico, Caribbean Sea, and western Atlantic Ocean.

Key Points

Cape Verde season ends, and activity shifts ***back*** to the Gulf of Mexico, Caribbean Sea, and western Atlantic Ocean. October storms often threaten Florida, such as Ian (2022) and Michael (2018). But there are several examples of October systems impacting the Mid-Atlantic and Northeast, with Sandy (2012) being a major recent example.

Visual 17: November Areas of Occurrence

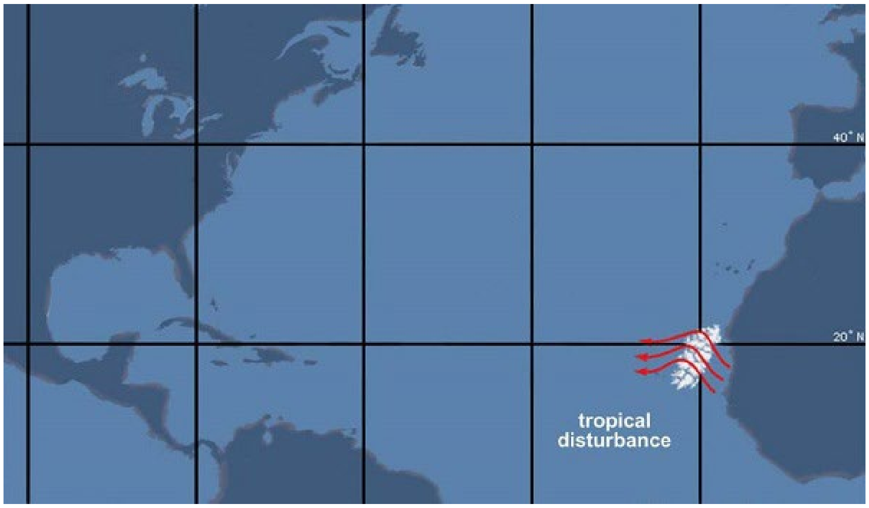


- On average, about one storm every other year.
- Storms typically occur in the western Caribbean Sea or western and central Atlantic Ocean.

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 Lifestyle 1



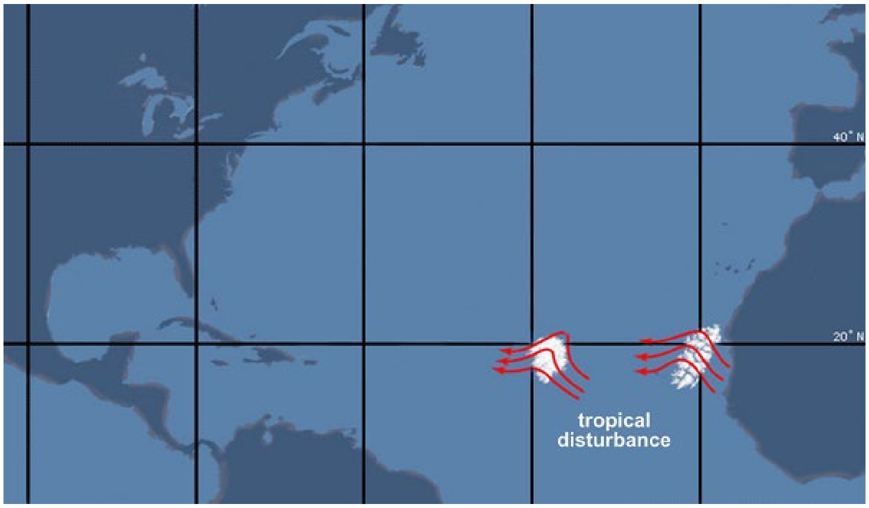
Key Points

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 tend to 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: Cape Verde Hurricane Lifestyle 2



Key Points

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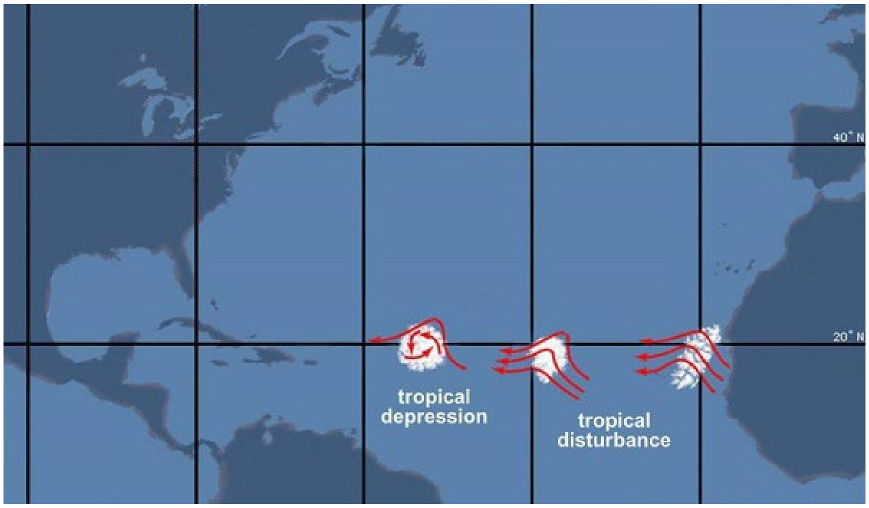
Visual 20: Cape Verde Hurricane Lifestyle 3



Key Points

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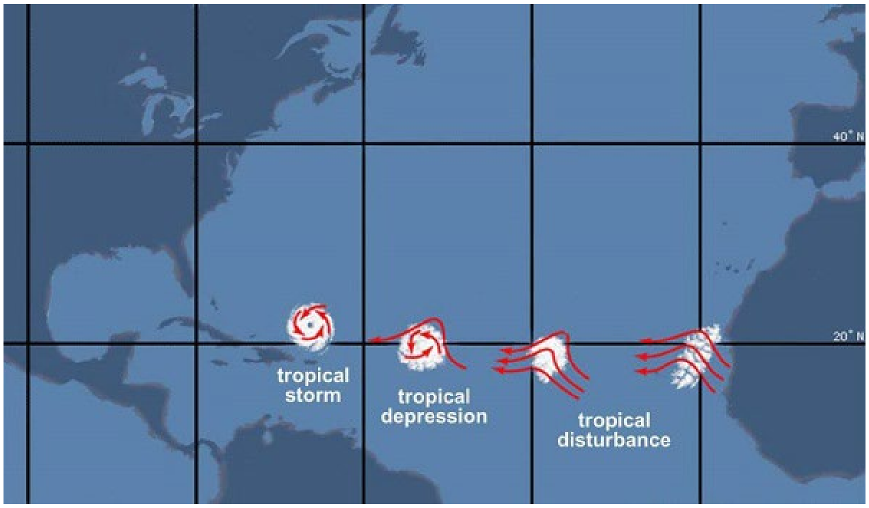
Visual 21: Cape Verde Hurricane Lifestyle 4



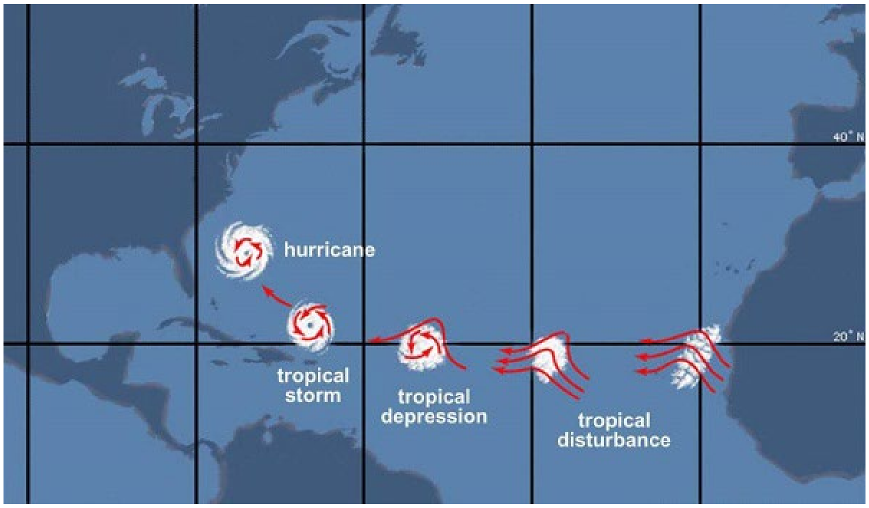
Key Points

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 tend to 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 22: Cape Verde Hurricane Lifestyle 5



Key Points

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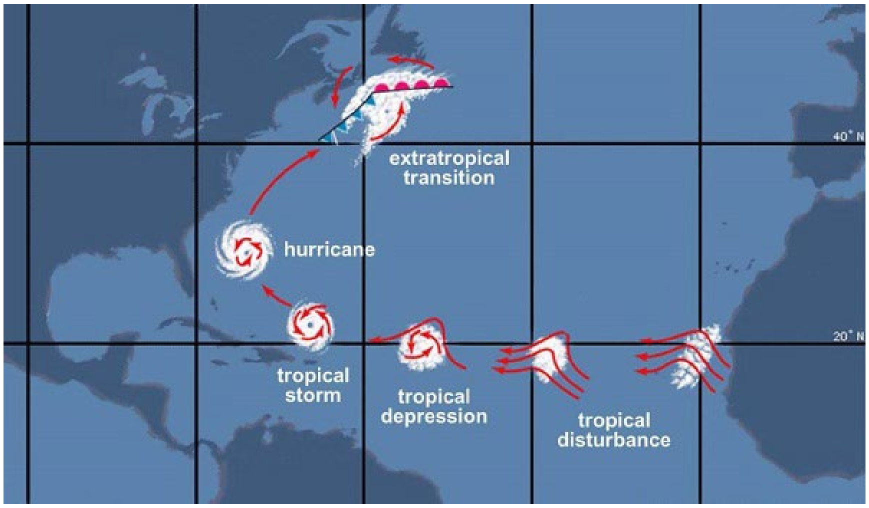
Visual 23: Cape Verde Hurricane Lifestyle 6



Key Points

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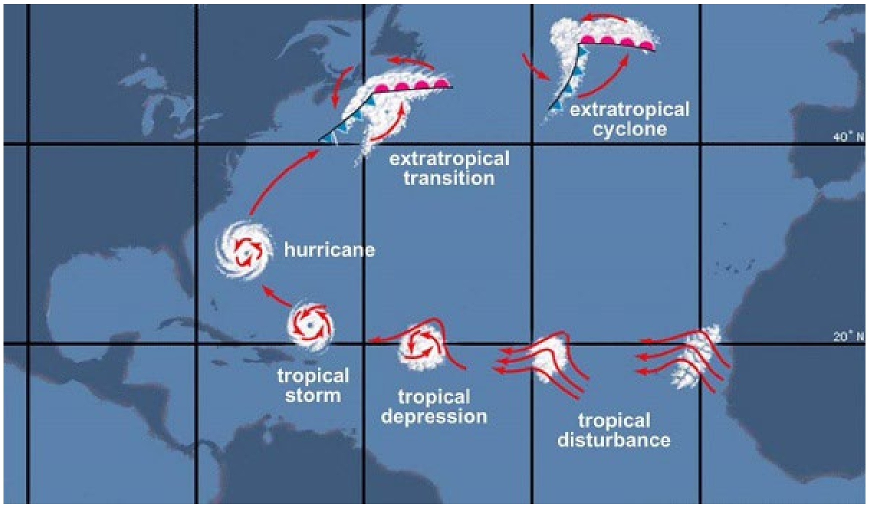
Weakening typically occurs when a tropical cyclone enters a hostile environment often caused by unfavorable wind conditions in the middle or upper atmosphere, moves over cooler waters, or interacts with land. Sometimes the weakening phase leads to **dissipation** of the tropical storm or hurricane.

Visual 24: Cape Verde Hurricane Lifestyle 7



Key Points

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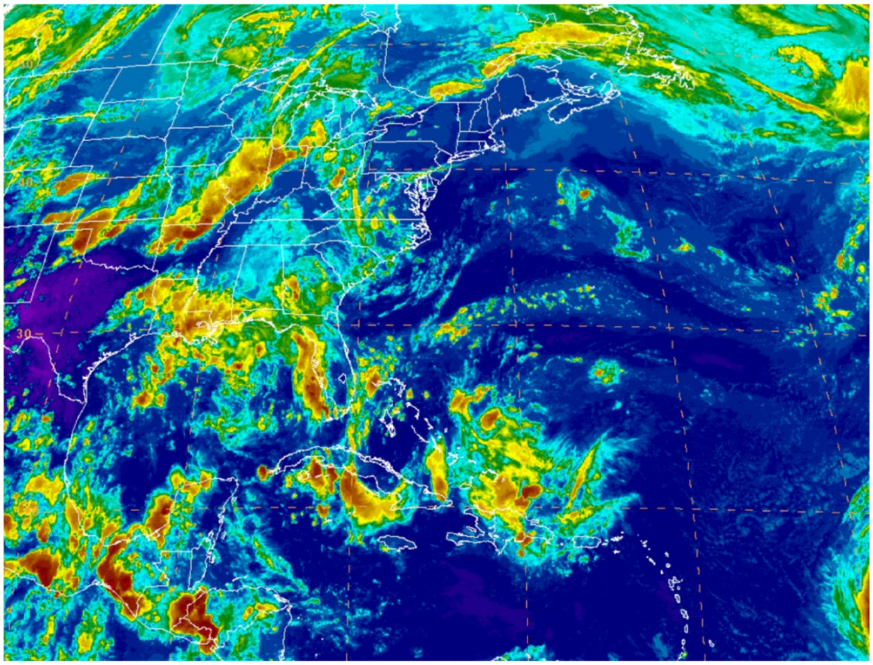
Weakening typically occurs when a tropical cyclone enters a hostile environment often caused by unfavorable wind conditions in the middle or upper atmosphere, moves over cooler waters, or interacts with land. Sometimes the weakening phase leads to **dissipation** of the tropical storm or hurricane.

Visual 25: 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, low-pressure area.

Visual 26: Hurricane Forecasting – Knowledge Check

Which of the following are ingredients for hurricane development?

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

Visual 27: Ingredients for TC Formation

Building Blocks

- A pre-existing disturbance (vorticity or spin)
- Location several degrees north of the equator
- Little change in wind speed or direction with height (vertical wind shear)

Fuel

- Warm sea surface temperatures (usually at least 80°F)
- Unstable atmosphere (temperature goes down as you go up)
- 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 (Building Blocks)
- Thermodynamic, or heat-related energy (Fuel)

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 within the Atlantic basin, 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 changes in elevation. Too much wind shear will tear a tropical cyclone apart. 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 warm water—a sea surface temperature of at least 80 degrees Fahrenheit (26.5 degrees Centigrade). The deeper the warm 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.

Ingredients for Tropical Storm Formation:

- **Pre-existing disturbance** (vorticity or spin): Frame
- **Location** several degrees north of the equator: Tires
- **Little change in wind speed or direction height** (vertical wind shear): Windshield (**Thermodynamic (heat-related) energy** provides fuel for the storm.)
- **Warm sea surface temperatures** (usually at least 80°F / 26.5°C): Fuel
- **Unstable atmosphere** (temperature goes down as you go up): Spark plugs
- **High atmosphere moisture content** (relative humidity): Oil

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

Visual 28: 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

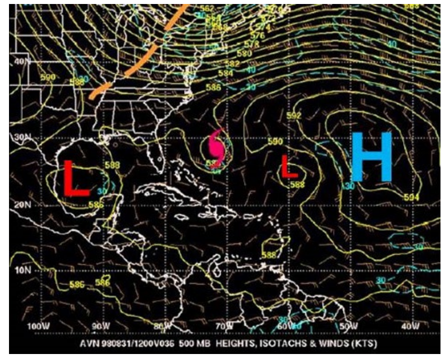
Key Points

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 during most of the season. 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.

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

Visual 29: Storm Motion and Track



Track forecasting is usually controlled by large-scale weather features

- "Cork in the 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 30: 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 31: Tropical Cyclone Hazards – Knowledge Check

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

A. Wind

B. Rain-induced flooding

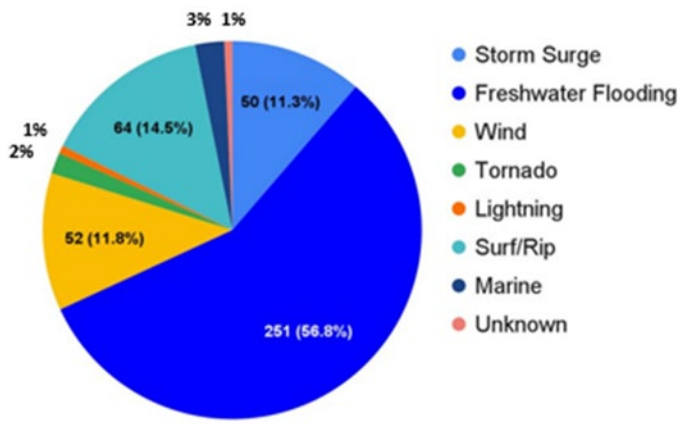
C. Tornadoes

D. Storm Surge

Visual 32: Atlantic Tropical Cyclone Deaths

U.S. tropical cyclone fatalities

- 2013-2022



Key Points

Water-related hazards from tropical cyclones (storm surge, flooding, or waves) account for about 83% 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 freshwater flooding has been the deadliest hazard associated with tropical cyclones in the United States during the past 10 years, accounting for 56.8% of the total fatalities. This is a recent change from the past 50 years in which storm surge was the deadliest hazard, previously responsible for 50% of all deaths associated with tropical cyclones. Within the last 10 years, however, storm surge has only accounted for about 11% of the total fatalities. Both surf and wind hazards account for more deaths associated with tropical cyclones, at 14.8% and 11.8%, respectively.

The other remaining hazards, including wind, tornadoes, lightning, and offshore conditions, combined account for only 5.6% of deaths caused by tropical cyclones.

Visual 33: Wind Intensity Factors

Intensity Factors

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	Depends on the interaction

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

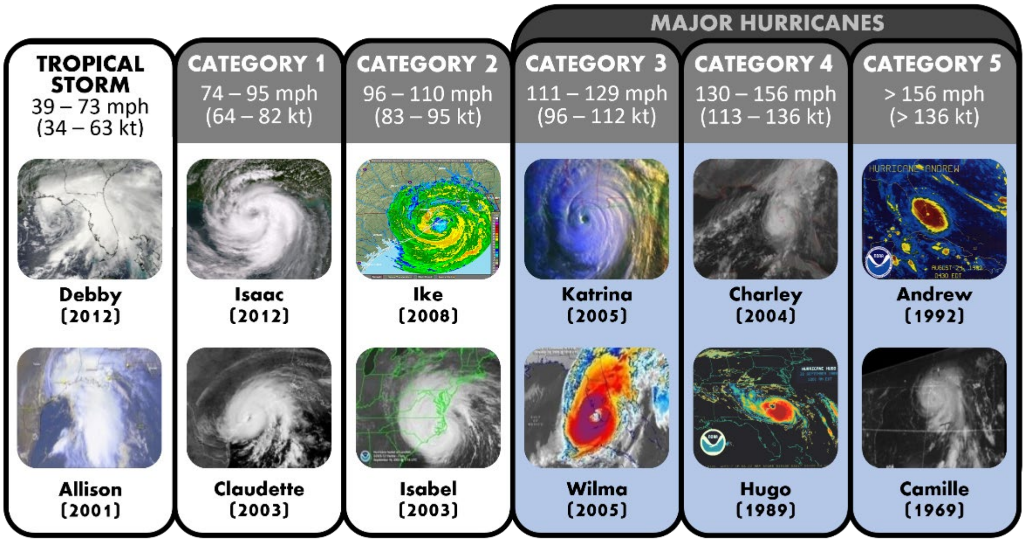
  Tropical cyclones require low vertical wind shear (little change in wind speed or direction with height) to strengthen.
- Moisture in Storm Environment

  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.
- Interactions with Other Weather Systems

  When a tropical cyclone interacts with another weather system, it can either strengthen or weaken, depending on the interaction.

Visual 34: 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).

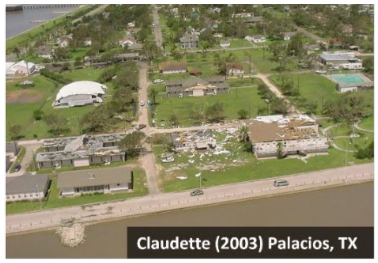
It should be noted that high winds affect more than just the coast. Although hurricanes do begin to weaken once they hit land, **inland areas are often subject to hurricane-force winds.**

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	Above 156	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 35: Category 1 (74–95 mph)



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.

Although these hurricanes produce very dangerous winds and will certainly cause damage, the wind impacts are 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.
Manufactured/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.

Subject	Potential Effect in a Category 1 Hurricane
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 36: Category 2 (96–110 mph)

Ike (2008) Houston, TX

Juan (2003) Halifax, NS

Wilma (2005) SE Florida

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 Juan in 2003 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.
Manufactured/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.

Subject	Potential Effect in a Category 2 Hurricane
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 37: Category 3 (111-129 mph)


Jeanne (2004) Cape Canaveral, FL


Rita (2005) Orange, TX


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 and Jeanne in 2004 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.
Manufactured/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.

Subject	Potential Effect in a Category 3 Hurricane
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 38: Category 4 (130–156 mph)

Catastrophic damage

- Well-constructed 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 Ike 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.
Manufactured/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.

Subject	Potential Effect in a Category 4 Hurricane
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 39: Category 5 (>156 mph)

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 sustainable 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.

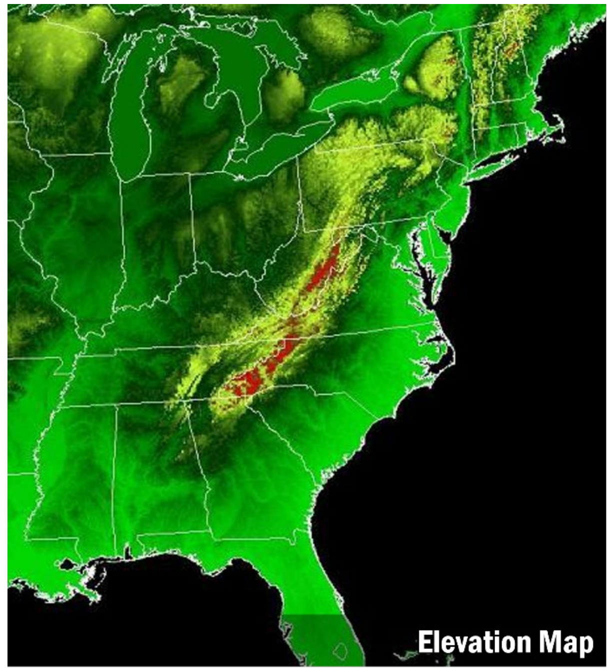
Subject	Potential Effect in a Category 5 Hurricane
People, Livestock, and Pets	People, livestock, and pets are at very high risk of injury or death from flying or falling debris, even if indoors in mobile homes or framed homes.
Manufactured/Mobile Homes	Almost complete destruction of all mobile homes 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.

Subject	Potential Effect in a Category 5 Hurricane
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 40: How Are Winds Altered by High Terrain?

ELEVATION AND GUSTS

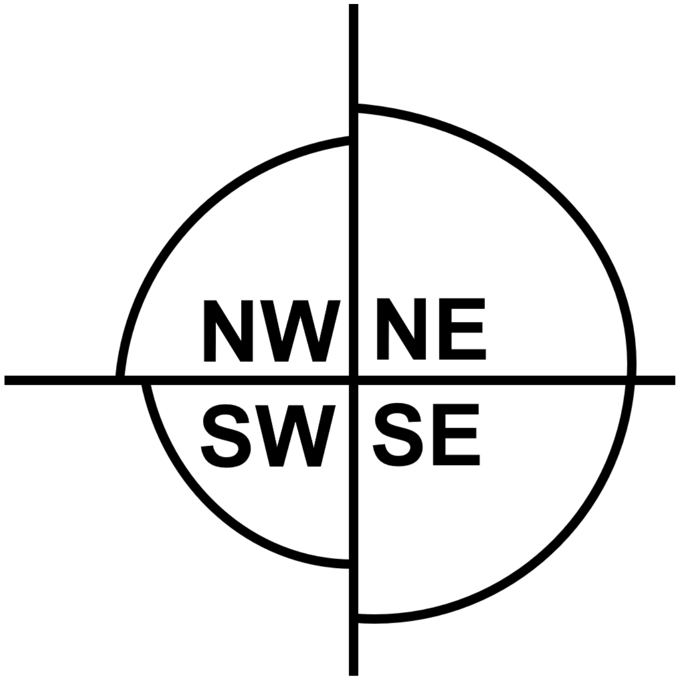
- **Elevated Terrain**
  - Can experience higher sustained winds and higher gusts
  - Also true for high-rise buildings
- **Normal wind gust factor = x1.3**
  - Sustained 60 mph -> Gusts to 80 mph
- **Complex terrain/eyewall = x1.65**
  - Sustained 60 mph -> Gusts to 100 mph



Key Points

Local knowledge of typical wind funnel effect locations is very useful at the local level.

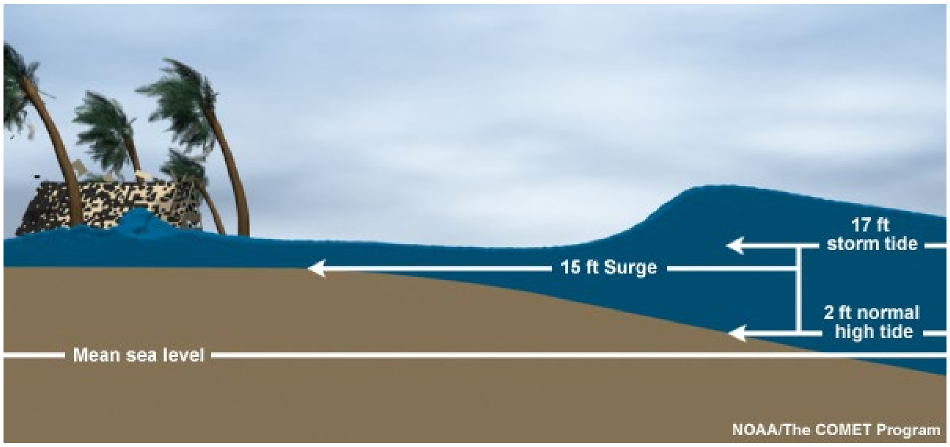
Visual 41: Wind Distribution and Storm Quadrants



Key Points

NHC forecasts provide the wind radii for a storm in terms of four quadrants. **Radii** are the largest distance from the center of the storm to their extent in a quadrant. The diagram shows the typical distribution of radii in a hurricane, with the right front and right rear containing equal, largest radii extents. Understanding the quadrants is important in understanding the coastal impacts from a tropical cyclone, although their importance matters less for most inland communities.

Visual 42: Storm Surge

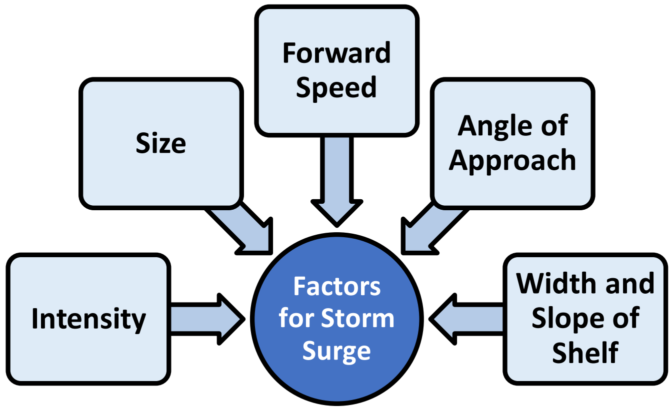


The abnormal rise of water generated by a storm, over, and above the predicted astronomical tides

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 43: Storm Surge: Factors




Hurricane Michael (2018)
Mexico Beach, Florida


Hurricane Hugo (1989)
Garden City Beach, South Carolina


Hurricane Sandy (2012)
Brick, New Jersey


Hurricane Carol (1954)
Groton, Connecticut

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.

Intensity	Stronger storm = More storm surge
Size (Radius of Maximum Winds)	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 sloping shelf = More storm surge

Visual 44: Inland Flooding

Key Points

Rainfall-induced freshwater flooding is the second leading cause of death from tropical cyclones after storm surge.

Weaker systems, such as tropical depressions or tropical storms, can produce more rainfall and flooding than hurricanes. Inland flooding comes in many forms, but it primarily comes in a variation of flash flooding and riverine (mainstem river) flooding.

Visual 45: Hurricane Harvey (2017) Flooding

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 46: Hurricane Irene (2011) Flooding 1


Photo courtesy of L. Gange, Mansfield Helifight


Prattsville, NY Damage (Jimmy Vielkind/Times Union)

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 47: Hurricane Irene (2011) Flooding 2

Visual 48: Types of Flooding

Flash Flooding:

Usually develops within 6 hours of the heavy rainfall (e.g., small stream flooding, debris flows/mudslides, urban flooding, levee or dam failures). Usually shorter duration.

River Flooding (Large Rivers):

Stormwater drains from the smaller tributaries into the larger mainstem rivers. Water levels rise and overflow banks, inundating normally dry areas. Usually longer duration.

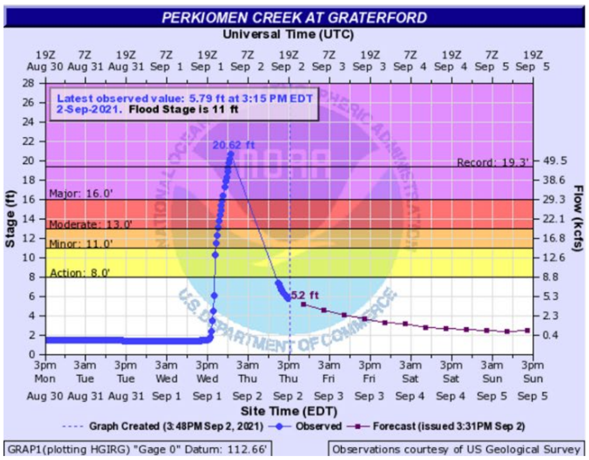
Key Points

Flash Flood: A **rapid,** and potentially extreme, flow of high water into a normally dry area, or a **rapid** water level rise in a stream or creek above a predetermined flood level, beginning within 6 hours of the causative event (e.g., intense rainfall, dam failure, ice jam). However, the actual time threshold may vary in different parts of the country. Ongoing flooding can intensify to flash flooding in cases where intense rainfall results in a rapid surge of rising flood waters.

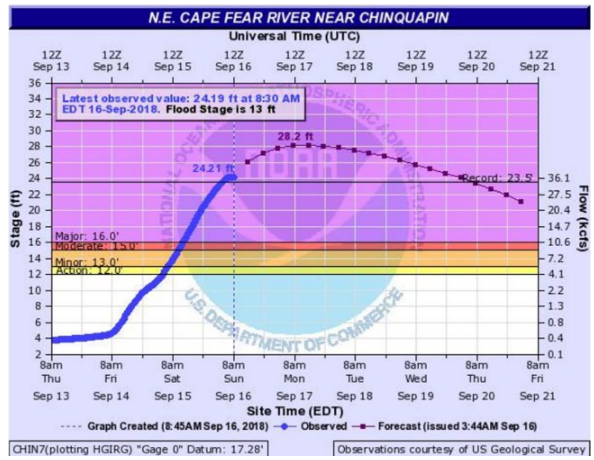
River Flooding: The rise of a large and/or mainstem river (and its larger tributaries) to an elevation such that the river overflows its natural banks, causing or threatening damage. This usually occurs as a result of the drainage of the rainfall and stormwater that generated flash flooding earlier in the event.

Visual 49: Types of Flooding

Flash Flooding



Mainstem River Flooding



Key Points

Here are hydrographs that show the differences between flash flooding and mainstem river flooding.

Visual 50: Flood Stages

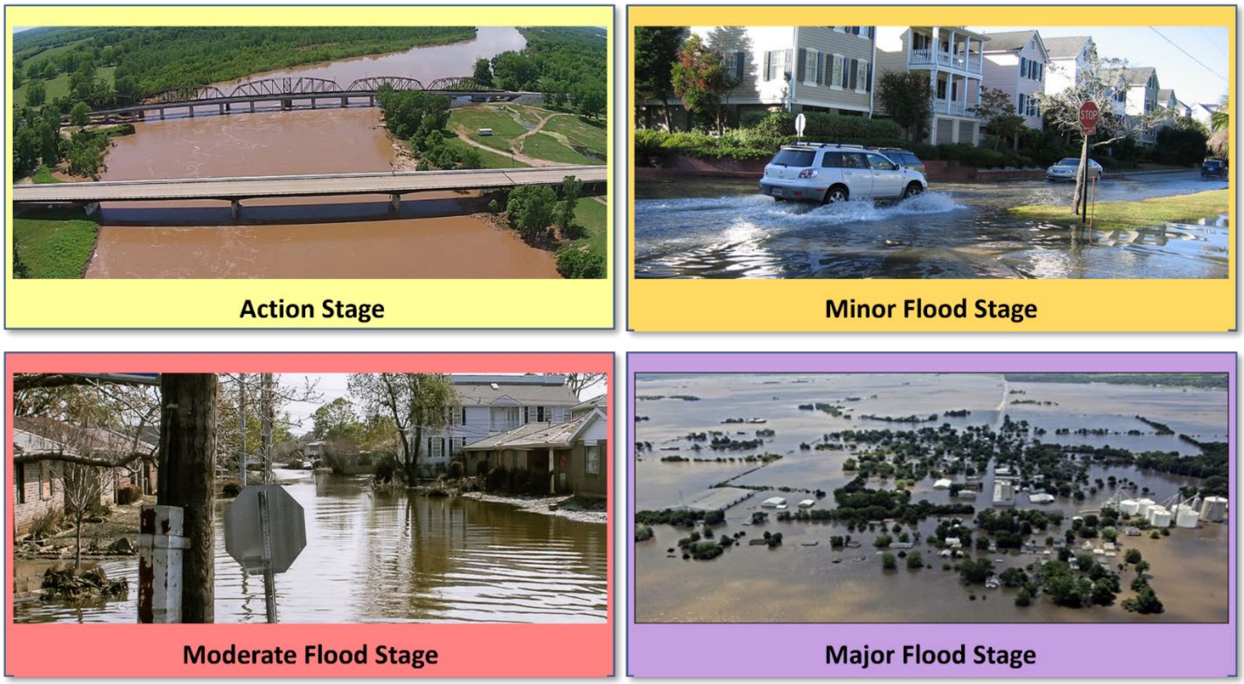
Major Flooding	Extensive inundation of structures and roads. Significant evacuations of people and/or transfer of property to higher elevations.
Moderate Flooding	Some inundation of structures and roads near the stream or river. Some evacuations of people and/or transfer of property to higher elevations.
Minor Flooding	Minimal or no property damage, but possibly some public threat.
Action Stage	Represents the level where the NWS or a partner/user needs to take some type of mitigation actions in preparation for possible significant hydrologic activity.

Key Points

The stages of river flooding:

- Major Flooding - Includes extensive inundation and property damage, and usually characterized by the evacuation of people and livestock and the closure of both primary and secondary roads.
- Moderate Flooding - The inundation of secondary roads; transfer to higher elevation necessary to save property; some evacuation may be required.
- Minor Flooding - Indicating minimal or no property damage but possibly some public inconvenience.
- Action Stage - The river is **approaching** flood stage.

Visual 51: Flood Stage Examples



Key Points

Visual examples of flood impacts at various flood stages.

Visual 52: Factors Affecting Tropical Cyclone Rainfall

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

Generally speaking, the **size of the storm** matters. A larger wind field can help transfer more tropical moisture from the Gulf or Atlantic into inland areas. As a result, 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 of elevated terrain, with less rain on the leeward side.

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

Visual 53: The Big Challenge

All Tropical Cyclones Have Rain

- "So what?" factor
- Already obvious

Many produce localized "hot spots"

- Tough to motivate large response
- Placement is difficult days in advance

Few with widespread, catastrophic rain

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

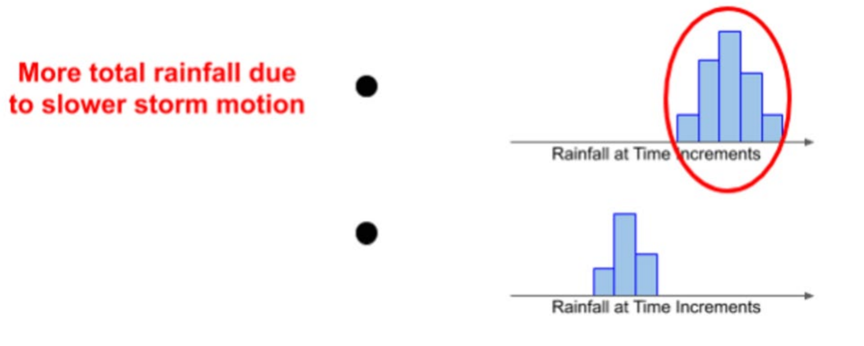
Key Points

One of the largest challenges is communicating the rainfall and messaging the associated risks. This is all along a spectrum. At the lowest end is an outcome of **"ordinary"** rainfall that is similar to a common rainstorm. Some storms have the possibility of more severe impacts interspersed among more "ordinary" rainfall locations, but these are difficult to predict and could be highly localized. There are few storms that have **"extraordinary"** catastrophic results, but it is imperative to make this determination as early and as accurately as possible.

Visual 54: Storm Forward Speed

Situations that favor the "Big Extraordinary Ones"

- Slow-Moving Storms that Create Multi-Day Opportunity for Repetitive, High-Intensity Rainfall.
- Storm speed being equal: larger, higher-intensity storms that approach areas with terrain or urban development are factors.



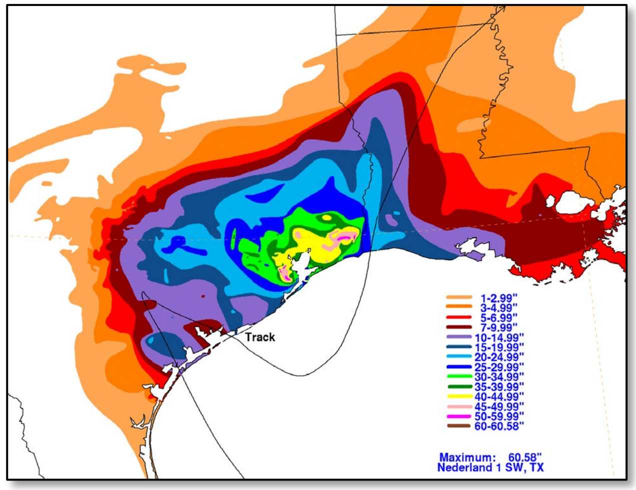
Key Points

Rainfall over a location (represented by the black dot) is higher for a storm with a slower forward motion than a storm with a faster forward motion.

Visual 55: Hurricane Harvey (2017)

Forward speed plays a major role in inland flooding threat potential.

After making landfall, Harvey stalled, with its center over or near the Texas coast for 4 days, dropping historic amounts of rainfall of more than 60 inches over southeastern Texas.



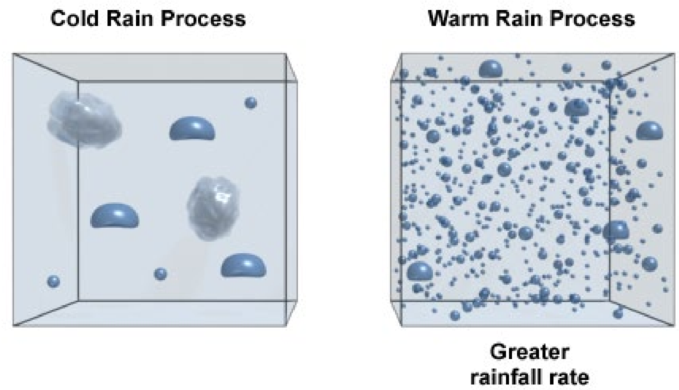
Key Points

As discussed on the previous slide, forward speed of a storm plays a critical role in determining the threat potential for inland flooding. Hurricane Harvey's slow forward motion, stall, reversal, and resumption of "forward" speed resulted in sustained rainfall over southeastern Texas. This resulted in 60.58 inches, which is now the storm total rainfall record from any tropical cyclone in U.S. history.

Visual 56: Rainfall Rates ("Efficiency")

Tropical Rainfall Efficiency

- Tropical cyclones generally build heavy rain through a warm rain process, without melting ice crystals or hail.
    - Result: a lot of smaller water droplets.
- **FEWER ice crystals = MORE rainfall droplets**

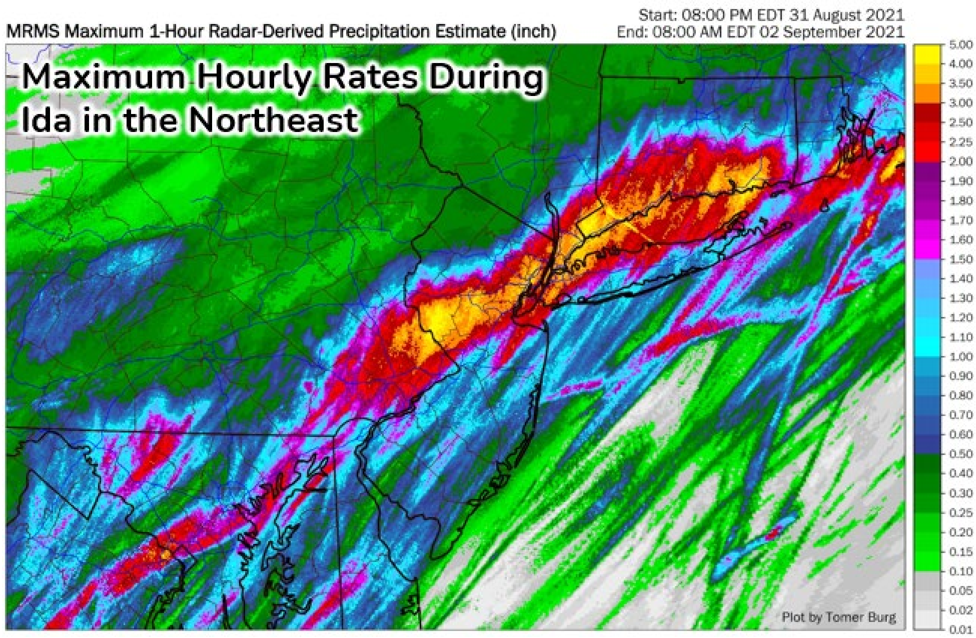


Key Points

The cold rain process includes ice particles in the upper atmosphere, compared to a warm rain process that does not have any ice. This means that tropical cyclones, which build through the warm rain process, have a higher density of water per given volume, as shown in the images above. This more efficient storage of moisture in the storm means higher rainfall rates.

Warm rain is problematic for inland communities because more rain can impact the same space in a shorter period of time.

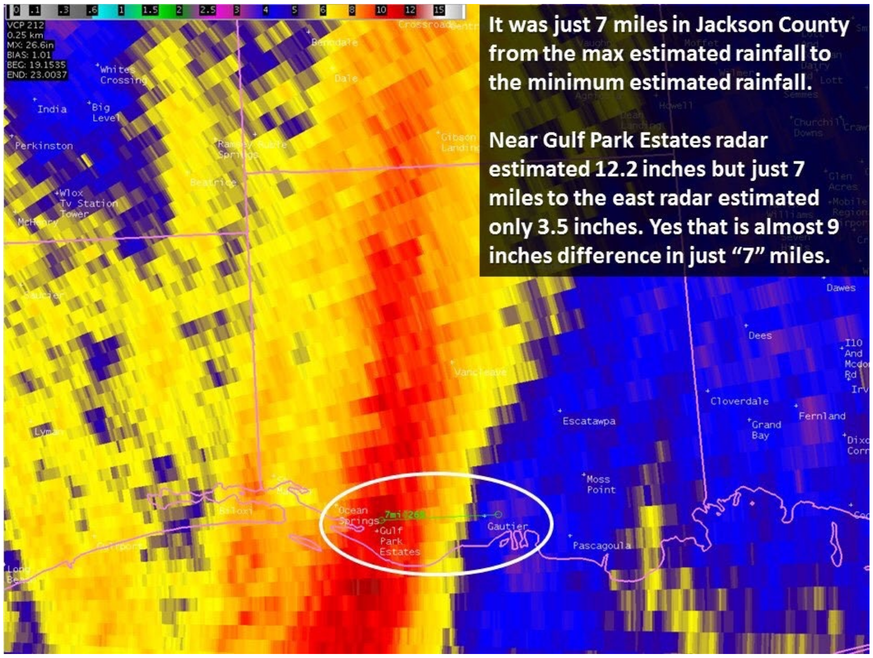
Visual 57: Rainfall Rates Example – Hurricane Ida (2021)



Key Points

Note the rainfall rates from Hurricane Ida (2021) and their concentration over the Northeast urban corridor. As you'll learn in a couple slides, urban environments exacerbate flash flooding. Therefore, the impacts from rainfall are a function of not just the hourly rate, but the location of that rainfall.

Visual 58: Rainfall Gradient Example - TS Cindy (2017)



Key Points

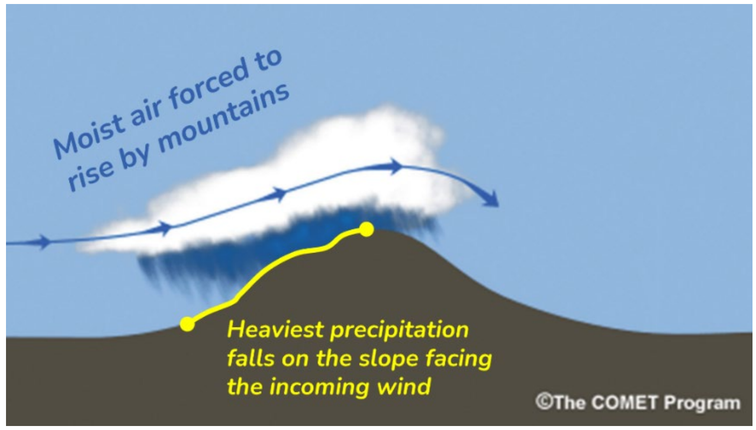
Heavy rain from tropical cyclones often falls in **"bands,"** which can result in sharp gradients in recorded rainfall. In this example from Tropical Storm (TS) Cindy in 2017, radar estimated rainfall amounts of more than 12 inches where a nearly stationary rainband ("training") set up over Mississippi. 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!

It is very difficult to forecast where exactly rainband training and rainfall bullseyes will occur, which is why it is very difficult to do evacuations and other protective actions in advance of the flash flooding.

Visual 59: Terrain Effects

Upslope Rainfall Enhancement

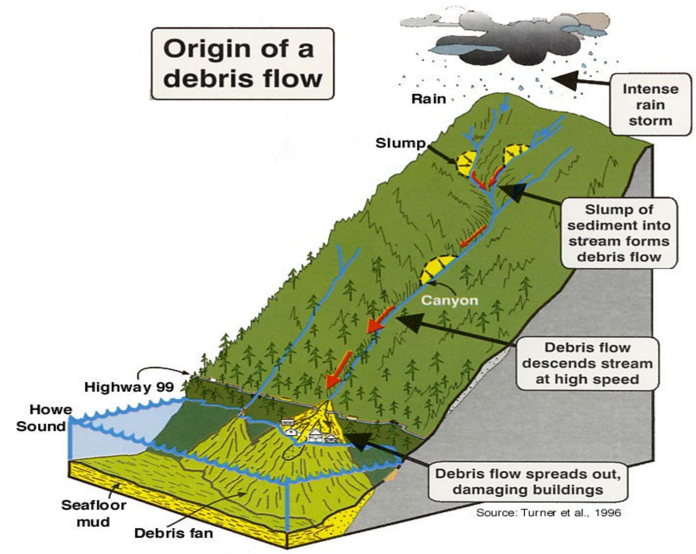
Extreme rainfall maxima can be focused in areas of terrain where winds around a tropical low can feed significant tropical moisture into mountainous areas.



Key Points

The movement of moisture up sharp rises in elevation (such as mountains) result in extreme rainfall on their upslopes. This is often referred to as “mountain-enhanced” rainfall. These localized extreme maxima have different impacts than if the rainfall occurred on flat terrain. Even if the terrain is not at an elevation to create mountain-enhanced rainfall, the steepness of slopes in the foothills/piedmont can still support a more violent flow of runoff more than it would in a flat area. These are the **“terrain effects”** on storm rainfall and its impacts.

Visual 60: Debris Flow

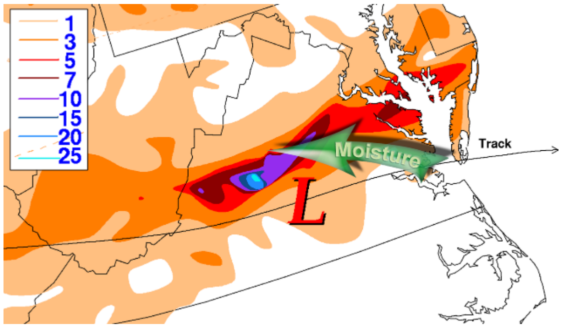


Key Points

The origins of a debris flow depend on slope, past precipitation (soil saturation), and amount and duration of rain. It's a called a "debris flow" because the flooding and landslide/mudslide starts to collect trees, buildings, cars, and other debris, which makes the impact even more severe.

Steep slope + **Saturated soils** + **Heavy rainfall** result in debris flows.

Visual 61: Hurricane Camille (1969) – Virginia

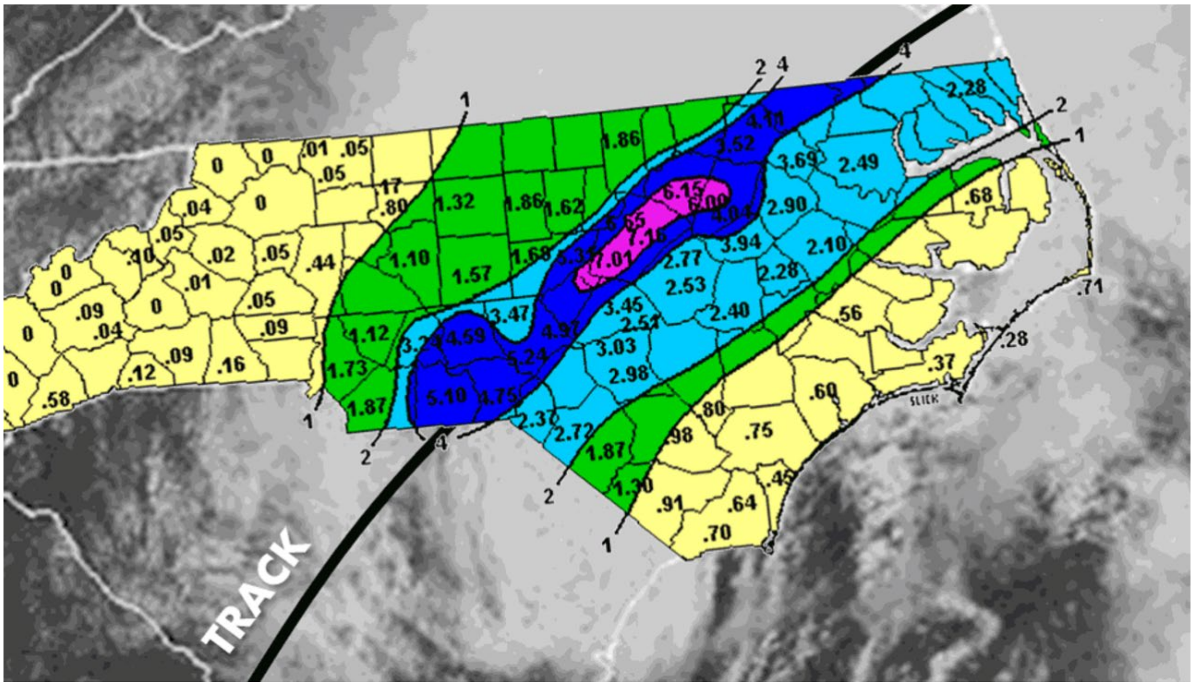


Hurricane Camille (1969) provides an excellent example of a very localized heavy rain where persistent easterly winds met the Virginia mountains, leading to catastrophic flooding, mudslides, and debris flows that killed at least 124 people.

Key Points

Hurricane Camille (1969) provides an excellent example of a very localized maximum of 27 inches of rain where persistent easterly winds north of the track met the Virginia mountains, leading to catastrophic flooding, mudslides, and debris flows that killed at least 124 people. Camille made landfall as a Category 5 along the Gulf Coast, killing approximately 150 people there. Therefore, nearly as many people died 700–800 miles inland as immediately along the coast during a Category 5 landfall.

Visual 62: TS Alberto (2016)



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 63: Urban Flooding

- Streets can become swift-moving rivers, and basements can fill with water.
- Flooding of low spots, underpasses, poorly drained locations, culverts, and drainages.

Key Points

Urban flooding presents a unique set of challenges because of how rainfall interacts with a built-up environment. The impervious surfaces result in increased water retention over an area, which is then channeled by buildings, drainage systems, and roadways. Understanding an urban area's environment and waterflows helps clarify the impacts of urban flooding.

Visual 64: Why "Urban" Flooding

More concrete

=

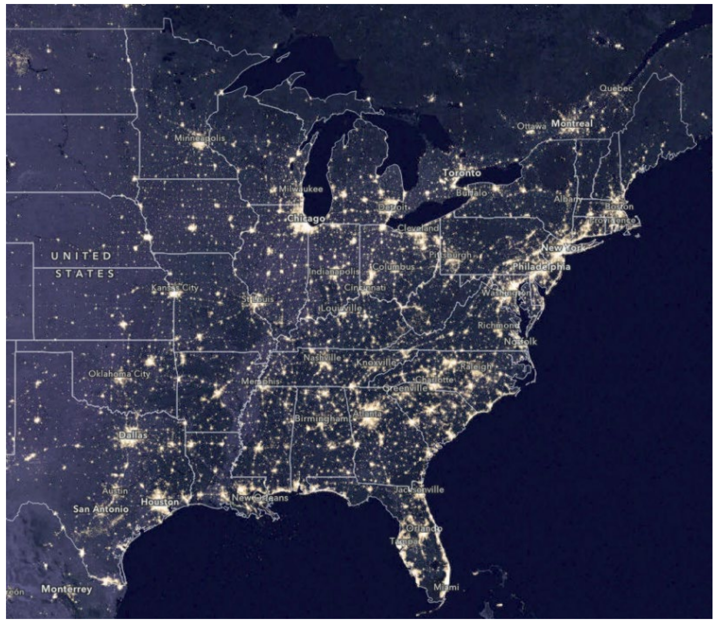
More impervious surface

=

Faster and greater runoff

=

Increased flooding risk



Key Points

Many cities are growing rapidly.

More concrete = More impervious surface = Faster and greater runoff = Increased Risk.

Visual 65: Hurricane Harvey (2017) Flooding: I-10

Key Points

Another example of the intensity of **freshwater flooding** in Houston as a result of Hurricane Harvey (2017).

Visual 66: TS 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 it 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 67: Urban Growth and Flooding

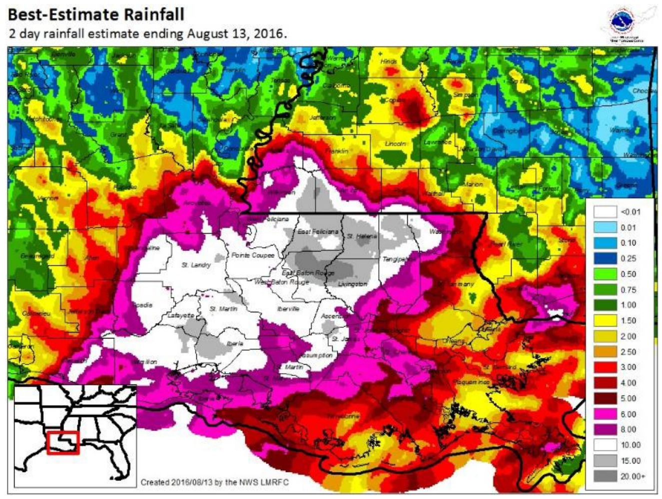
Expanding Urban Areas Make a Difference

Key Points

Expanding urban areas have resulted in greater urban flooding impacts from storms. Note the difference in impervious surface percentages in the image on the left between 1950 and 2019 in relation to the contour for 20” of rainfall from Tropical Storm (TS) Imelda (2019).

Visual 68: Unnamed Low (2016) - Louisiana

- Notice that the list of rainfall factors did not include level of organization and wind strength.
- A tropical system doesn't need to be an organized cyclone to have catastrophic impacts.
- In 2016, a disorganized tropical system stalled over Louisiana, dropping 3x the amount of rainfall that Katrina brought to the State in 2005.



Key Points

A tropical system doesn't need a name to produce significant rainfall and catastrophic 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.

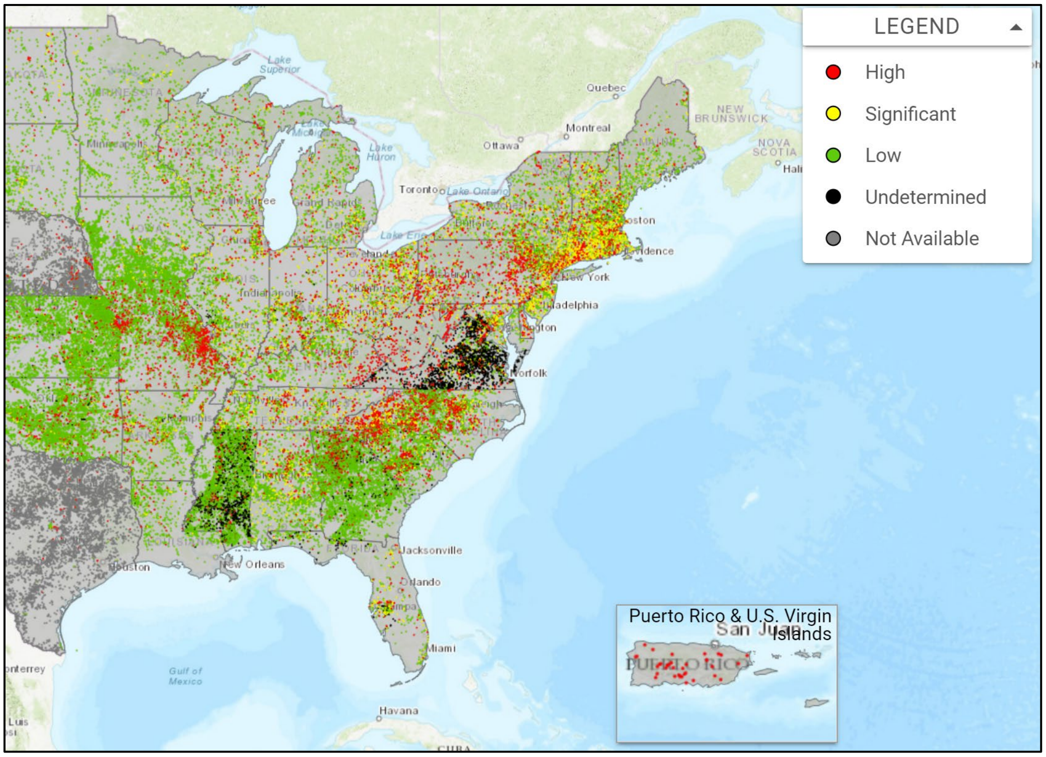
Visual 69: Lake Overflow and Dam Breaks

- Dam breaks are more likely to occur on smaller, poorly maintained dams.
- Overflow of lakes.
- Know what is upstream.

Key Points

Lakes can overflow, and dams can break. Dam breaks are much more likely on smaller or poorly maintained dams. Threat increases due to amount and duration of rainfall, plus soil saturation for earthen dams.

Visual 70: Dams Failure Risk Levels



Hazard Potential Classification	Loss of Human Life	Economy, Environment, Lifeline Losses
High	Probable. One or more expected	Yes (but not necessary for this classification)
Significant	None Expected	Yes
Low	None Expected	Low and generally limited to owner

Key Points

This image is a snapshot of the National Inventory of Dams (NID) (https://nid.sec.usace.army.mil/#/). Note that each location is color-coded by its impact rating (not its risk condition). It is important to keep an awareness of the dams in your locality and be cognizant of their potential impacts in the event of a storm.

The NID documents all known dams in the United States and is maintained by the U.S. Army Corps of Engineers (USACE). It is designed to provide searchable information on dams, such as location, type, size, purpose, date of last inspection, and other structural and geographical information. These can be used to assist EMs in understanding risks and impacts.

Common practice among Federal and state dam safety offices is to classify a dam according to the potential impact a dam failure (breach) or mis-operation (unscheduled release) would have on upstream and/or downstream areas or at locations remote from the dam. The existing classification systems are numerous and vary within and between both the Federal and state sectors. Although differences in classification systems exist, they share a common thread: each system attempts to classify dams according to the potential impacts from a dam failure or mis-operation, should it occur. Most agencies use a variation on the following terminology:

High Hazard

Dams assigned the high hazard potential classification are those where failure or mis-operation will probably cause loss of human life.

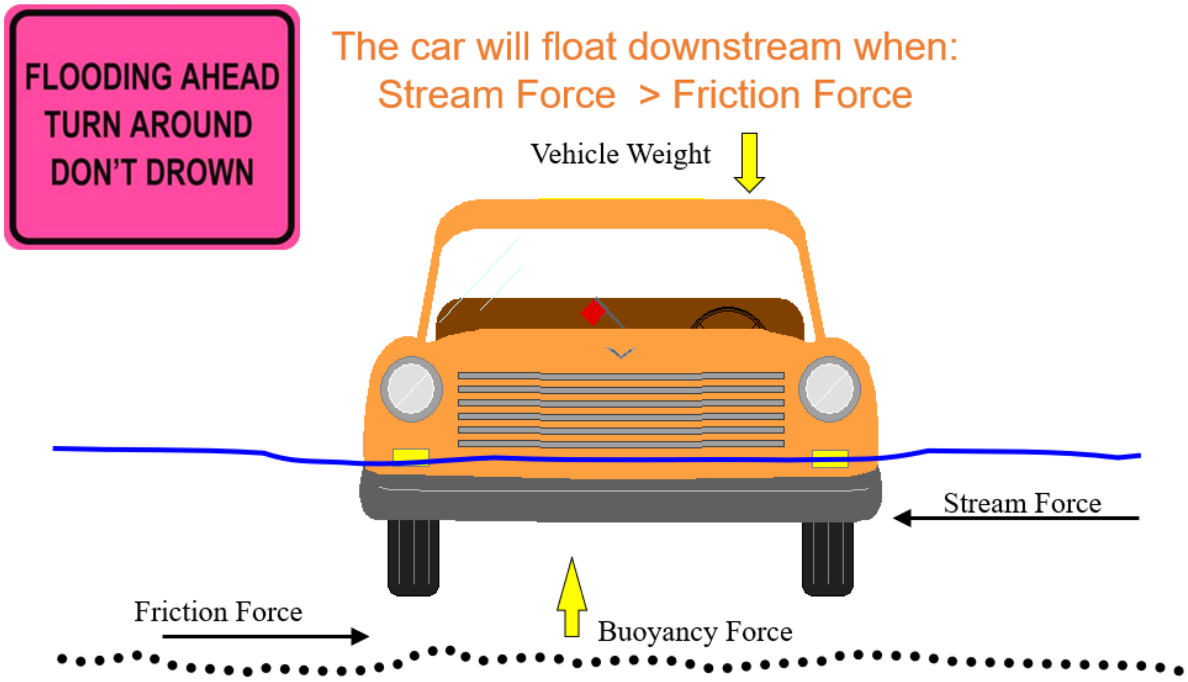
Significant Hazard

Dams assigned the significant hazard potential classification are those dams where failure or mis-operation results in no probable loss of human life but can cause economic loss, environmental damage, disruption of lifeline facilities, or can impact other concerns. Significant hazard potential classification dams are often located in predominantly rural or agricultural areas but could be located in areas with population and significant infrastructure.

Low Hazard

Dams assigned the low hazard potential classification are those where failure or mis-operation results in no probable loss of human life and low economic and/or environmental losses. Losses are principally limited to the owner’s property.

Visual 71: Flooding Forces on Vehicles



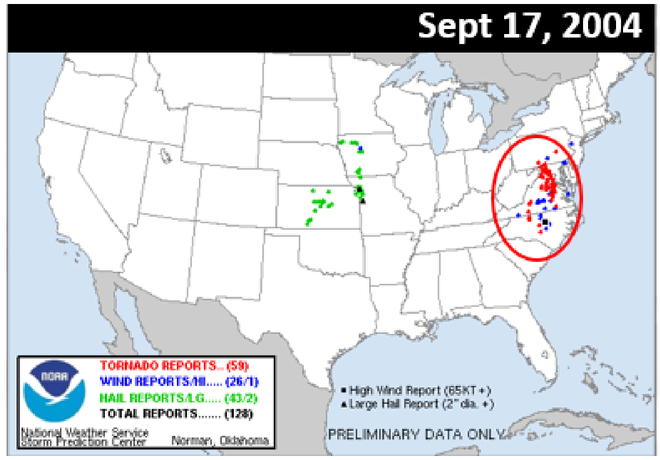
Key Points

Nearly half of flash flooding-related deaths are vehicle-related. Flooding will influence vehicles not just by the water rendering a vehicle inoperable, but also through exerting forces on the car. As the water forces (right side of the image) move against the side of the car, the friction forces (left side) are the counter to keep it in place. If the force of the steam is fast enough to overcome the friction, the car will move sideways. This is further influenced by the depth of water. As the water level rises, the more buoyancy force there is to counteract the vehicle's weight. As the buoyancy force begins to counteract the vehicle's weight, this will reduce the friction force, accentuating the stream force.

Visual 72: Landfalling Hurricanes Spawn Tornadoes

Hurricanes:

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



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.

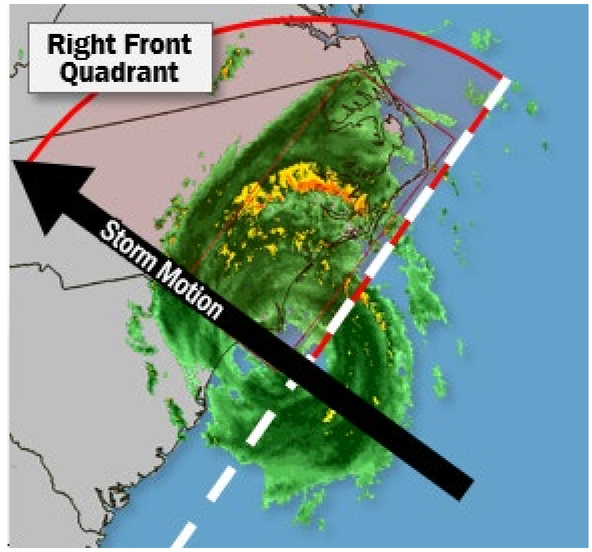
- 70% of land-falling hurricanes produce at least one tornado sometime after making landfall.
- 40% produce more than three tornadoes.
- Tropical cyclones can create favorable conditions to produce cluster outbreaks.

Size of some noteworthy 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).
- Hurricane Ida (2021) – 35 (while a relatively smaller outbreak overall, the remnants of Ida produced significant tornadoes in Pennsylvania and New Jersey.)

Visual 73: Tornado Development

- Right-front quadrant.
- Friction over land creates low-level wind conditions favorable for the development of tornadoes.
- Tornadoes can be far from the center.



Key Point

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 during the landfall phase are relatively small and short-lived. They are created in the storm's outer rain bands. However, some large or strong tornadoes have occurred, including when the cyclone is a remnant system and days after landfall.

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

Visual 74: Tornado Meteorology

What is happening to make tornadoes develop?

- In the front-right quadrant, wind speed and orientation create **vertical shear profiles** resembling Great Plains supercells.
    - Generally, the **bigger and stronger the wind fields** are with a tropical cyclone, the **bigger the area of favorable wind shear** for supercells and tornadoes.
- Occasionally a tornado will form in the inner bands, but the majority form ***outside*** **the hurricane force wind zone.**

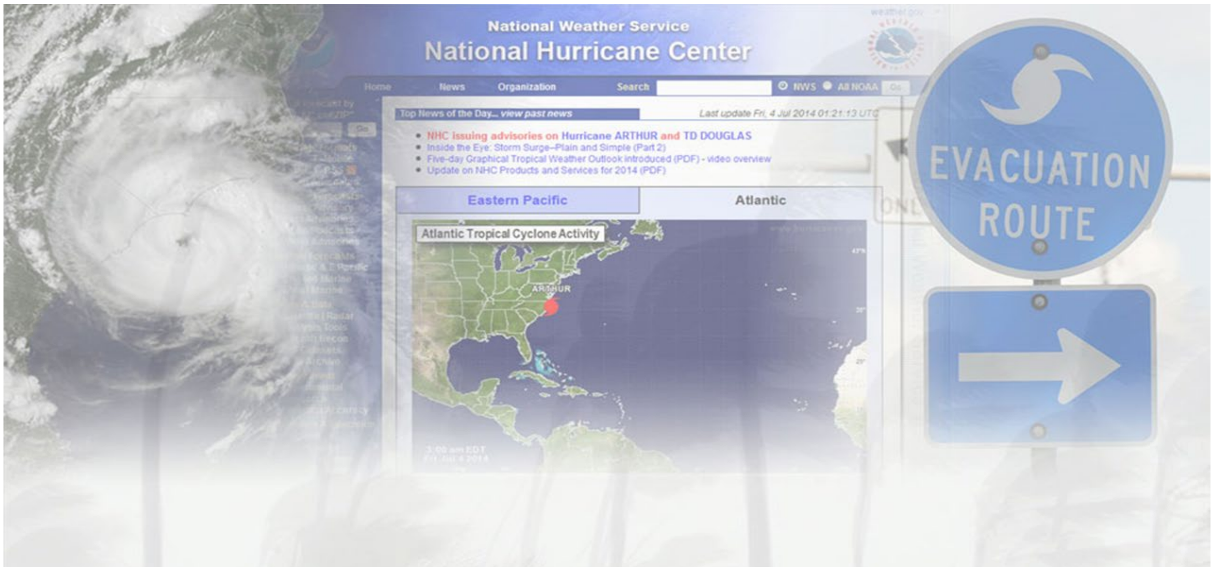
Key Points

The closer you get towards the eye wall in the right-front quadrant of a land-falling hurricane, you encounter too much shear for the development of a mesocyclone and therefore tornadoes often do not occur. Instability is often maximized along the right-front quadrant of the hurricane which plays a role as well.

They can also develop at any time of the day or night during landfall. However, by 12 hours after landfall, tornadoes tend to occur mainly during daytime hours (due to instability). Thunderstorms are typically low topped and with a nearly saturated atmospheric profile, this is not very conducive for the production of hail.

Doppler radar systems have greatly improved the forecaster’s warning capability, but the technology usually provides lead times from only a few minutes up to about 30 minutes.

Visual 75: 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 National Hurricane Center (NHC) and 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.

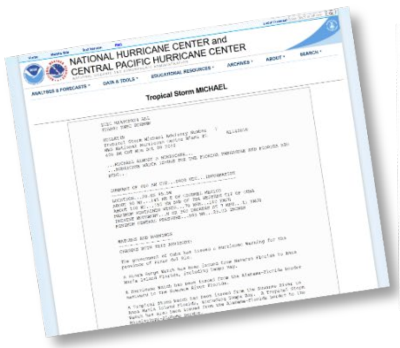
Visual 2: Unit 2 Objectives

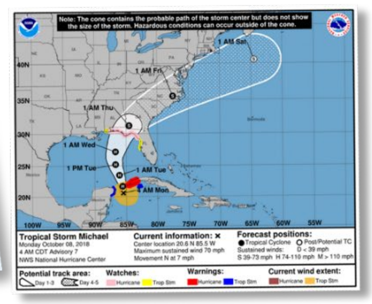
At the end of this unit, you should be able to:

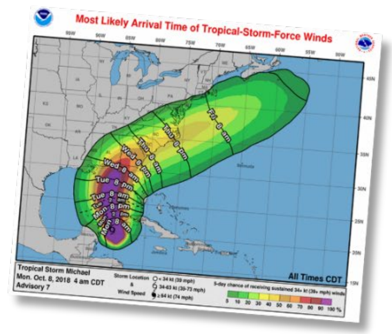
1. Identify the National Weather Service (NWS) forecast products.
2. Explain when NWS products are available.
3. Describe NHC text and graphics products related to wind, such as the Public Advisory, Forecast Discussion, Wind Speed Probabilities, and Arrival Times.
4. Describe NWS text and graphics products related to rainfall and flooding, such as Quantitative Precipitation Forecast (QPF), Excessive Rainfall Outlook (ERO), and hydrographs.

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 Hurricane Center (NHC) provides the tropical cyclone forecasts and analyses. The Weather Prediction Center (WPC) is the source of national-level analysis of precipitation. The National Water Center (NWC) issues products for riverine flooding.

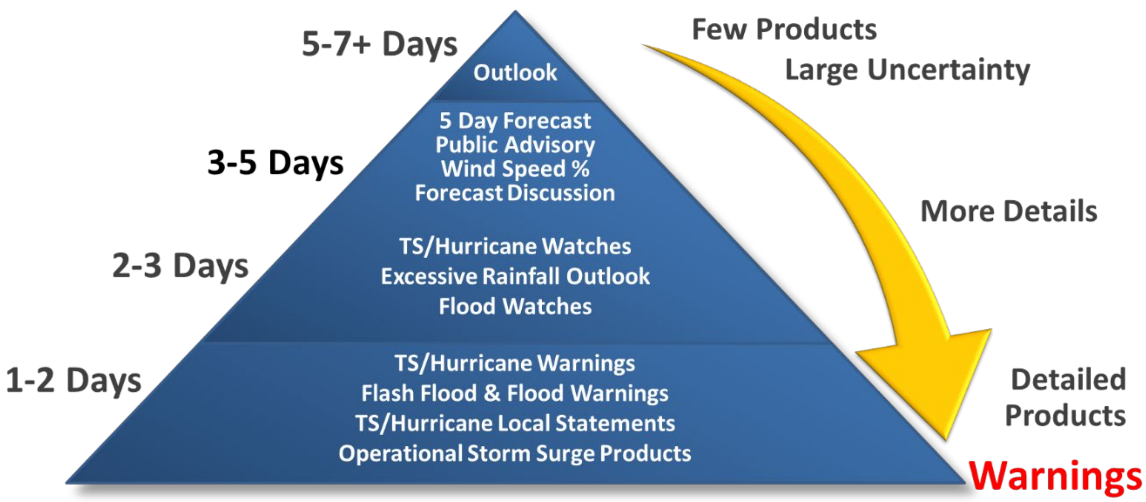
Find more information:

- National Hurricane Center (https://www.nhc.noaa.gov/)
- Weather Prediction Center (WPC) Home Page (www.wpc.ncep.noaa.gov)
- National Water Center Operations (www.weather.gov/owp/operations)

These national centers provide the “big picture” that complements and guides local NWS Weather Forecast Office (WFO) and NWS River Forecast Center (RFC) products.

The NHC provides products and information that form the basis for tropical 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.

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 involved in forecasting a potentially significant event more than 5 days out. As we get closer, the forecasts and products get more detailed and precise.

Visual 5: NWS TC Product Overview

Wind-related Products

- Tropical Weather Outlook
    - Special 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

Water-related Products

- SLOSH MEOWs/MOMs
- Rainfall forecasts
    - QPF
    - ERO
- Hydrographs
- Flash Flood Warnings/Emergencies
- Flood Warnings (Mainstem)

Key Points

NWS publishes a range of products that Emergency Managers (EMs) can use in making decisions. This slide outlines the products from that suite that will be discussed in this unit. On the left are the primarily **wind-based products** and the right has the **water-based products.**

Visual 6: Tropical Weather Outlook (TWO)

Tropical Weather Outlook (TWO) addresses:

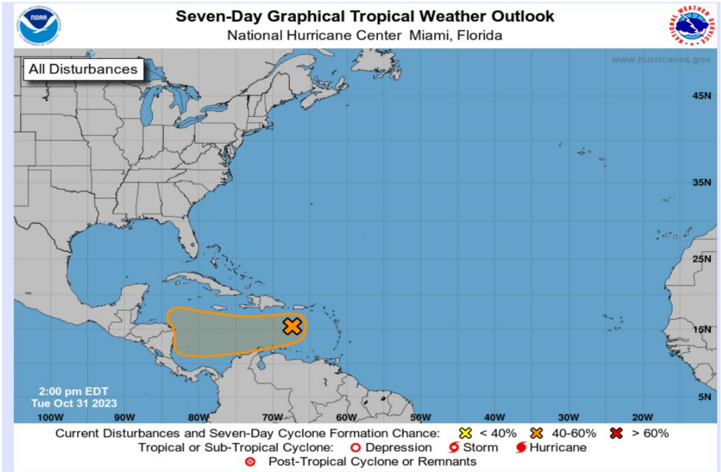
- What's going on in the tropics?
- Any potential for development?
- Should we be concerned?

Key Points

All of the products created by the NHC are designed to answer questions from a concerned public. This unit 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.

The first product to introduce is the Tropical Weather Outlook (TWO), issued by the NHC.

Visual 7: 7-Day TC Formation Potential



- Shows initial location of two disturbances (X), if existing.
- Shading represents the potential formation area within next 7 days.
- What's the chance these areas form in the next 7 days?

Key Points

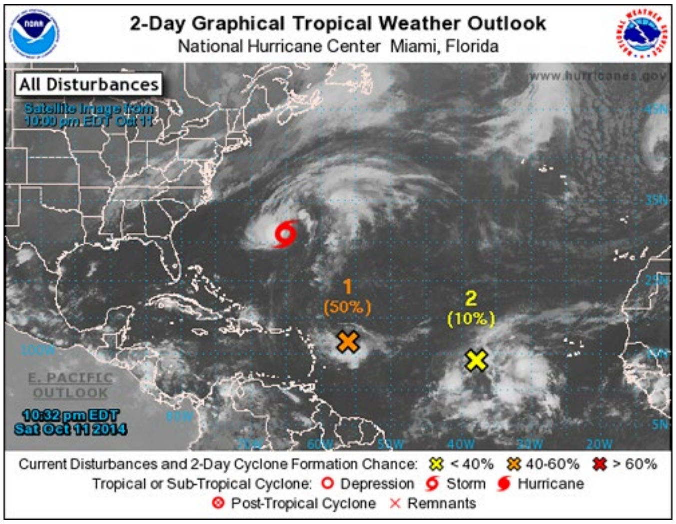
Graphical Tropical Weather Outlook: 7-Day Outlook

The 5-day Graphical Tropical Weather Outlook (TWO) provides the formation potential for individual disturbances during the next 7-day period. The areas enclosed on the graph represent the potential formation area during the forecast period. The hatched formation area does not necessarily mean the cyclone will head in that direction once it forms.

The areas are color-coded based on the potential for tropical cyclone formation. Yellow indicates a Low probability of development (0–30%), orange indicates Medium likelihood (40–60%), and red indicates a High likelihood of development (70–100%).

The location of existing disturbances is indicated by an X. If the formation potential of an existing disturbance does not include the area in which the disturbance is currently located, an arrow will connect the current location of the disturbance to its area of potential formation. Areas without an X or not connected by an arrow to an X indicate that the disturbance does not currently exist but is expected to develop during the 7-day period.

Visual 8: 2-Day TC Formation Potential



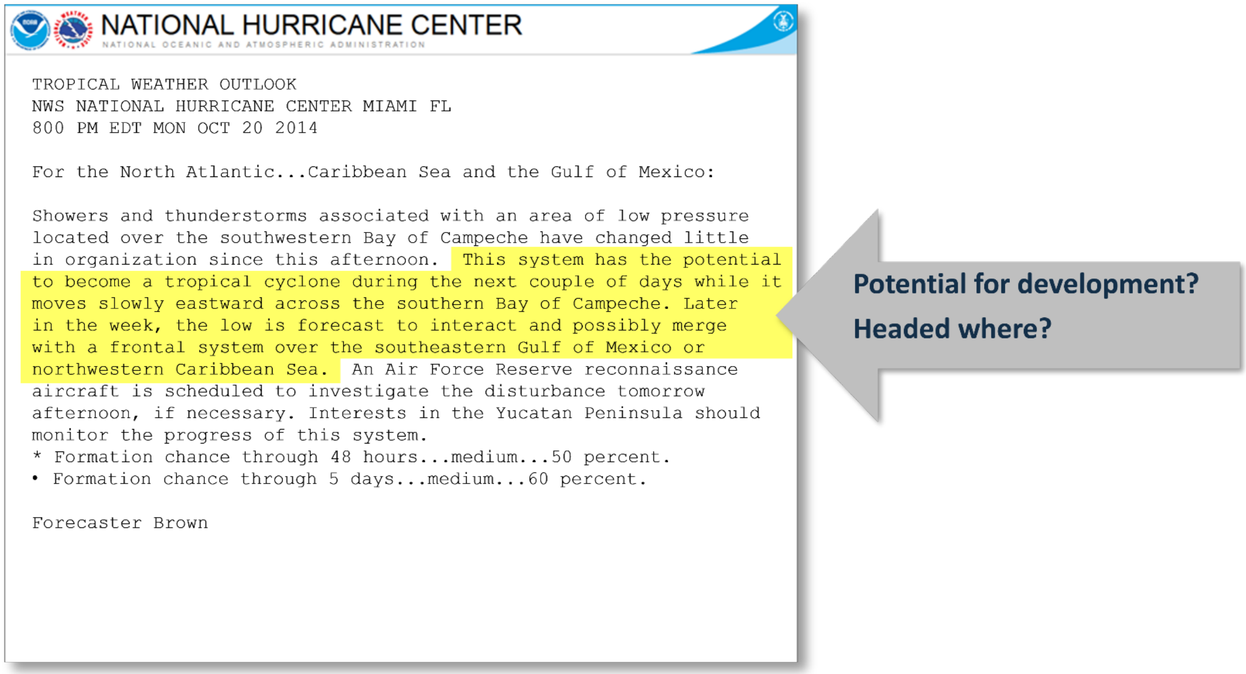
- Identifies the current location of disturbed weather (discussed in the Tropical Weather Outlook)
- Formation chance during the next 48 hours:
  - Categories (Low, Medium, or High)
  - Probabilities

Key Points

The 2-Day Graphical Tropical Weather Outlook (TWO) depicts significant areas of disturbed weather and their potential for development during the next 48 hours. The 2-Day Graphical TWO also shows the locations of any active tropical cyclones. The location of areas of disturbed weather on the graphic are denoted by an X and numbered, with text discussions for each disturbance given beneath the graphic. Besides the timing differences, the graphical 2-day outlook is usually overlaid a satellite image.

The color-coding and caveats for the 7-day outlook apply to the 2-day outlook.

Visual 9: Assessment of Tropical Activity



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:

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 5 days...medium...60 percent.

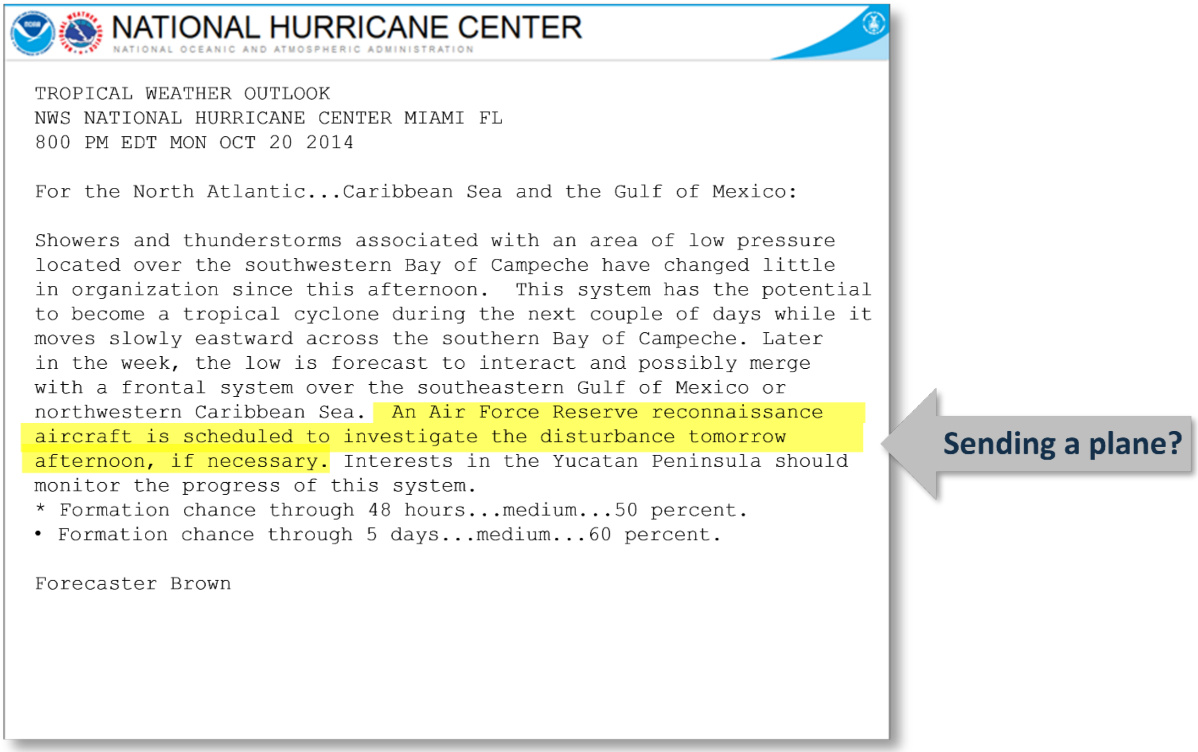
Forecaster Brown

Key Points

Tropical Weather Outlook: 7-day

The text portion of the Tropical Weather Outlook (TWO) briefly describes the disturbances that NHC is formally tracking and their potential for tropical cyclone development during the next 7 days, including a categorical forecast of the probability of formation during the first 48 hours, and during the entire 7-day forecast period. The categories and associated probabilities are the same as described on the slide that discussed the 7-day graphical outlook.

Visual 10: Potential for Aerial Surveillance



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:

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.

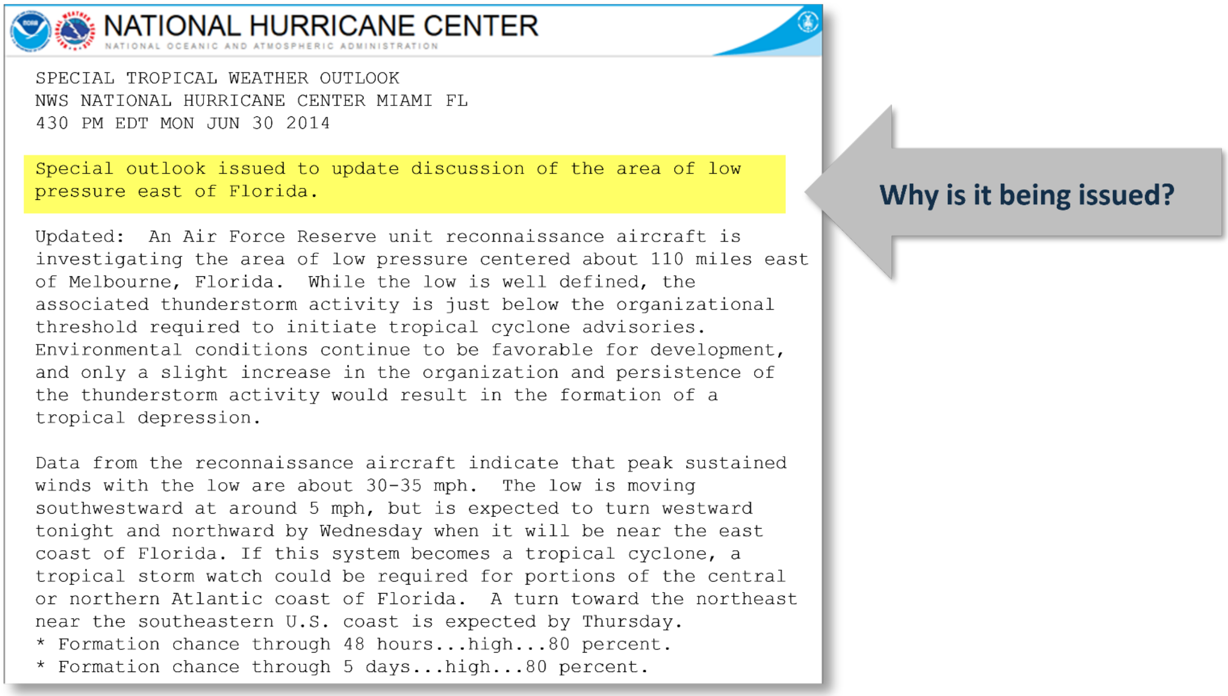
* Formation chance through 48 hours...medium...50 percent.
* Formation chance through 5 days...medium...60 percent.

Forecaster Brown

Key Points

The outlook sometimes includes updates about the deployment of USAF/NOAA Hurricane Hunter aircraft to investigate the system further.

Visual 11: Special Tropical Weather Outlook



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 with regard to a tropical disturbance.

Visual 12: Reports from Hurricane Hunter Flights

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.

What did the aircraft find?

Key Points

New and Different Information

The highlighted portion of this visual shows the new and different information. In this case, NHC issued the special outlook to report that the information gathered from the Hurricane Hunter flight indicates that disturbance is close to meeting the tropical cyclone criteria.

Visual 13: Possibility of Watch/Warning

NATIONAL HURRICANE CENTER
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

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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

Information about potential impacts from the disturbance are sometimes mentioned in the Tropical Weather Outlook. In this case, the highlighted portion of this visual shows that a Tropical Storm Watch may be required if the disturbance becomes a tropical depression or tropical storm.

Visual 14: Tropical Weather Outlook Schedule

Tropical Weather Outlook schedule:

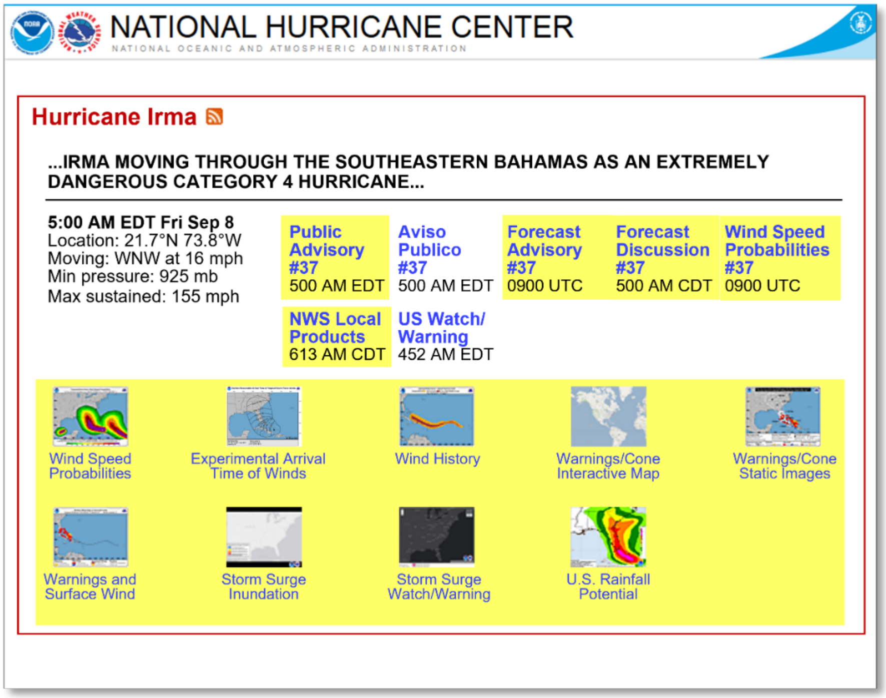
- 2 a.m. – Tropical Weather Outlook
- 8 a.m. – Tropical Weather Outlook
- 2 p.m. – Tropical Weather Outlook
- 8 p.m. – Tropical Weather Outlook

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 above are in Eastern time.**

Visual 15: Visual 15: www.hurricanes.gov



Key Points

The products for a specific tropical cyclone are available on the [NHC website](https://www.nhc.noaa.gov) (https://www.nhc.noaa.gov). Emergency Managers can also access most of these products via the [HURREVAC software](http://hurrevac.com) (http://hurrevac.com).

Visual 16: Public Advisory

Public Advisory addresses:

- How strong is the storm?
- What are the hazards?
- Are there any Warnings?
- When is new information available?
- When is a good time for a conference call?

Key Points

The Public Advisory is a text product that provides a summary of an active tropical cyclone.

It 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.

Visual 17: Public Advisory – Issued for…

Public Advisories issued for:

Tropical Cyclones

- Tropical Depressions
- Tropical Storms
- Hurricanes

Post-Tropical Cyclones

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

Potential Tropical Cyclones

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

Key Points

This slide lists the situations during which a Public Advisory will be issued. NHC will issue advisories for tropical depressions, tropical storms, and hurricanes. NHC will issue advisories for post-tropical cyclones if they remain a threat to land.

NHC will also issue advisories for **Potential Tropical Cyclones**, which are reserved for situations in which a tropical cyclone hasn't officially formed yet, but NHC feels confident it will form soon, but not soon enough to get necessary Watches and Warnings issued at the normal lead times.

Visual 18: Public Advisory - Example

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

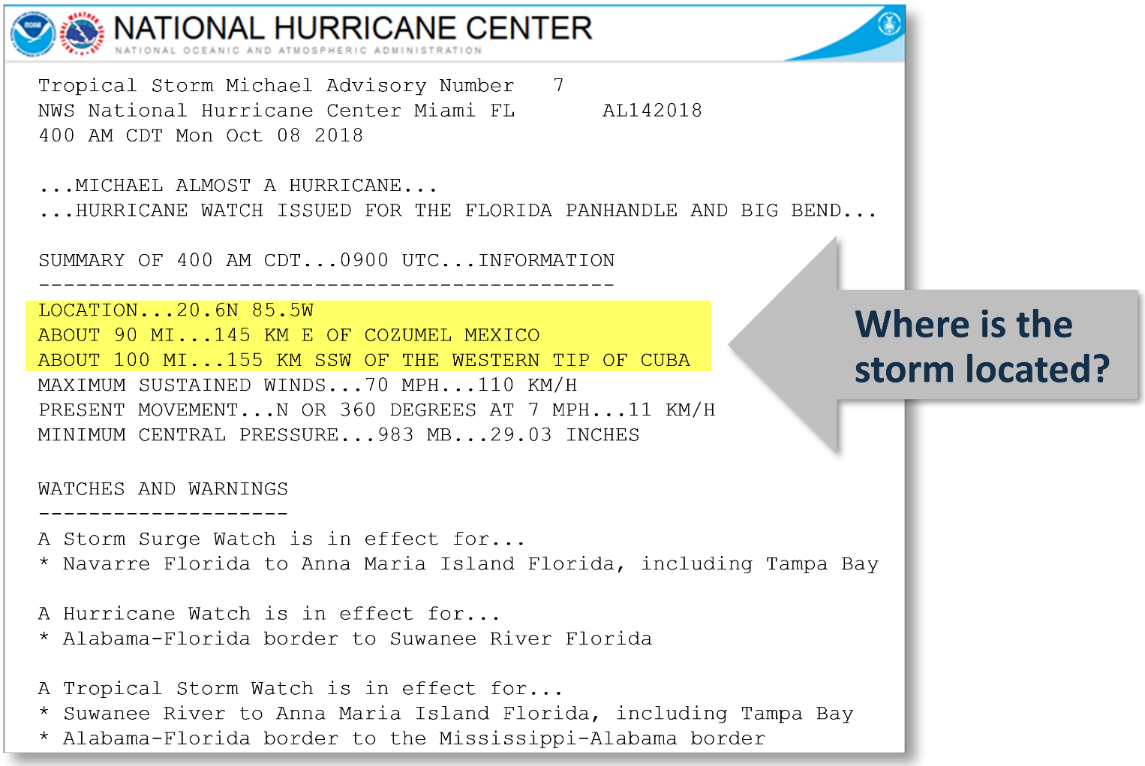
A Tropical Storm Watch is in effect for...
* Suwanee River to Anna Maria Island Florida, including Tampa Bay
* Alabama-Florida border to the Mississippi-Alabama border
```

- **Plain-language text**
- **Originally intended as “rip and read”**

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.

Visual 19: Public Advisory - Location

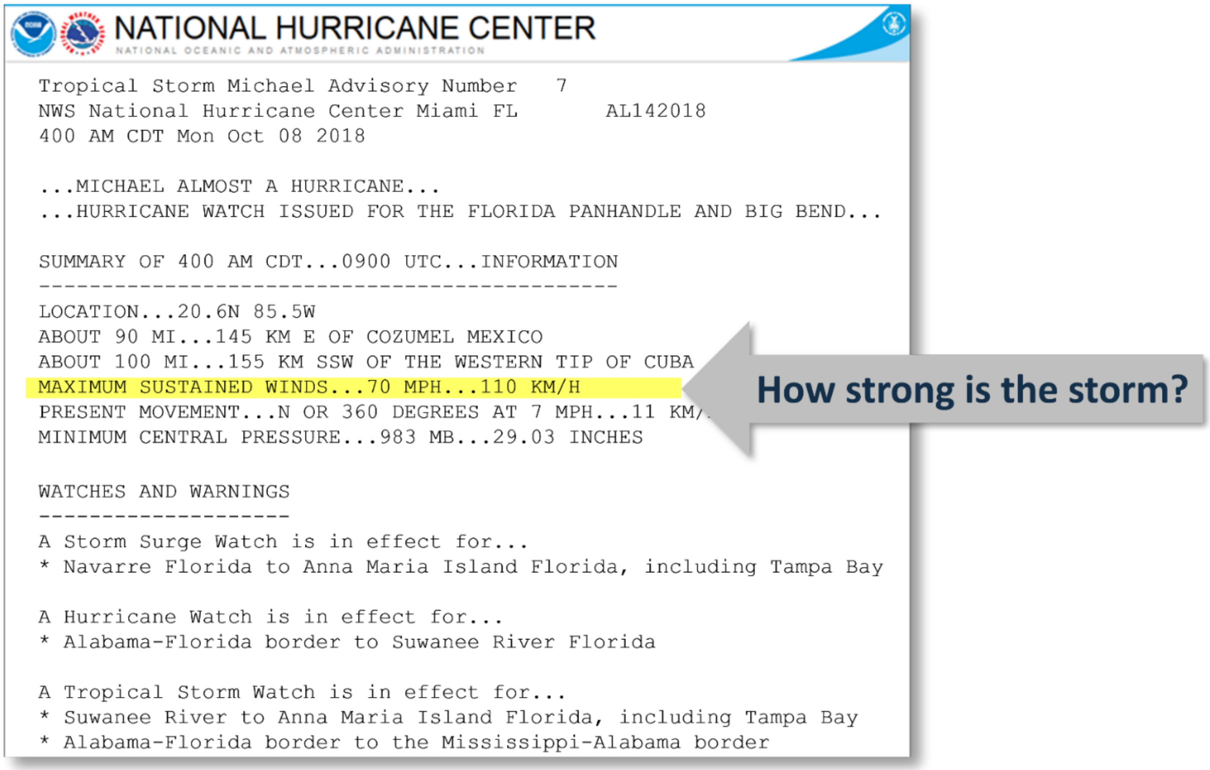


Key Points

Current 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 20: Public Advisory – Strength




```
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

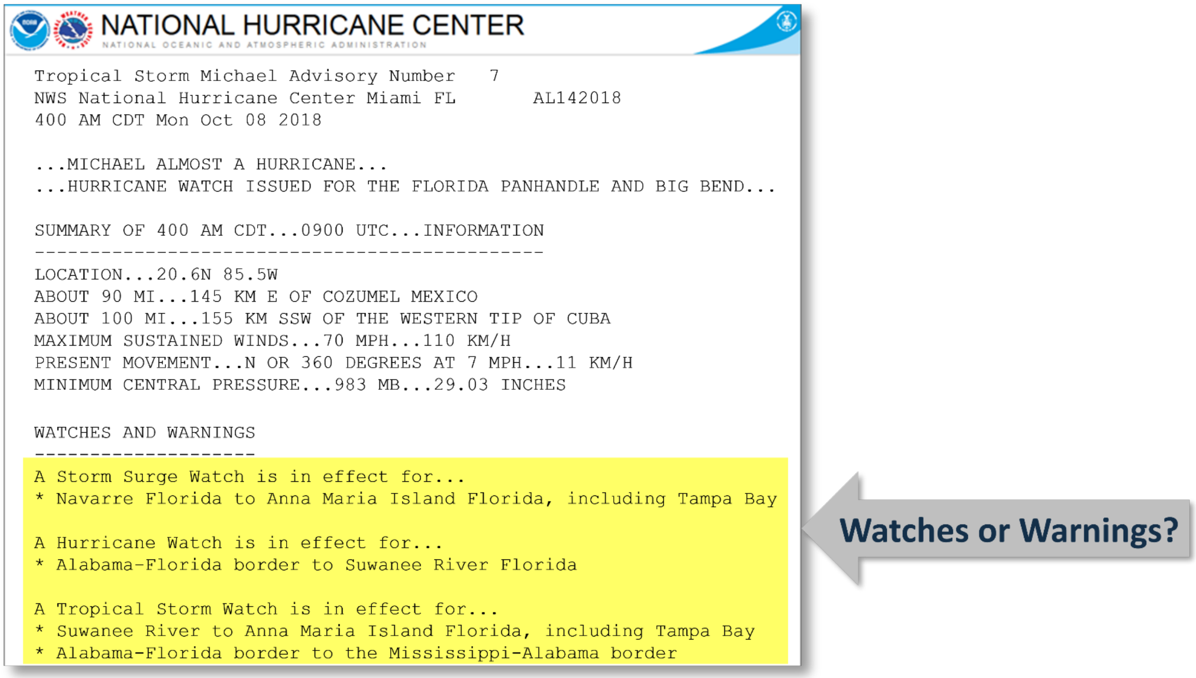
A Tropical Storm Watch is in effect for...
* Suwanee River to Anna Maria Island Florida, including Tampa Bay
* Alabama-Florida border to the Mississippi-Alabama border
```

Key Points

Current Strength

The advisory also answers the question of the current strength of the tropical cyclone.

Visual 21: Public Advisory – Watches/Warnings




```
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

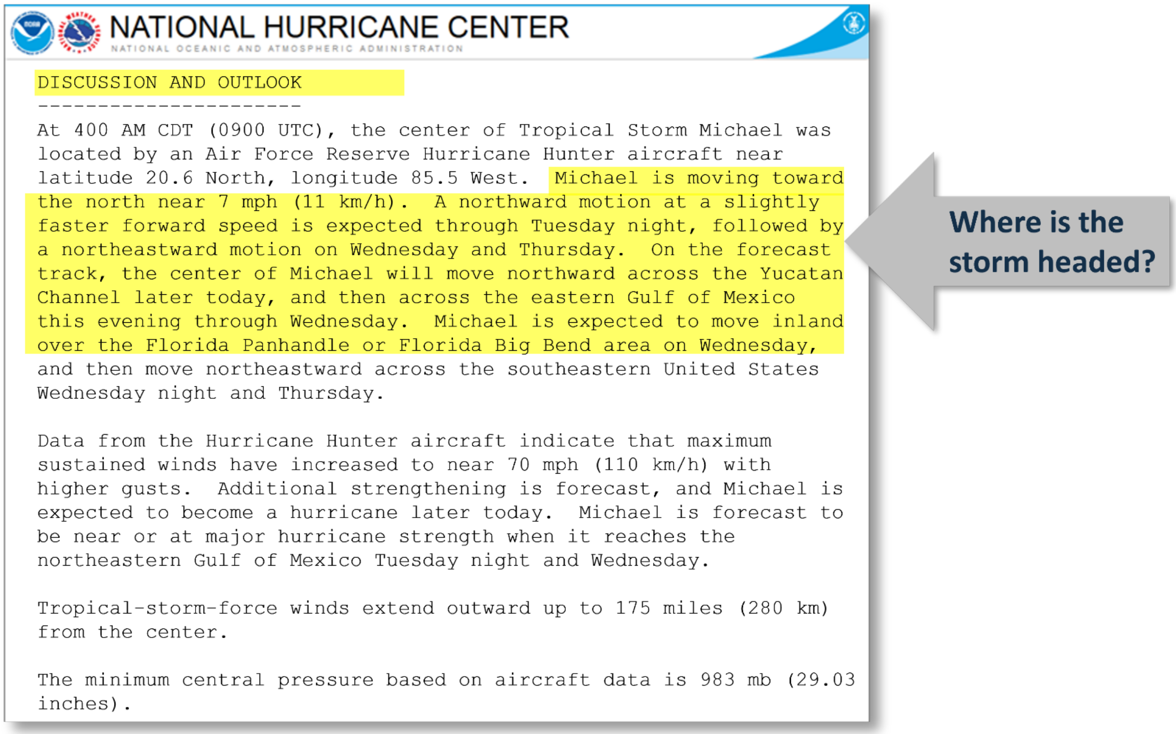
A Tropical Storm Watch is in effect for...
* Suwanee River to Anna Maria Island Florida, including Tampa Bay
* Alabama-Florida border to the Mississippi-Alabama border
```

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 22: Public Advisory – Track 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).

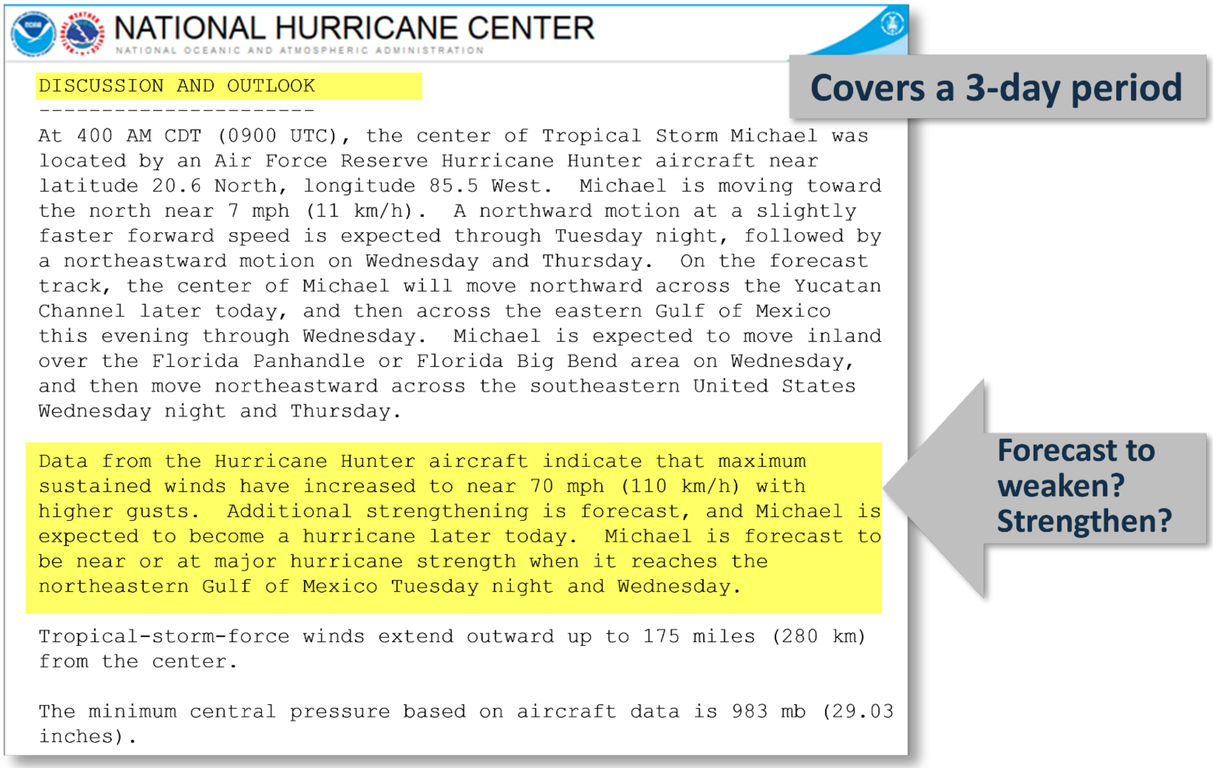
Key Points

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 narrative is a great resource to pull text out for crafting messaging.

Visual 23: Public Advisory – Wind 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.

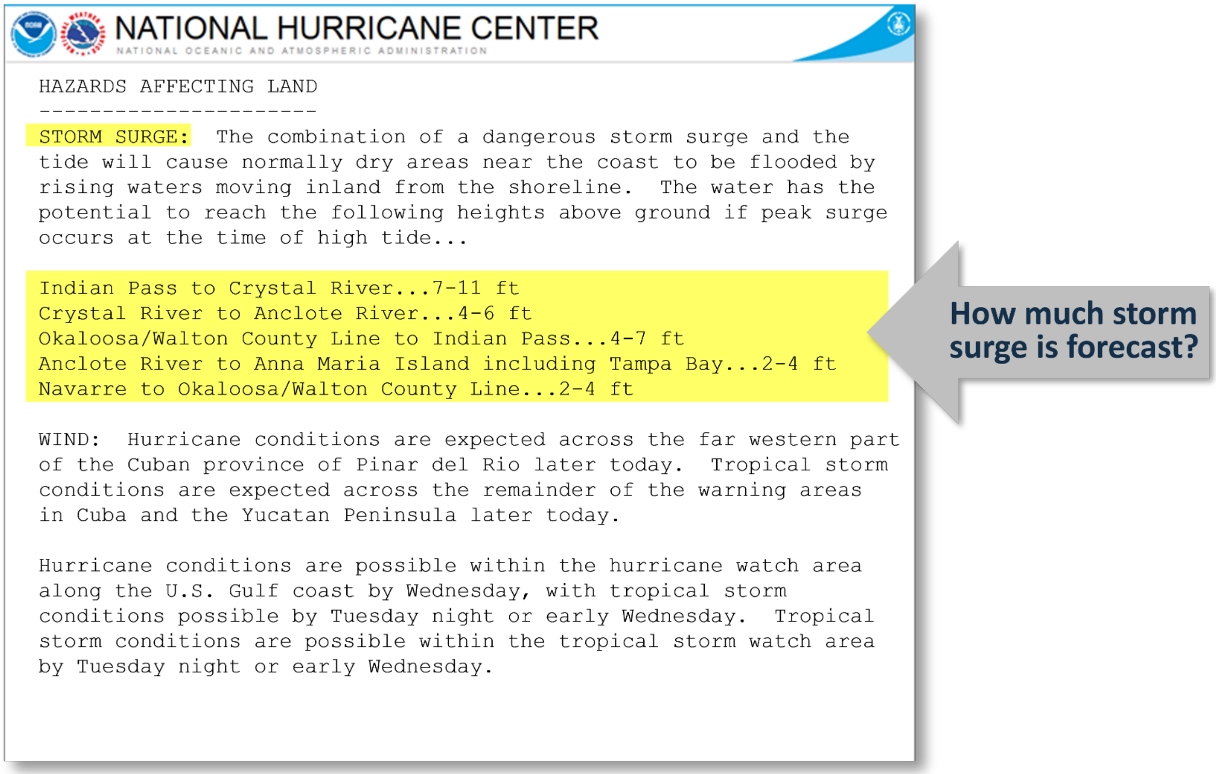
The minimum central pressure based on aircraft data is 983 mb (29.03 inches).

Key Points

Wind Intensity Forecast

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

Visual 24: Public Advisory – Surge Forecast



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.

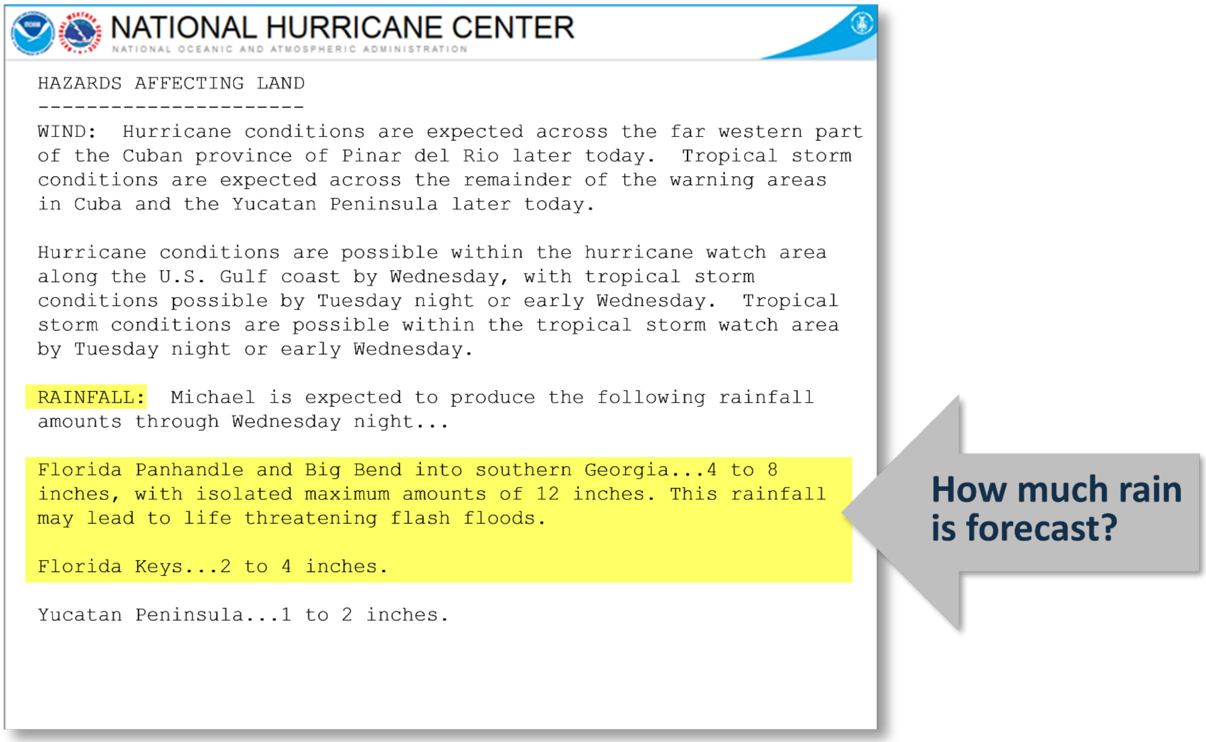
Key Points

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 advisory for this hurricane started first with storm surge. Ranges of possible storm surge inundation (above ground) are given for segments of the coast. In the Public Advisory, the surge ranges are generalized. Not all locations in the area described will see those levels.

Visual 25: Public Advisory – Rain Forecast



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.

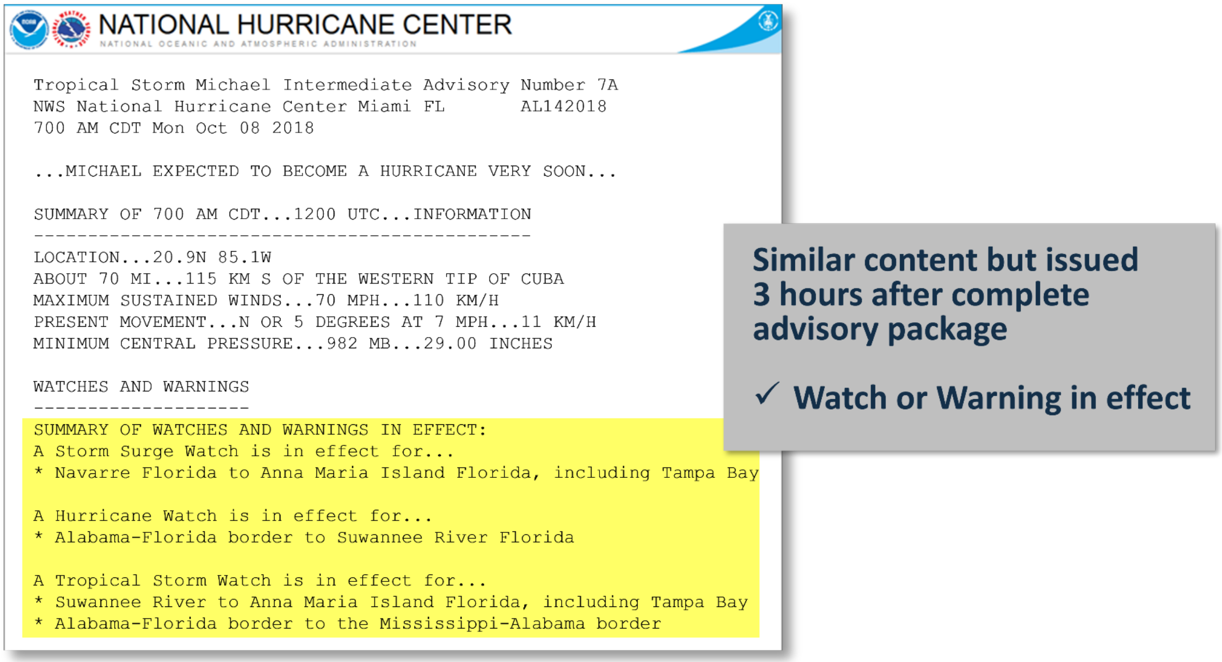
Yucatan Peninsula...1 to 2 inches.

Key Points

Rain Forecast

The hazard section of the Public Advisory also provides the predicted storm total rainfall amounts associated with the tropical cyclone. Like with the surge statement, the rainfall ranges are generalized. Not every location within the areas identified will see the forecast rainfall amounts.

Visual 26: Intermediate Public Advisory



Key Points

Public Advisories are normally issued every 6 hours, but whenever Watches or Warnings are in effect, Intermediate Advisories will be issued every 3 hours in between the Public 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 27: 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
```

- **Unexpected changes occur in the cyclone**
- **Cyclone landfall**
- **Issuing international watches and warnings**
- **1-hourly position estimates when a cyclone with an eye is nearing land**

Key Points

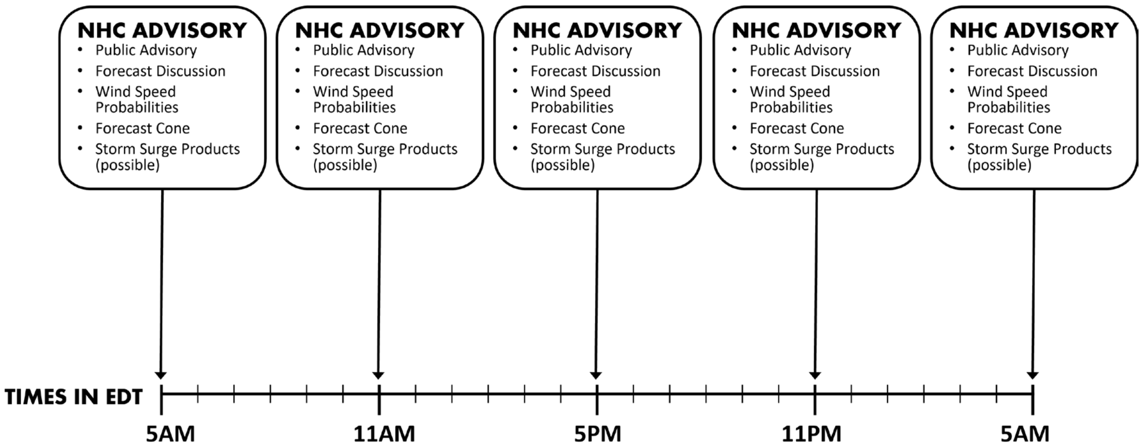
A Tropical Cyclone Update is issued between regularly scheduled Public Advisories and Intermediate Advisories to inform users of significant changes in a tropical cyclone.

This product is issued when:

- Unexpected changes occur in the wind intensity of a tropical cyclone.
- A tropical cyclone is nearing land and the center can be easily tracked by radar, therefore hourly position estimates are provided.
- A tropical cyclone makes landfall.
- International Watches and Warnings are issued.

Visual 28: Scheduled Updates

No Watches/ Warnings



Key Points

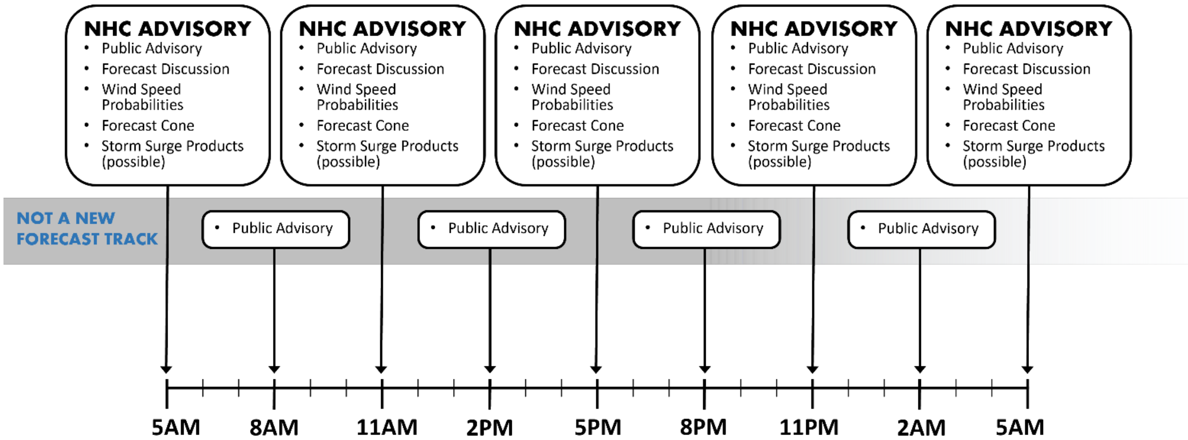
While tracking a system that meets the advisory criteria, the NHC will issue an advisory package that includes:

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

NHC issues a new advisory package every 6 hours – at 5 a.m., 11 a.m., 5 p.m. and 11 p.m. (all times Eastern and during Daylight Savings Time).

Visual 29: Scheduled Updates – W/W

Watches/Warnings in effect

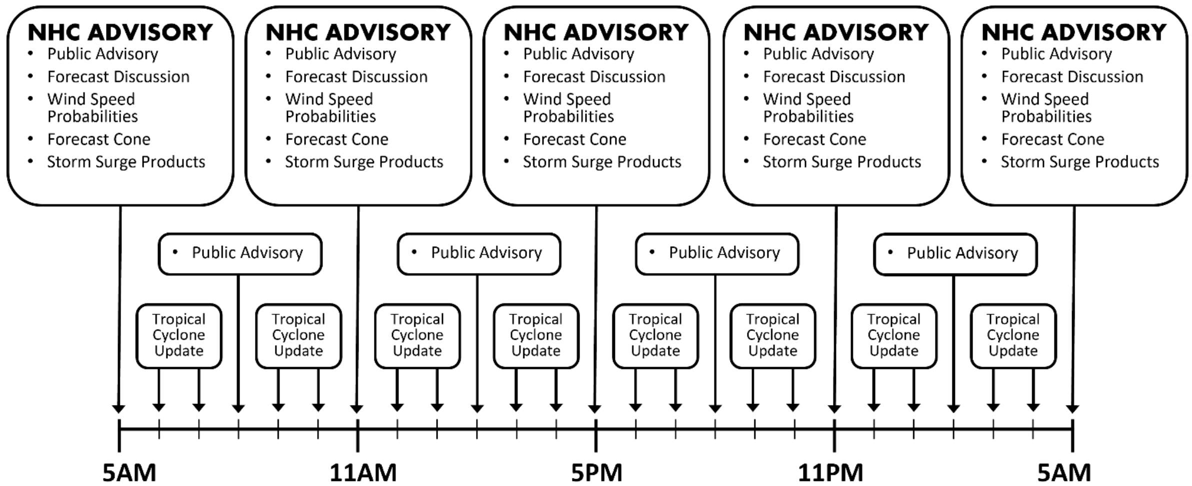


Key Points

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. The Intermediate Advisory is issued every 3 hours but does not contain a new forecast track.

Visual 30: Scheduled Updates – Eye Tracked

Watches/Warnings in effect and eye tracked by radar



Key Points

To recap an earlier slide, the Tropical Cyclone Update provides more information as the storm is closer to the coast and can be tracked with radar. These updates come at least every hour from the NHC (more frequently as it nears landfall). The updates include:

- Status of the storm
- Strength
- Location

Visual 31: Forecast Discussion

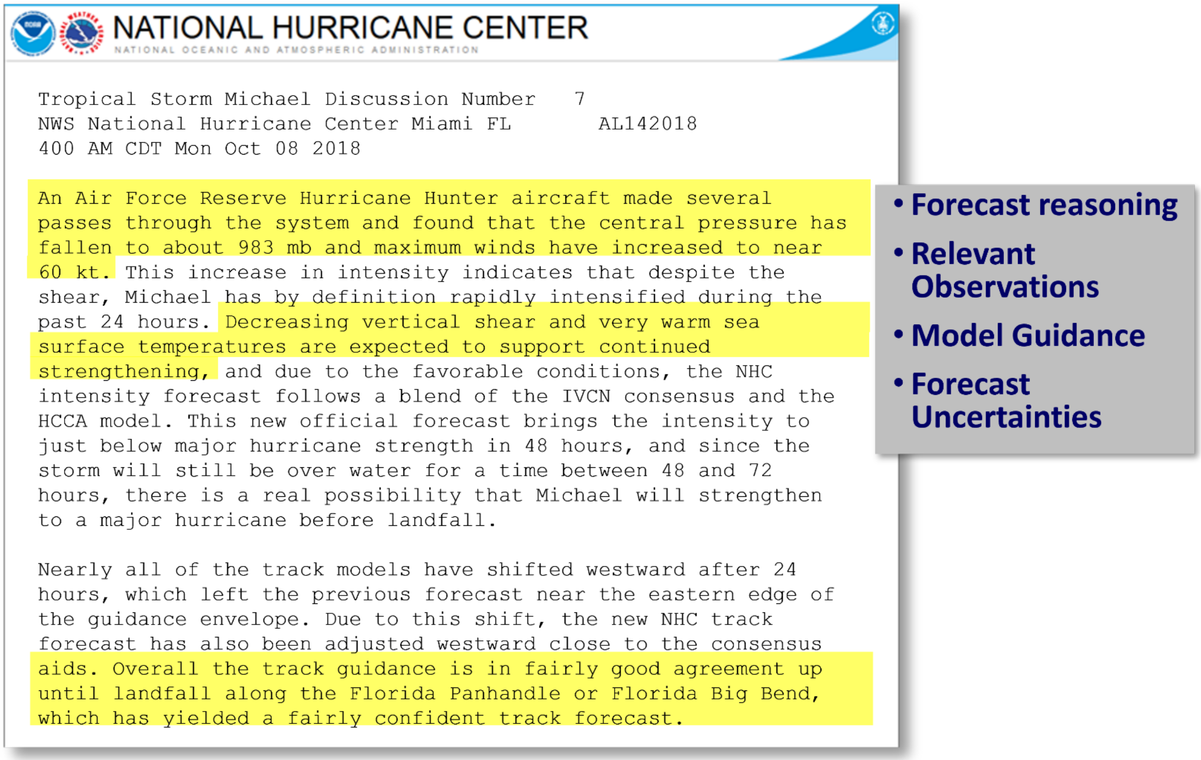
Forecast Discussion addresses:

- How confident are the forecasters?
- Key messages?

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 issued every 6 hours.

Visual 32: Reasoning? Confidence? Scenarios?



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

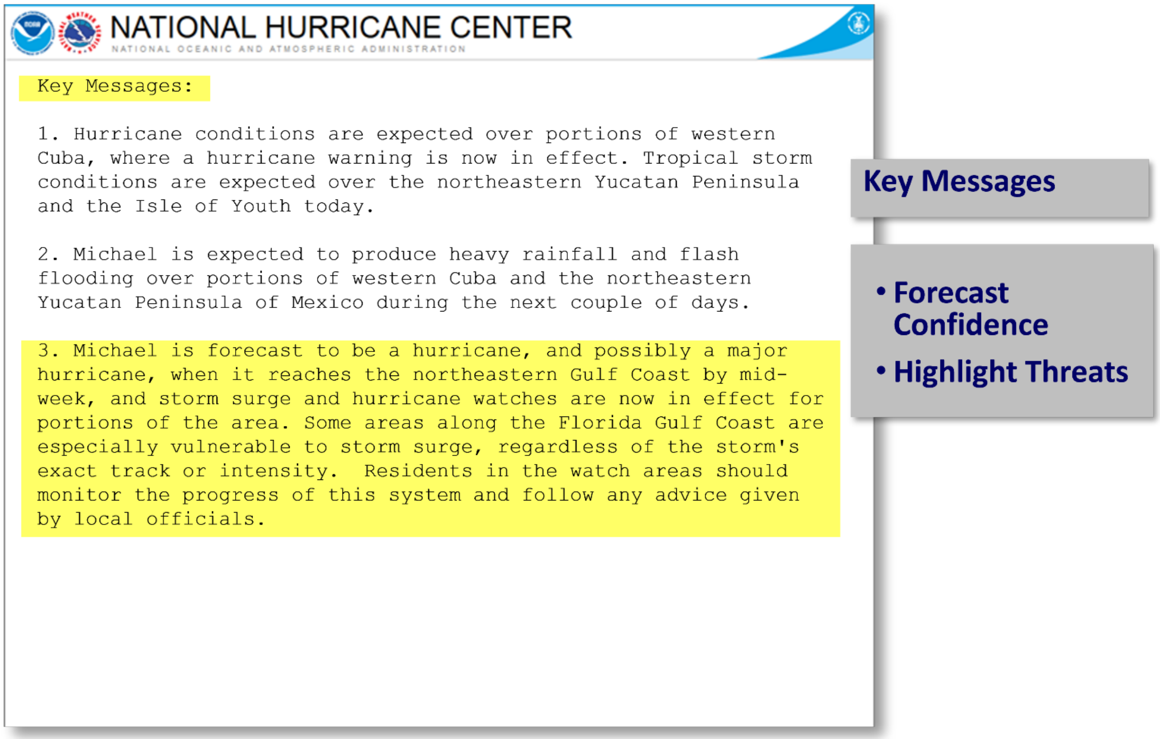
Forecast Reasoning

The Forecast Discussion provides the reasoning behind forecasts and warnings, as well as a discussion of relevant observations, model guidance, and forecast uncertainties It may also describe the forecaster’s degree of confidence in the official forecast, discuss possible alternate scenarios, and highlight unusual hazards.

The discussion is often more technical than other public-facing products.

The Forecast Discussion is issued for active cyclones every 6 hours along with the new advisory package.

Visual 33: Key Messages



Key Points

While the first part of the Forecast Discussion is more technical than other public-facing NHC products, it’s also the product through which you can see the latest “Key Messages.” The Key Messages are purposefully non-technical and are designed to be used to provide the most important, high-level information about the current situation to the general public.

Visual 34: Forecast Error Cone

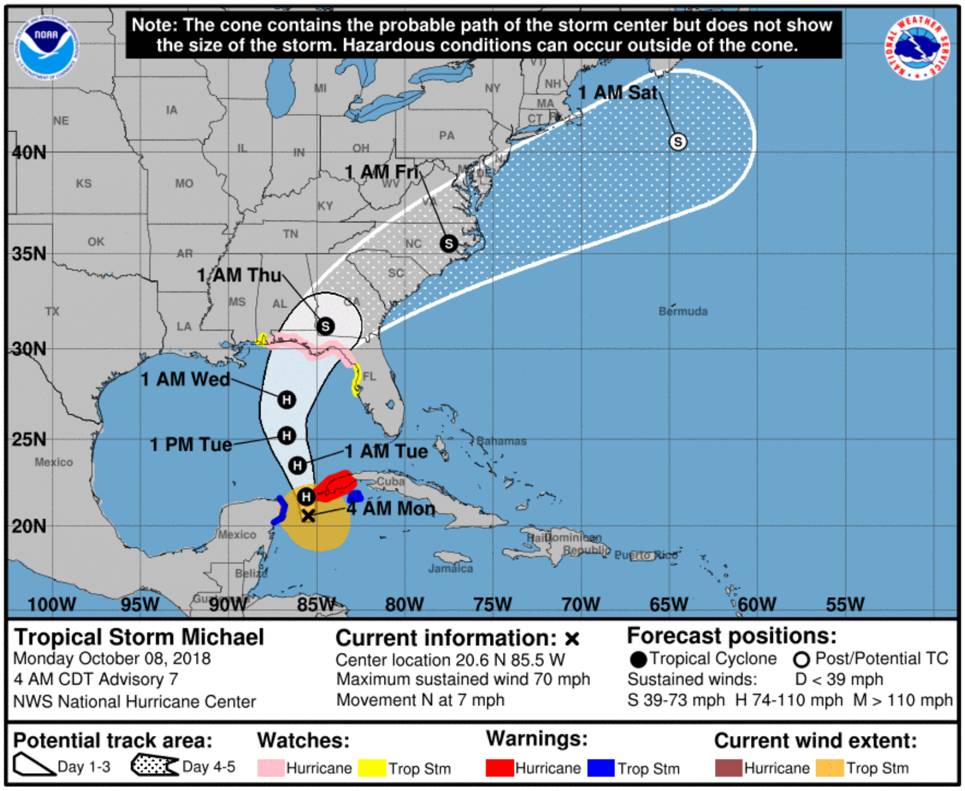
Forecast Error Cone addresses:

- What is the official NHC-issued forecast storm track?
- How can I see this in non-text format?

Key Points

Much of the information found in the Public Advisories is also contained in the Forecast Error Cone graphics. **These are often the most consumed products issued by the NHC, and it is imperative to understand the information they do and do not contain.**

Visual 35: Forecast Error Cone



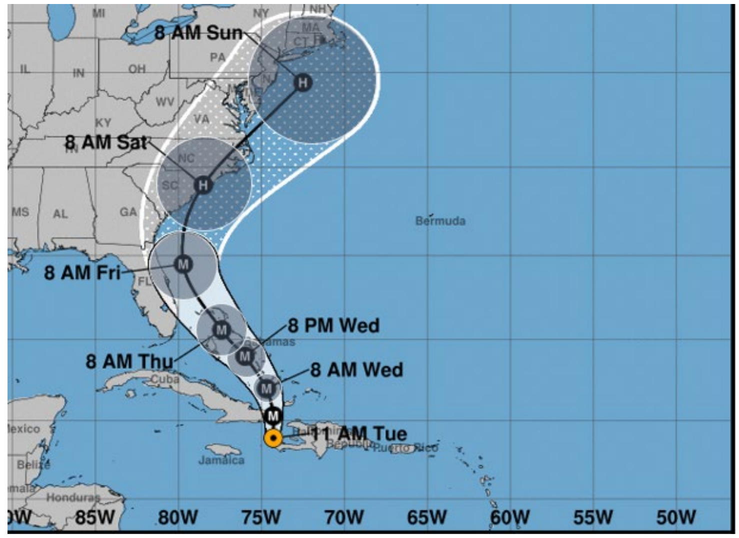
Key Points

This is an example of the error cone graphic. Do you see how the information in the Public Advisory is displayed in the cone graphic?

Visual 36: Cure For the Skinny Black Line?

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 center of the storm will be outside the cone 1/3 of the time.

Visual 37: Not in The Cone: No Worries?

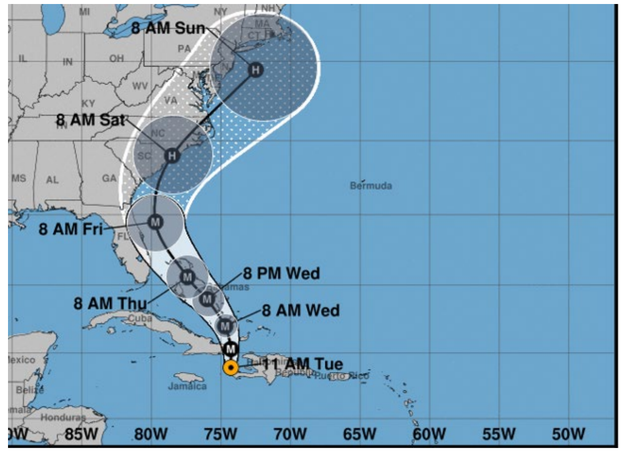
ERROR CONE

Only displays information about track uncertainty.

- Nothing about specific impacts.

Impacts can occur well outside the area enclosed by the cone.

- Center is expected to be outside the cone about 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 track uncertainty.
- It contains no information about specific impacts.
- Tropical cyclone impacts can occur well outside the area enclosed by the cone. 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 cone's borders.
- The tropical cyclone center could move outside the cone about one-third of the time.
- The size of the cone is average error over the past 5 years. The size is not influenced by the current spread in the weather models.

Keep in mind that a tropical cyclone is not a point. As discussed in Unit 1, 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 cone's borders.

Visual 38: Wind Speed Probabilities

Wi**nd Speed Probabilities address:**

- Chance for some effects?
- How can I better see the forecast wind impacts?
- Are staging areas at risk?

Key Points

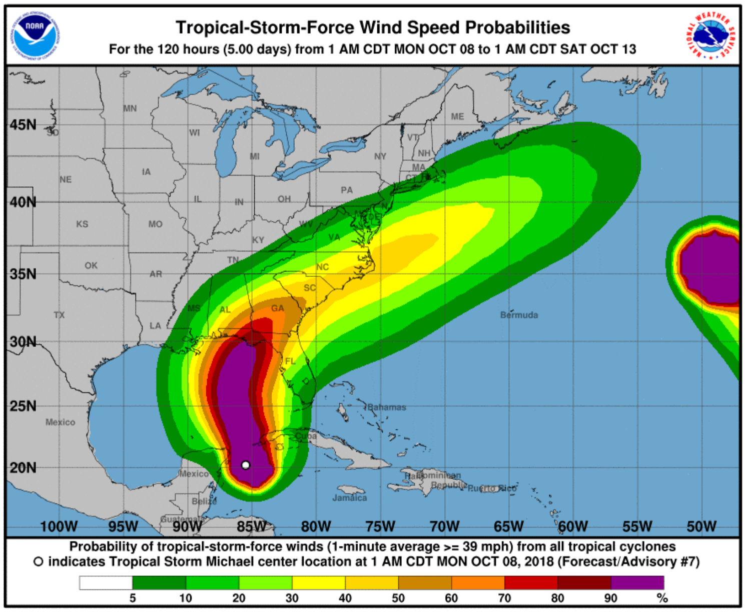
The Wind Speed Probability product is a graphic that provides probabilistic information (i.e., the likelihood of an event, expressed as a percentage) on the likelihood of sustained winds meeting or exceeding specific thresholds.

The three thresholds for which graphics are created are:

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

Wind speed probability forecasts for particular locations can also be communicated via a tabulated text product. Given that this is an inland-focused course, we will not cover that specific product.

Visual 39: 5-Day Cumulative Graphic: TS-Force



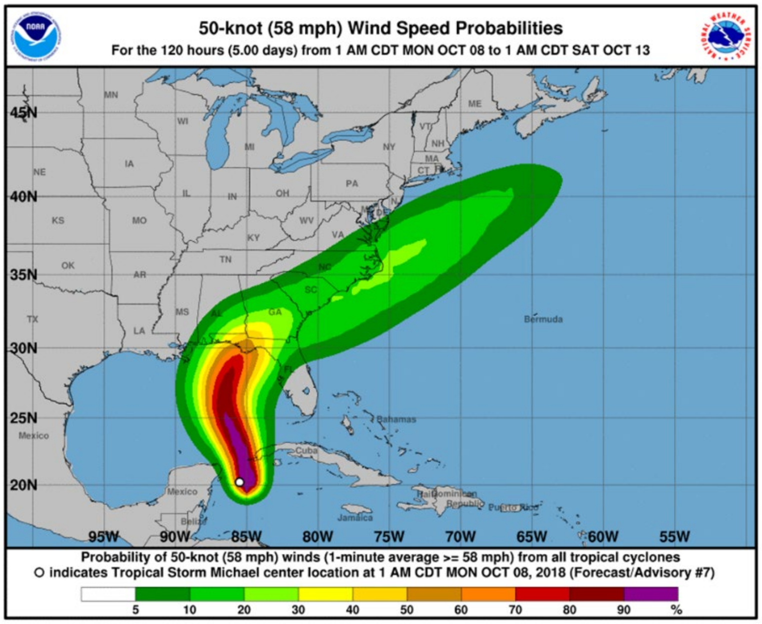
Location-specific Probabilities

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

Key Points

This is one of the Wind Speed Probability graphics, specifically the chance for tropical storm-force winds (39–73 mph).

Visual 40: 5-Day Cumulative Graphic: 'Strong' TS-Force



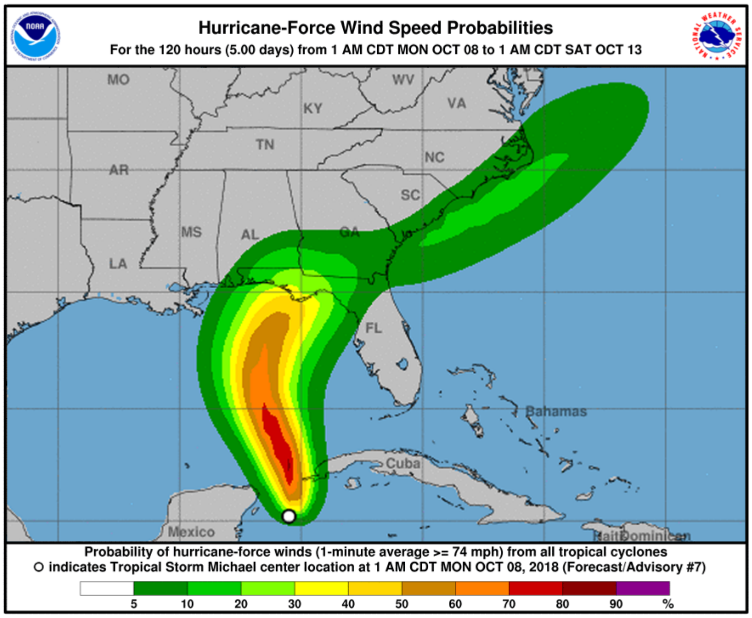
Location-specific Probabilities

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

Key Points

Here is the probability of experiencing "strong" tropical storm-force winds (58 mph–73 mph).

Visual 41: 5-Day Cumulative Graphic: Hurricane-Force



Location-specific Probabilities

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

Key Points

Here is the last Wind Speed Probability graphic, which shows the chances of hurricane-force winds (74+ mph).

Visual 42: Arrival Times

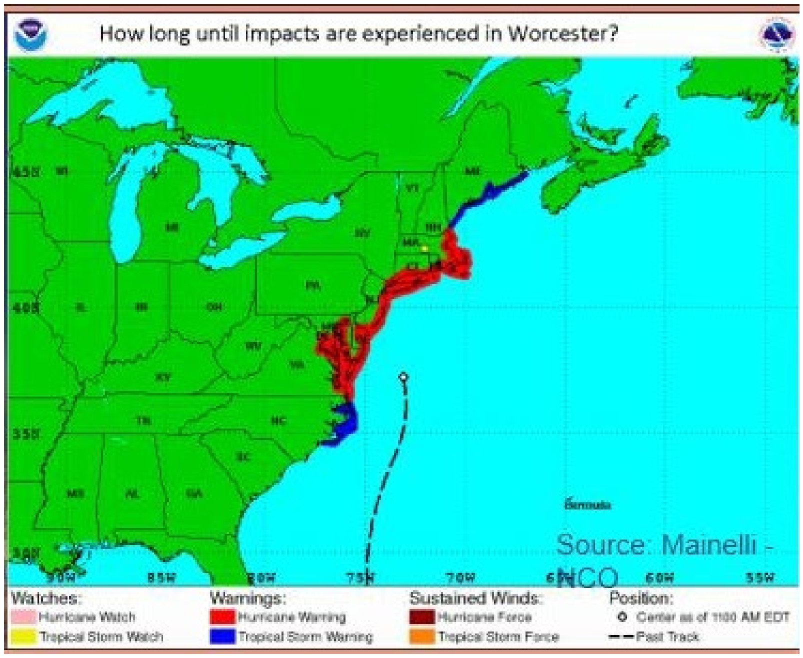
Arrival Times address:

- When is the earliest TS winds could begin?

Key Points

In addition to the Wind Speed Probabilities, NHC issues products that show the possible arrival times of these windspeeds.

Visual 43: 1938 Hurricane Demonstration



Key Points

This example is based on the Great New England Hurricane of 1938 (aka the “Long Island Express” Hurricane).

Based on the first map, how long until the storm’s impacts are felt in Worcester, Massachusetts (the yellow dot)?

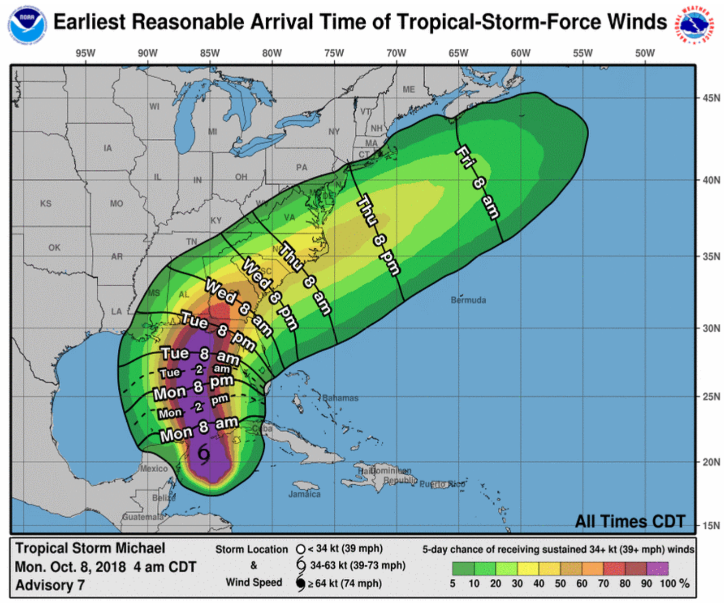
With the wind-fields revealed in the second map, you can see that the effects have already been felt in Worcester, Massachusetts, for several hours. This just demonstrates that the Watch/Warning advisories don't convey timing of impacts.

This is important to keep in mind since inland Emergency Managers in the Mid-Atlantic and Northeast will need to be aware of storms even in their early development. It is important to keep up to date on existing and potential storm threats even when they seem far away.

Visual 44: Earliest Reasonable Onset of TS Winds

Earliest Reasonable

- 10% chance of onset (Most conservative timing)
- Black Contours: Arrival time of TS winds
- Color fill: 5-day cumulative TS probabilities



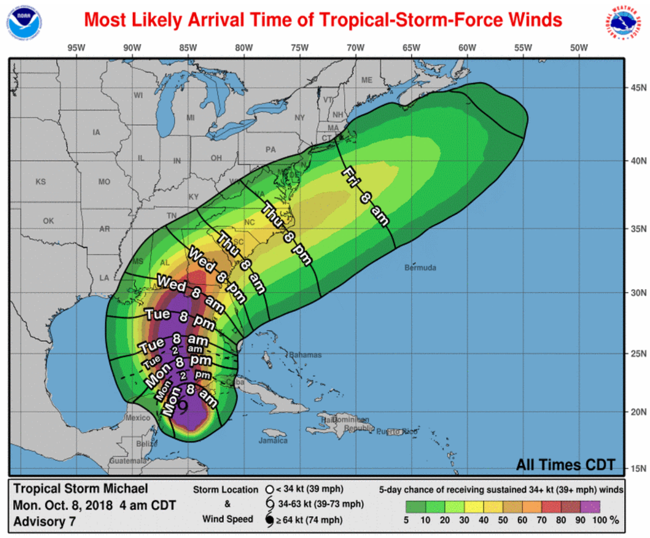
Key Points

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 45: Most Likely Onset of TS Winds

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 46: Timing Uncertainty

Earliest Reasonable

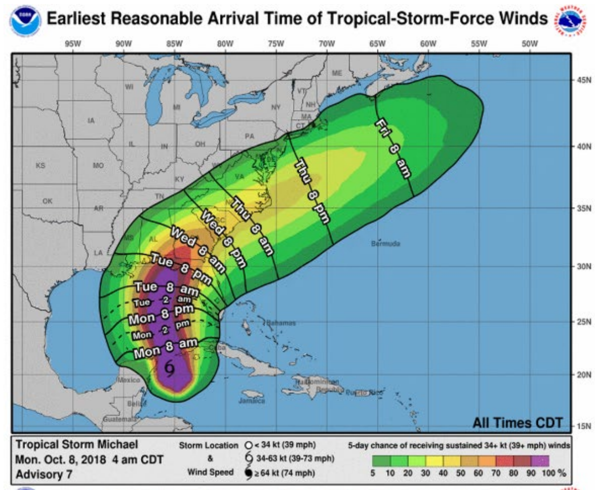
- 10% chance of onset
- Most conservative timing
- Tuesday 8 p.m.

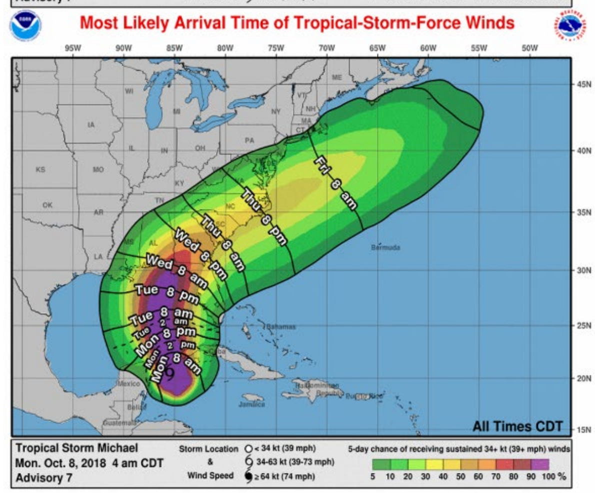
Most Likely

- 50% chance of onset
- Equally likely before as after
- Wednesday 8 a.m.

Range of wind arrival: 12 h

- Tuesday 8 p.m.–Wednesday 8 a.m.





Key Points

This example is of Hurricane Michael in Tallahassee. You can use either earliest reasonable and most likely arrival estimates to make decisions and plans. It is critically important for your agency and/or Emergency Operations Center make it clear which of the two is the planning assumption. Otherwise, there could be a serious common operating picture issue.

Visual 47: Wind Watches and Warnings

Wind Watches and Warnings address:

- Where is the greatest concern for damaging winds?
- When will hurricane winds begin?

Key Points

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

- Where is the greatest concern for damaging winds?
- When will hurricane winds begin?

There are several types of wind-related Watches and Warnings.

Visual 48: Hurricane Watches/Warnings

The lead time for Tropical Storm and Hurricane Watches and Warnings are tied to the anticipated arrival time of tropical storm-force winds.

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.**

Key Points

Both 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 49: Tropical Storm vs. High Wind Watches/Warnings

Tropical Storm Watches/Warnings

- Issued for tropical storm-strength wind speeds (sustained winds of 39 to 74 mph).
- Watches issued when tropical storm winds **possible** within **36 to 48 hours.**
- Warnings issued when tropical storm winds are **expected** within **36 hours.**
- **Will be issued for inland counties covered by WFOs designated to issue Tropical Cyclone Products (based on historical return periods for tropical storm winds).**

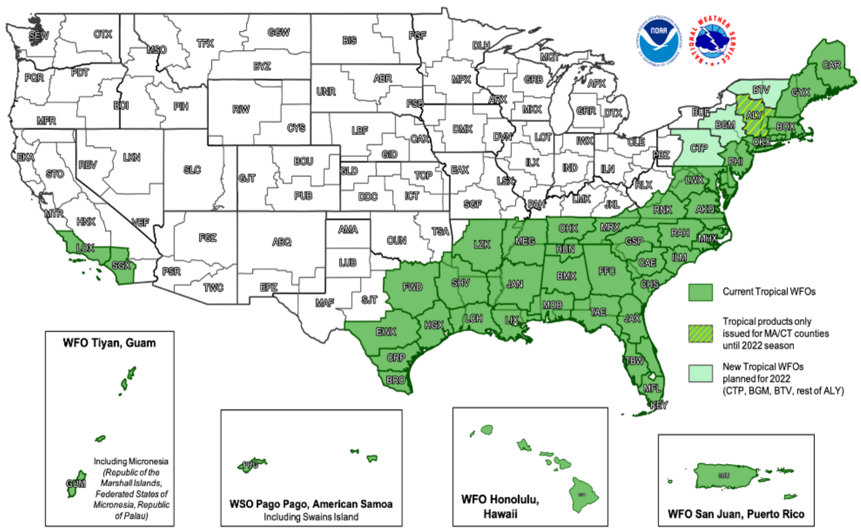
High Wind Watches/Warnings

- Issued for wind speeds that meet or exceed locally defined warning criteria (typically sustained wind speeds of 40 mph or greater lasting for 1 hour or longer, or winds of 58 mph or greater for any duration).
- Watches issued when high winds are **possible** within **12 to 48 hours.**
- Warnings issued when high winds are **expected** within **12 hours.**
- **Will be issued for inland counties covered by WFOs that are <u>not</u> designated as "tropical."**

Key Points

WFOs can issue additional Warnings to complement the Hurricane Watches/Warnings. The Tropical Storm and High Wind Watches/Warnings are meant to provide additional information that Emergency Managers can use when considering impacts to their jurisdictions that may not rise to the level of hurricane winds and might not be considered otherwise. Only certain WFOs are authorized to issue Tropical Storm Watches/Warnings. The WFOs that aren't authorized will issue High Wind Watches/Warnings instead.

Visual 50: Which NWS Offices Will Issue Tropical Storm vs. High Wind Watches/Warnings?



Green/Teal = you will receive Tropical Storm or Hurricane Watches/Warnings for inland wind hazards.

White = you will receive High Wind Watches/Warnings for inland wind hazards.

Key Points

Review the map and note what type of Warnings your jurisdiction will receive for inland wind hazards.

Visual 51: Tornado Watches & Warnings

Tornado WATCH

- Conditions are favorable for severe thunderstorms and tornadoes. It does not mean tornadoes will occur, but they are possible.

Tornado WARNING

- A tornado has been spotted or indicated by weather radar, meaning a tornado is occurring or expected soon.

Tornado EMERGENCY

- A special type of Tornado Warning issued for exceedingly rare situations when a severe threat to human life and catastrophic damage due to a confirmed violent tornado is imminent or occurring.

Visual 52: Storm Surge Products

Storm Surge Products address:

- Where might storm surge occur?
- What are the possible impacts of storm surge?

Key Points

NHC issues several products that assist EMs in understanding the potential risk and impacts from storm surge to their jurisdictions.

Visual 53: SLOSH MOMs and MEOWs - MOMs

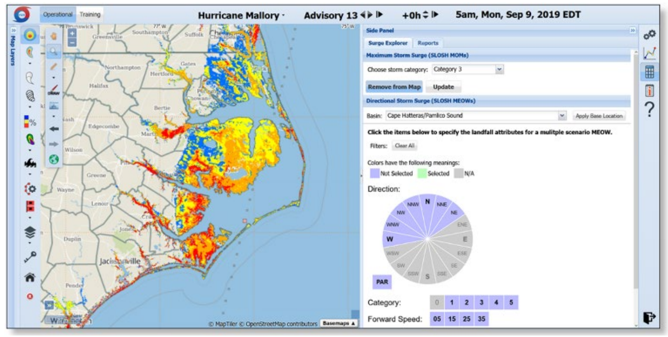
<u>MOMs</u> - Maximum of Maximums

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 MOMs.



Key Points

Maximum Envelope of Water (MEOW) and Maximum of Maximum (MOM) are used to help assess the potential impact from storm surge during blue sky planning and during the early phases of a tropical response. Each MEOW is a composite of the maximum storm surge based on a set of specific storm parameters. A MOM is a combination of MEOWs across multiple scenarios. While a MEOW is a possible outcome from a storm, a MOM is not possible since it includes too many variations of parameters (ex: angle of approach, speed).

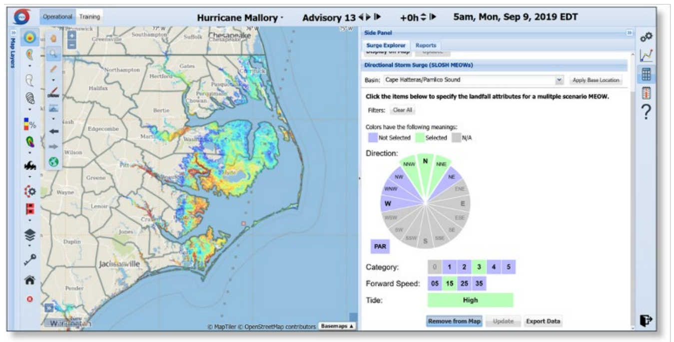
Visual 54: SLOSH MOMs and MEOWs - MEOWs

<u>MEOWs</u> – Maximum Envelope of Water

Composite of the maximum storm surge for a given set of parameters (by basin)

Used as guidance of planning and operations

- Category (Cat 3)
- Landfall direction (NW, N, NE)
- Forward speed (15 mph)
- Initial tide (High)



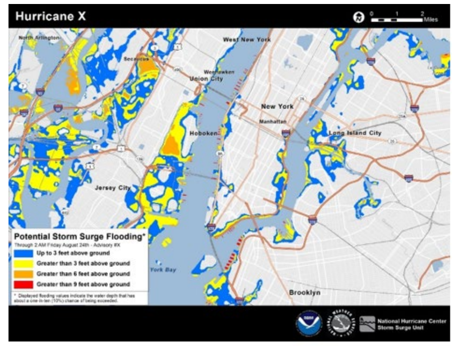
Key Points

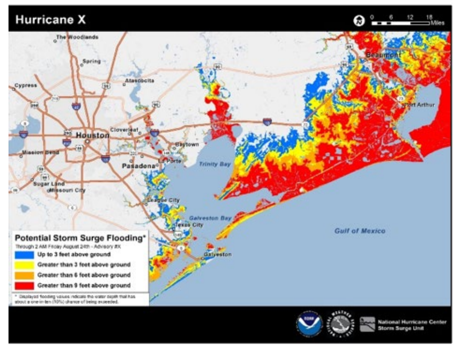
Maximum Envelope of Water (MEOW) and Maximum of Maximum (MOM) are used to help assess the potential impact from storm surge on a community. Each MEOW is a composite of the maximum storm surge based on specific storm parameters (ex: angle of approach, forward speed, intensity, etc.). MEOWs can be useful during the early phases of a response assuming there is reasonable confidence about the angle of approach. However, MEOWs should be replaced by the storm-specific surge products once you're within 2–3 days of onset of hazards (such as the Potential Storm Surge Flooding Map).

Visual 55: Potential Storm Surge Flooding Map

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 with Hurricane Watch
  - Sometimes with Tropical Storm Watch
- Available 60+ minutes after the advisory release





Key Points

The inundation map is calculated using the official forecast for the storm in question . It is released about an hour after the issuance of a Public Advisory.

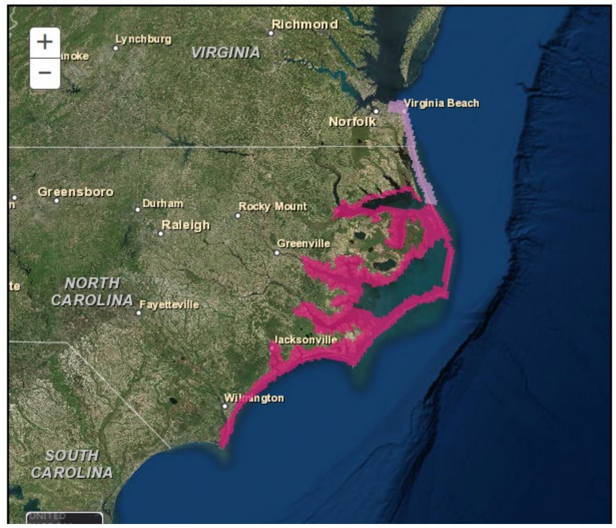
Visual 56: Storm Surge Watches/Warnings

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.**



Key Points

While the Hurricane/Tropical Storm Watches and Warnings will communicate the wind threats, the Storm Surge Watch/Warning will focus exclusively on the coastal inundation threat.

Visual 57: Rainfall & Inland Flooding Products

Rainfall & Inland Flooding Products address:

- How much rain is forecast?
- What areas will flood?
- How do wireless emergency alerts work?

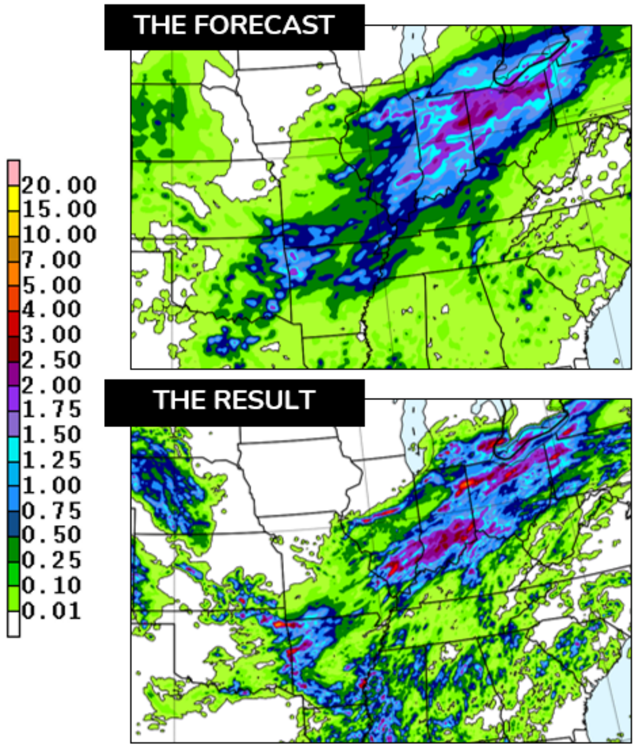
Key Points

NWS-issued rainfall and inland flooding products answer questions like:

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

There are several products that provide different types of information that should be used in concert to answer those questions.

Visual 58: Quantitative Precipitation Forecast (QPF)



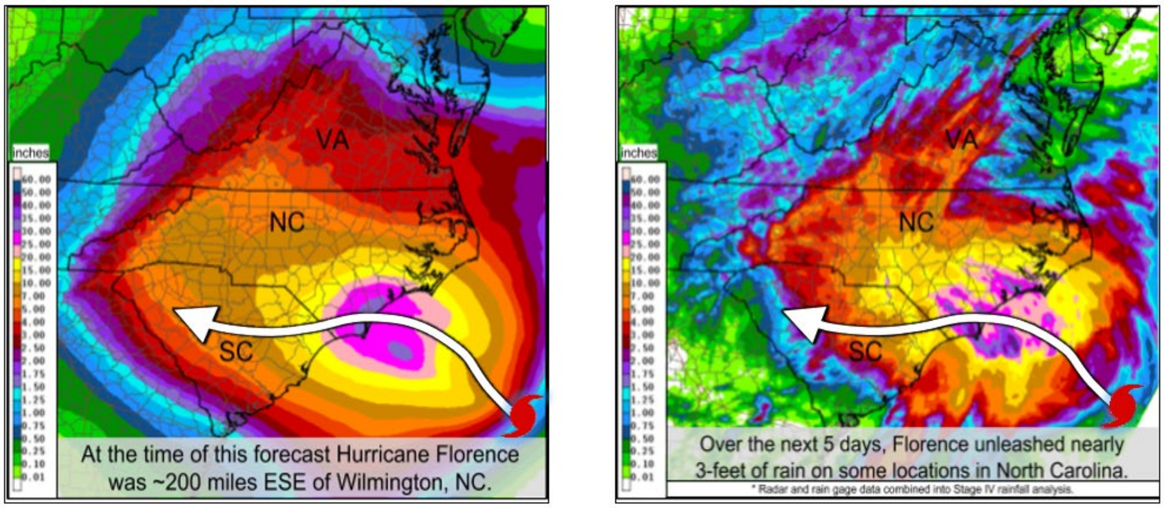
- Forecast precipitation over a given period of time for tropical cyclones.
- The forecast depicts areal average amounts; does not capture localized minimum or maximum.
- More accurate in situations with large, organized weather systems.

Key Points

Most EMs have likely seen a **Quantitative Precipitation Forecast (QPF)** before, which is the primary product through which NWS communicates expected rainfall amounts. In the example shown here, the forecast had areas of heavy rain in the correct regions but did not capture the localized extremes, which is not the intent of the product.

Visual 59: Hurricane Florence (2018)

5-Day Forecast vs. Observed Rainfall



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

Key Points

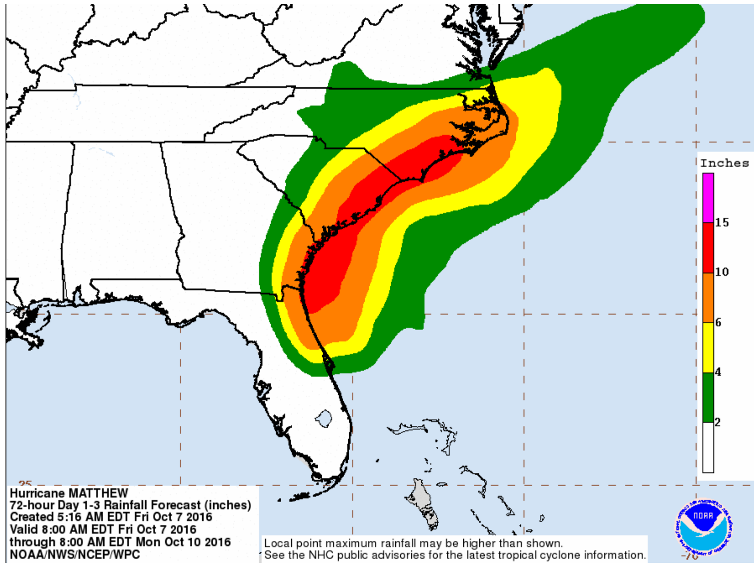
Tropical cyclone rainfall forecasts can generally highlight the areas at risk of heavy rains, but it's sometimes more difficult to pinpoint the specifics of where the highest amounts might occur. Five days before Hurricane Florence hit the Carolinas, the NWS Weather Prediction Center correctly forecast the threat of significant rainfall across a broad swath of the 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 60: Rainfall Forecast

WPC issues *storm-specific* rainfall forecast graphic.

- Simplified scale

This is the version included with the NHC Public Advisory forecast package.



Key Points

The NHC coordinates with the WPC on the rainfall forecast portion of the Public Advisory. The NHC will also share a WPC-generated version of the Quantitative Precipitation Forecast graphic that shows a simpler and more generalized range of how much rain is expected to fall in that area.

This is a storm-specific graphic and doesn't necessarily include rainfall from predecessor rainfall events (PREs) and post-storm rainfall, which could be relevant for an inland EM.

Visual 61: Rainfall Forecasts

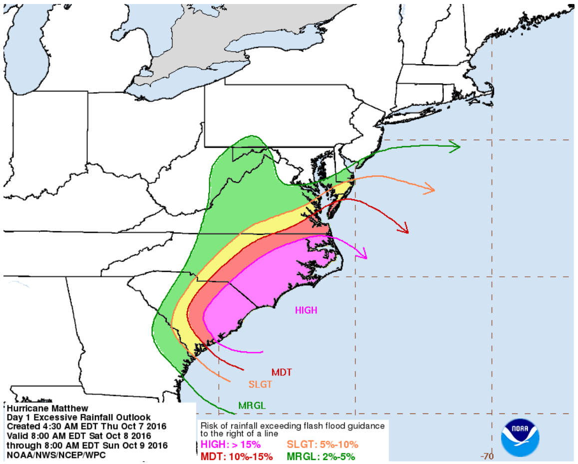
Context Matters:

A forecast of 1 inch has different impacts if the rain falls over 24 hours vs. 10 minutes.

Key Points

Context matters: Forecasts of just rainfall amounts do not convey impacts. The amount of rain is only one factor that helps determine flood risk. A QPF does not say anything about antecedent conditions or rainfall rates. For instance, if 1 inch of rain falls over the course of 24 hours, then you might see little to no impacts (see image on the left). However, if 1 inch falls in 10 minutes, then you might see significant impacts.

Visual 62: Excessive Rainfall Outlook (ERO)



- Chance that rainfall can cause flash flooding
- A situational awareness and planning tool
- Accounts for some uncertainty
- Summarizes large-scale risk factors
- Does NOT
  - Account for longer-term flooding on mainstem rivers
  - Forecast flash flooding at specific locations

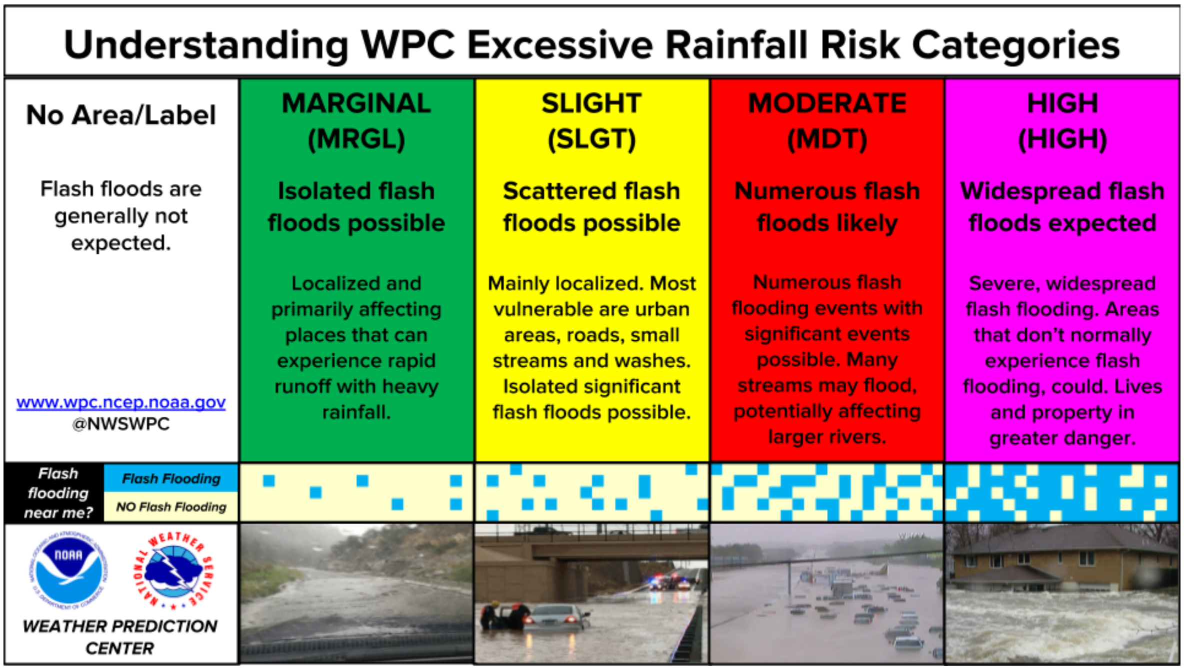
Key Points

The **Excessive Rainfall Outlook** is available on a daily basis on the WPC's website. It shows areas that are at high risk of flash flooding over the next 3 days.

Is NOT an explicit forecast of flash flooding at a specific location and does NOT account for longer-term flooding on mainstem rivers.

Accounts for uncertainty in placement and timing of intense rainfall and summarizes the larger-scale risk factors.

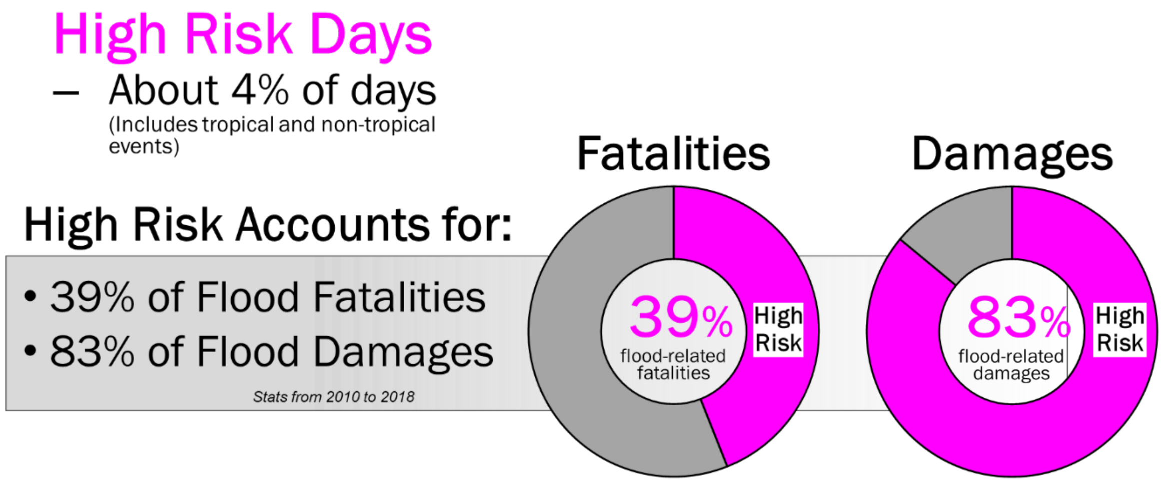
Visual 63: Excessive Rainfall Categories



Key Points

The categories explained in the graphic correspond to the categories mapped out on the ERO forecast product.

Visual 64: Excessive Rainfall Outlook 1



Key Points

The issuance of a High Risk is extremely rare, accounting for only about 4% of total days in a calendar year. This includes both tropical and non-tropical events! Despite their infrequent nature, High Risk Days have proven both deadly and costly. High Risks account for 39% of all flood fatalities and 83% of flood damages within the last ~10 years. As such, Emergency Managers should be especially proactive, alert, and aware of the hazards posed on days that High Risks are issued.

Visual 65: Excessive Rainfall Outlook 2

High Risk Days

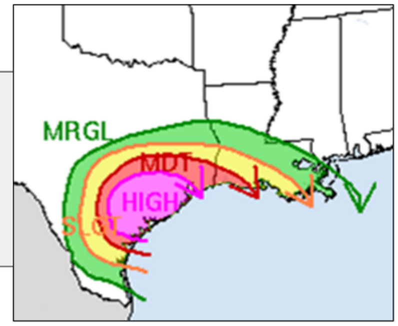
– About 4% of days

(Includes tropical and non-tropical events)

What happens during High Risk days?

- 46% have at least 1 fatality or injury
  Compared to 23% for Moderate Risk Days
- 62% have at least $1 million in damages
  Compared to 33% for Moderate Risk Days

Stats from 2010 to 2020

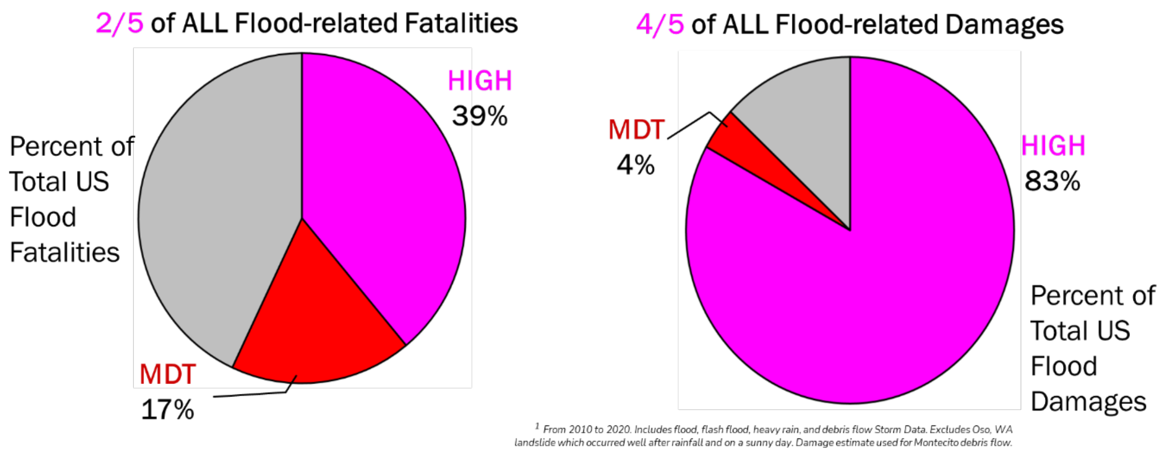


Key Points

High Risk days have proven especially deadly and costly. Nearly half of all High Risk days account for at least 1 fatality or injury, and 62% of High Risk Days account for at least $1 million in damages. Emergency Managers should be aware of these statistics when preparing and responding to such events.

This is not to say that Moderate Risk days are also not dangerous. Nearly a quarter of Moderate Risk days account for at least one fatality or injury. A third account for at least $1 million in damages. Individuals residing in either Moderate Risk or High Risk locations can expect to be greatly impacted by rainfall-induced flooding hazards.

Visual 66: Excessive Rainfall Outlook 3



Key Points

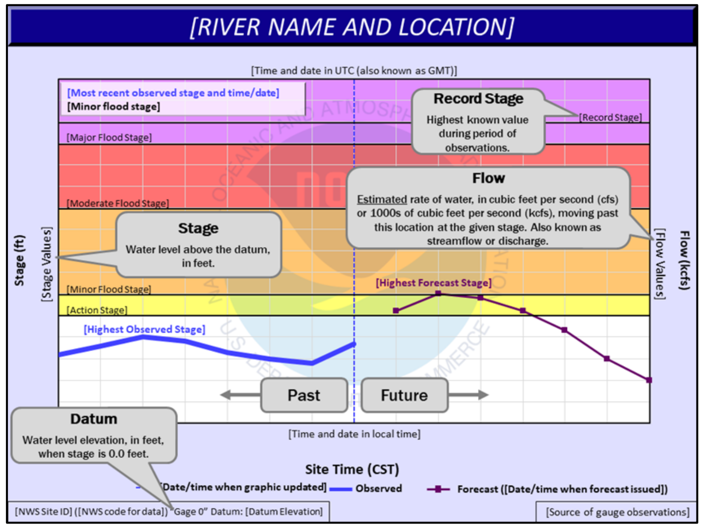
Nearly 56% of all flood-related fatalities have occurred on either Moderate or High Risk days within the last decade. Moreso, nearly 90% of all flood-related damages can be attributed to either Moderate or High Risk days! These days are rare, but when they do occur, Emergency Managers must take notice and be prepared to respond to significant rainfall-induced impacts.

Visual 67: Excessive Rainfall Outlook 4

Based on records over the past 11 years, we can say: **WPC High Risks are a strong indicator of a potentially deadly and damaging flash flood day!**

Visual 68: Hydrographs

- Display water level information over time.
- Hydrograph Plot
  - May display stage, streamflow, and sometimes both.
- Hydrographs visualize water-level observations and forecasts on a single graphic.
- Forecast hydrographs are great for assessing potential mainstem river flooding ahead of impact, but not great for assessing flash flood potential.



Key Points

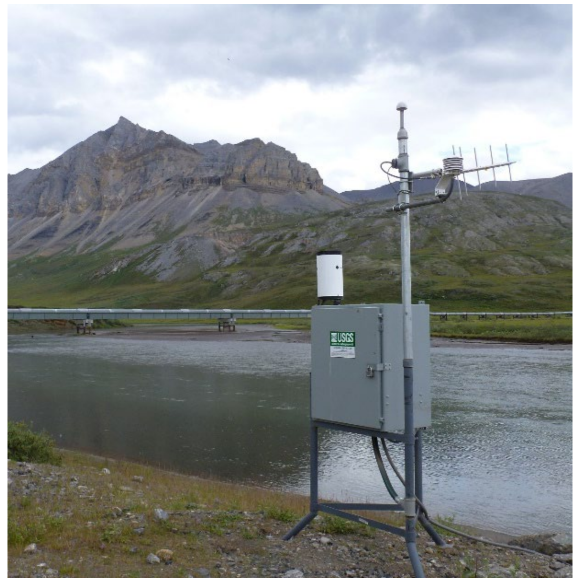
Forecasts on hydrographs are issued once a day during blue skies and every 6 hours during periods of flood risk. Not all gauges are “forecast points.” In fact, the vast majority of gauges are only “observation points” (they only show current and past water levels).

Visual 69: River Gauges

Monitor the volume of water flowing through streams.

Typical measurements include stage and discharge (flow):

- Stage: The water level above a reference elevation, called a datum.
  - **Not the same as depth!**
- Discharge (flow): The rate of water moving past a location.



Key Points

Note that these gauges provide not just the height but a calculated discharge volume that can be used in various modeling.

Visual 70: AHPS Demonstration

Instructor-Led Demonstration of AHPS (Advanced Hydrologic Prediction Service) **Website**

Time: 5 minutes

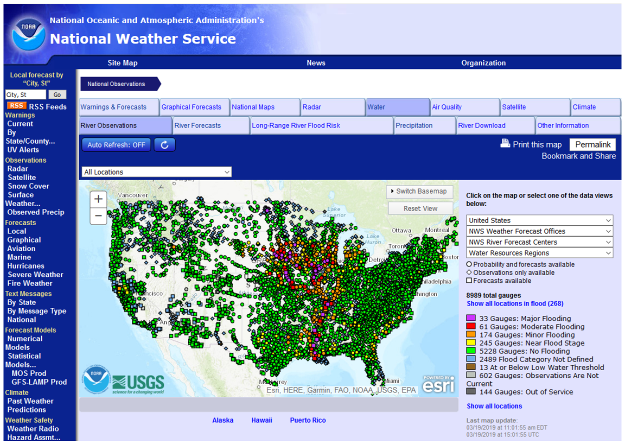
Goal: Explore the AHPS website (https://water.weather.gov/ahps).

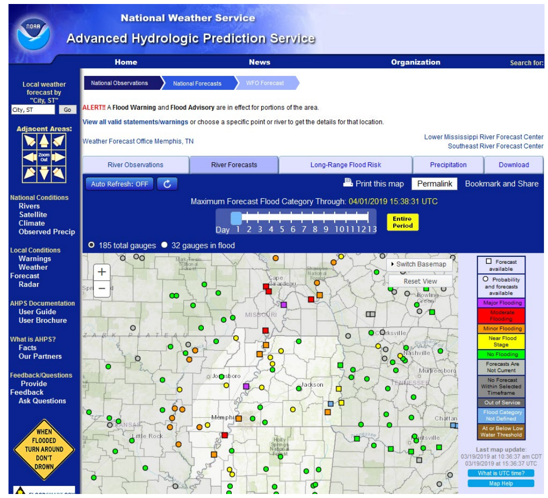
1. Layout of the interface
2. Locations of key information
3. How to view:
   - Hydrographs, Impact tables, Crest records, Hydro watches/warnings in effect, Links to FIM and probabilistic models, Other Data about the gauge

Key Points

This is a quick demonstration of how to access the Advanced Hydrologic Prediction Service (AHPS) website, how to navigate the AHPS interface, and how to access key information such as hydrographs, impact tables, crest records, hydro watches/warnings in effect, and other data about certain gauges.

Visual 71: Monitoring Rivers Demo 1

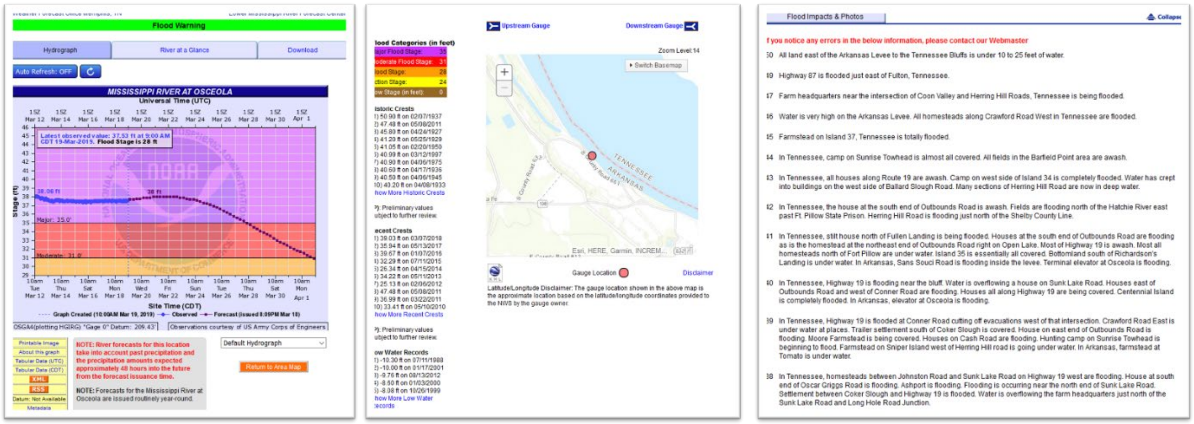




Key Points

The one-stop web page for river information is the National Weather Service Advanced Hydrologic Prediction Service (NWS AHPS) web page. Simply go to the [AHPS website](https://water.weather.gov/ahps/) (https://water.weather.gov/ahps/) and click on the Rivers tab.

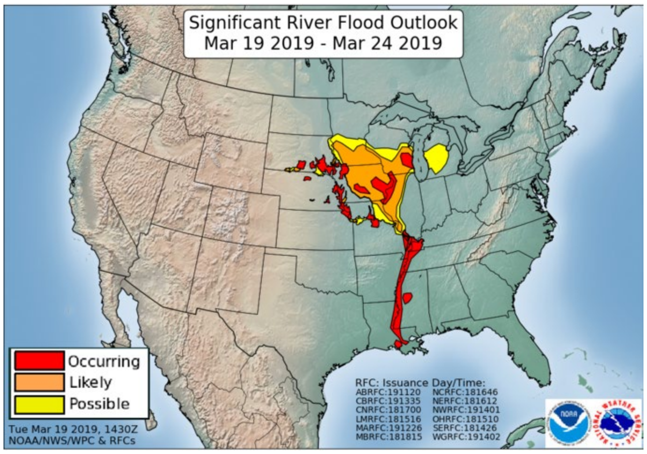
Visual 72: Monitoring Rivers Demo 2

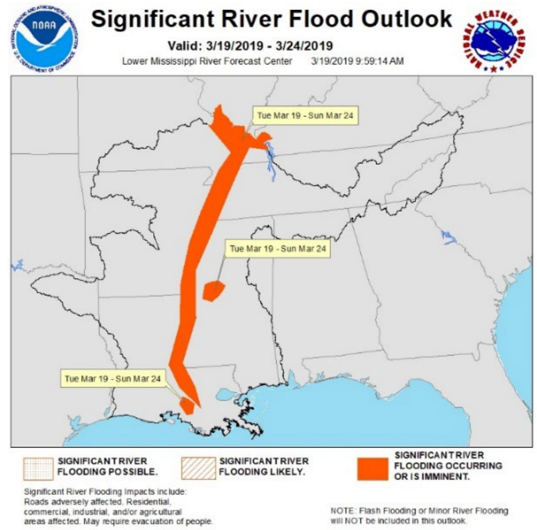


Key Points

The one-stop web page for river information is the National Weather Service Advanced Hydrologic Prediction Service (NWS AHPS) web page. Simply go to the AHPS website (https://water.weather.gov/ahps/) and click on the Rivers tab.

Visual 73: Significant River Flood Outlooks





Key Points

Another resource to gain even greater readiness or situational awareness is the **Significant River Flood Outlook,** which is available and updated daily on every NWS River Forecast Center web page. This outlook highlights the potential for significant river flooding over the next 5 days in addition to showing what rivers are currently observing significant flooding. Dates are added to show the period that is being affected.

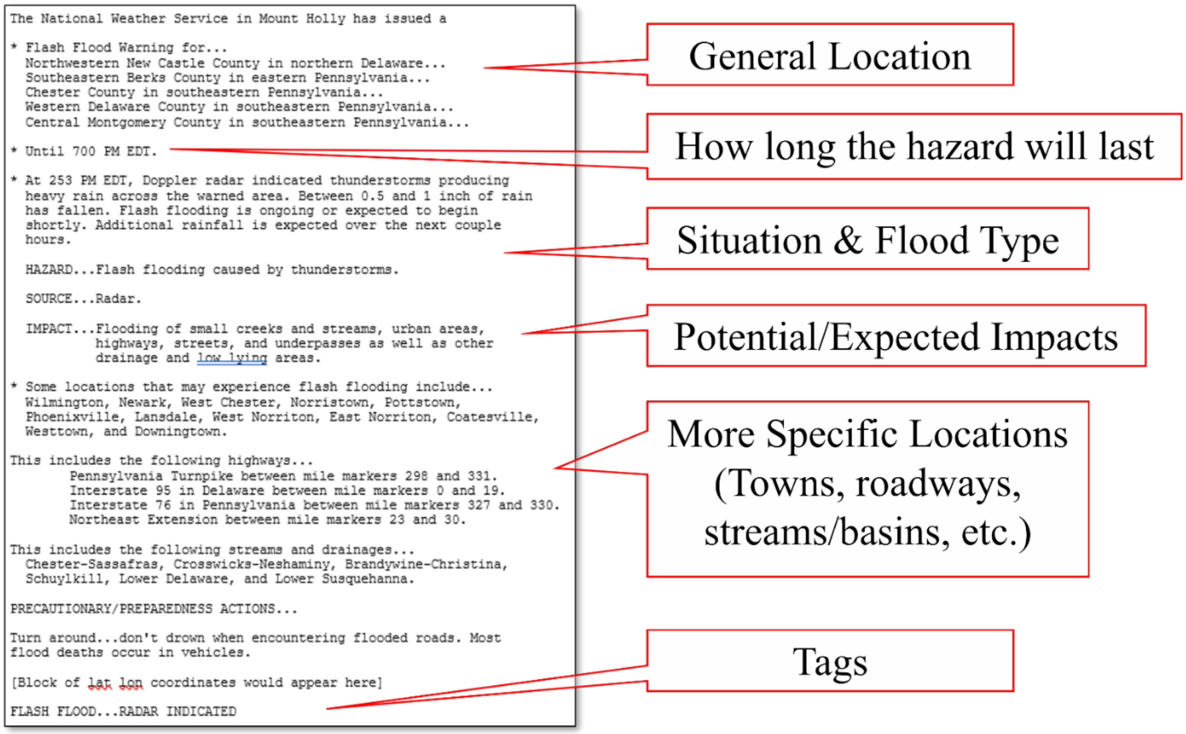
Visual 74: Flood-Related Watches & Warnings

- **Flood Watch**
  - Conditions are favorable for flash flooding or mainstem river flooding. It does not mean flooding will occur, but it is possible.
- **Flood Warning**
  - Mainstem river flooding is imminent or occurring.
- **Flash Flood Warning**
  - Flash flooding is imminent or occurring. Some roads will be flooded. Homes and businesses may flood.
- **Flash Flood Emergency**
  - A special type of Flash Flood Warning issued for exceedingly rare situations when a severe threat to human life and catastrophic damage from a flash flood is imminent or occurring. At-risk individuals should evacuate to higher ground immediately. Travel is discouraged unless the individual is under an evacuation order.

Key Points

When rivers are flooding or expected to flood, NWS relays this information to the EM community and general public through a variety of flood-related Watches and Warnings. NWS will issue one type of Watch for both potential flash flooding and potential mainstem river flooding. However, NWS will differentiate between the two types of flooding during the Warning phase.

Visual 75: Flash Flood Warnings


The National Weather Service in Mount Holly has issued a

* Flash Flood Warning for...
Northwestern New Castle County in northern Delaware...
Southeastern Berks County in eastern Pennsylvania...
Chester County in southeastern Pennsylvania...
Western Delaware County in southeastern Pennsylvania...
Central Montgomery County in southeastern Pennsylvania...

* Until 700 PM EDT.

* At 253 PM EDT, Doppler radar indicated thunderstorms producing heavy rain across the warned area. Between 0.5 and 1 inch of rain has fallen. Flash flooding is ongoing or expected to begin shortly. Additional rainfall is expected over the next couple hours.

HAZARD...Flash flooding caused by thunderstorms.

SOURCE...Radar.

IMPACT...Flooding of small creeks and streams, urban areas, highways, streets, and underpasses as well as other drainage and low lying areas.

* Some locations that may experience flash flooding include... Wilmington, Newark, West Chester, Norristown, Pottstown, Phoenixville, Lansdale, West Norriton, East Norriton, Coatesville, Westtown, and Downingtown.

This includes the following highways...
Pennsylvania Turnpike between mile markers 298 and 331.
Interstate 95 in Delaware between mile markers 0 and 19.
Interstate 76 in Pennsylvania between mile markers 327 and 330.
Northeast Extension between mile markers 23 and 30.

This includes the following streams and drainages...
Chester-Sassafras, Crosswicks-Neshaminy, Brandywine-Christina, Schuylkill, Lower Delaware, and Lower Susquehanna.

PRECAUTIONARY/PREPAREDNESS ACTIONS...

Turn around...don't drown when encountering flooded roads. Most flood deaths occur in vehicles.

[Block of lat lon coordinates would appear here]

FLASH FLOOD...RADAR INDICATED

Key Points

Flash Flood Warnings are issued generally within a few minutes to hours of the expected event, not days in advance. These are based on observed conditions in an area and predictions based on expected duration or movement in the near future for the target area. Note that these products have location, duration, and potential impacts.

Visual 76: Flash Flood Emergencies

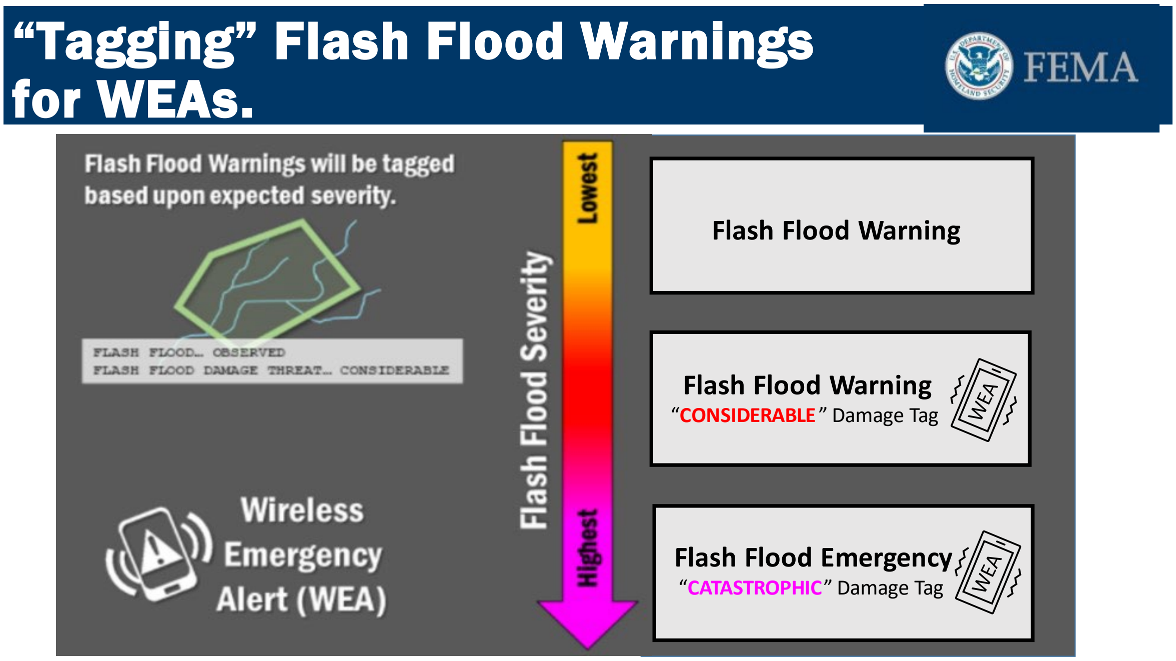
```
...FLASH FLOOD EMERGENCY FOR MONTGOMERY COUNTY...

...FLASH FLOOD WARNING REMAINS IN EFFECT UNTIL 845 PM EDT THIS
EVENING FOR NORTHEASTERN CHESTER, NORTHWESTERN DELAWARE, AND
MONTGOMERY COUNTIES...

At 621 PM EDT, Thunderstorms are producing heavy rain in Northern
Chester County and Southern Montgomery County. Between 3 and 4.5
inches of rain have fallen. Additional rainfall amounts of 1.5 to 3
inches are possible in the warned area. Flash flooding is already
occurring. Over 30 water rescues are ongoing in portions of
Montgomery County.

This is a FLASH FLOOD EMERGENCY for Montgomery County. This is a
PARTICULARLY DANGEROUS SITUATION. SEEK HIGHER GROUND NOW!

HAZARD...Life threatening flash flooding caused by thunderstorms.

SOURCE...Emergency management reported.

IMPACT...This is a PARTICULARLY DANGEROUS SITUATION. SEEK HIGHER
         GROUND NOW! Life threatening flash flooding of low water
         crossings, small creeks and streams, urban areas,
         highways, streets, and underpasses.

Some locations that may experience flash flooding include...
  West Chester, Norristown, Pottstown, Phoenixville, Lansdale, West
  Norriton, East Norriton, Westtown, Downingtown, Souderton, Ambler,
  and Collegeville.

This includes the following highways...
        Pennsylvania Turnpike between mile markers 307 and 333.
        Interstate 76 in Pennsylvania between mile markers 327 and 330.
        Interstate 476 in Pennsylvania between mile markers 17 and 19.
        Northeast Extension between mile markers 21 and 38.

PRECAUTIONARY/PREPAREDNESS ACTIONS...

Move to higher ground now! This is an extremely dangerous and
life-threatening situation. Do not attempt to travel unless you are
fleeing an area subject to flooding or under an evacuation order.

Turn around...don't drown when encountering flooded roads. Most
flood deaths occur in vehicles.

Motorists should not attempt to drive around barricades or drive
cars through flooded areas.

[Block of lat lon coordinates would appear here]

FLASH FLOOD...OBSERVED
FLASH FLOOD DAMAGE THREAT...CATASTROPHIC
```

Red lettering and underlining added for emphasis.

Key Points

Note the change in tone and language in these products as compared to the "Warnings." Also note that "Emergencies" can be issued as updates to Flash Flood Warnings. Flash Flood Emergencies are reserved for particularly severe flash flooding threats.

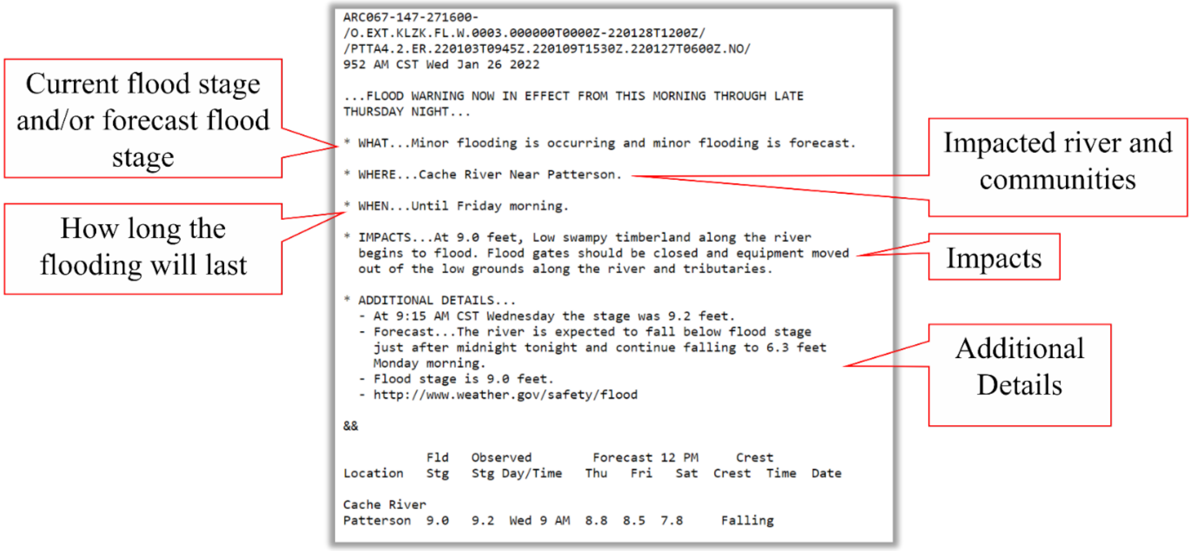
Visual 77: “Tagging” Flash Flood Warnings for WEAs



Key Points

Wireless Emergency Alerts (WEAs) are issued in areas where a Flash Flood Warning is believed to have a “considerable” or “catastrophic” impacts.

Visual 78: Flood Warnings for Mainstem Rivers




```
ARC067-147-271600-
/O.EXT.KLZK.FL.W.0003.000000T0000Z-220128T1200Z/
/PTTA4.2.ER.220103T0945Z.220109T1530Z.220127T0600Z.NO/
952 AM CST Wed Jan 26 2022

...FLOOD WARNING NOW IN EFFECT FROM THIS MORNING THROUGH LATE
THURSDAY NIGHT...

* WHAT...Minor flooding is occurring and minor flooding is forecast.

* WHERE...Cache River Near Patterson.

* WHEN...Until Friday morning.

* IMPACTS...At 9.0 feet, Low swampy timberland along the river
  begins to flood. Flood gates should be closed and equipment moved
  out of the low grounds along the river and tributaries.

* ADDITIONAL DETAILS...
  - At 9:15 AM CST Wednesday the stage was 9.2 feet.
  - Forecast...The river is expected to fall below flood stage
    just after midnight tonight and continue falling to 6.3 feet
    Monday morning.
  - Flood stage is 9.0 feet.
  - http://www.weather.gov/safety/flood

&&

           Fld   Observed        Forecast 12 PM     Crest
Location   Stg   Stg Day/Time   Thu   Fri   Sat  Crest  Time  Date

Cache River
Patterson  9.0   9.2  Wed 9 AM  8.8   8.5   7.8     Falling
```

Key Points

Flood Warnings for mainstem river flooding are different from Flash Flood Warnings. These products generally have longer durations and are based on river stage levels.

Visual 79: Local NWS Weather Forecast Office

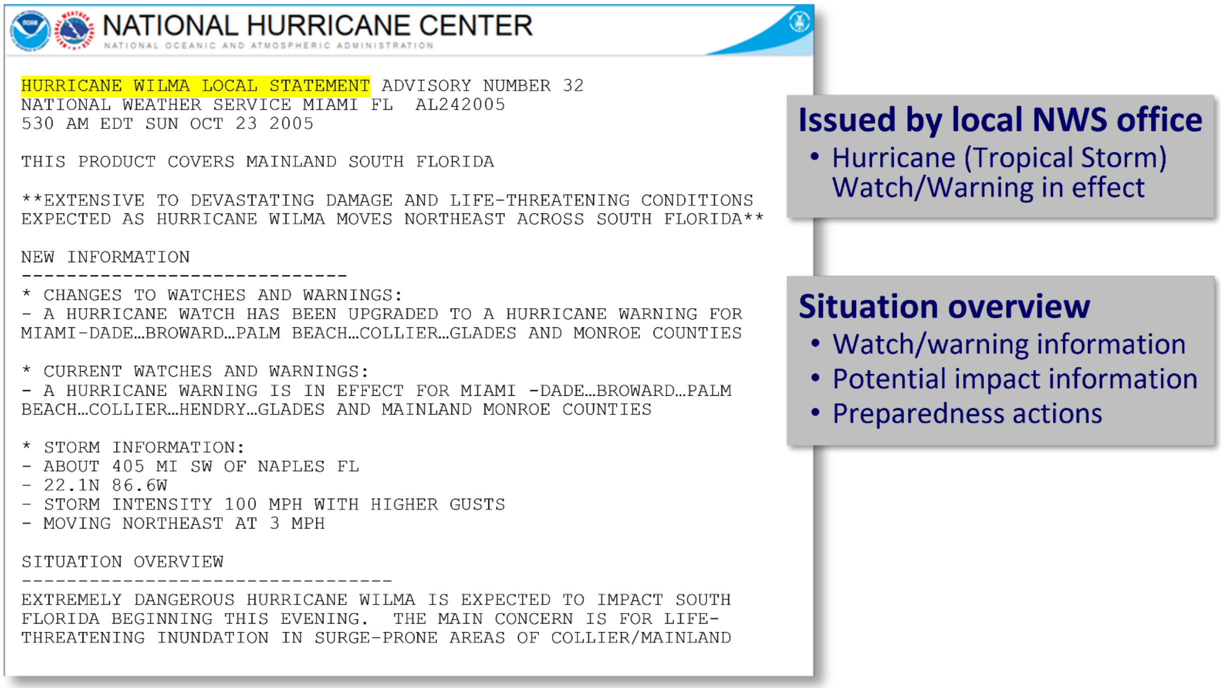
Local NWS Weather Forecast Office addresses:

- Where can I find more detailed localized forecast information?

Key Points

Local NWS Weather Forecast Offices (WFOs) provide information to answer questions about a local jurisdiction.

Visual 80: Hurricane Local Statements



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

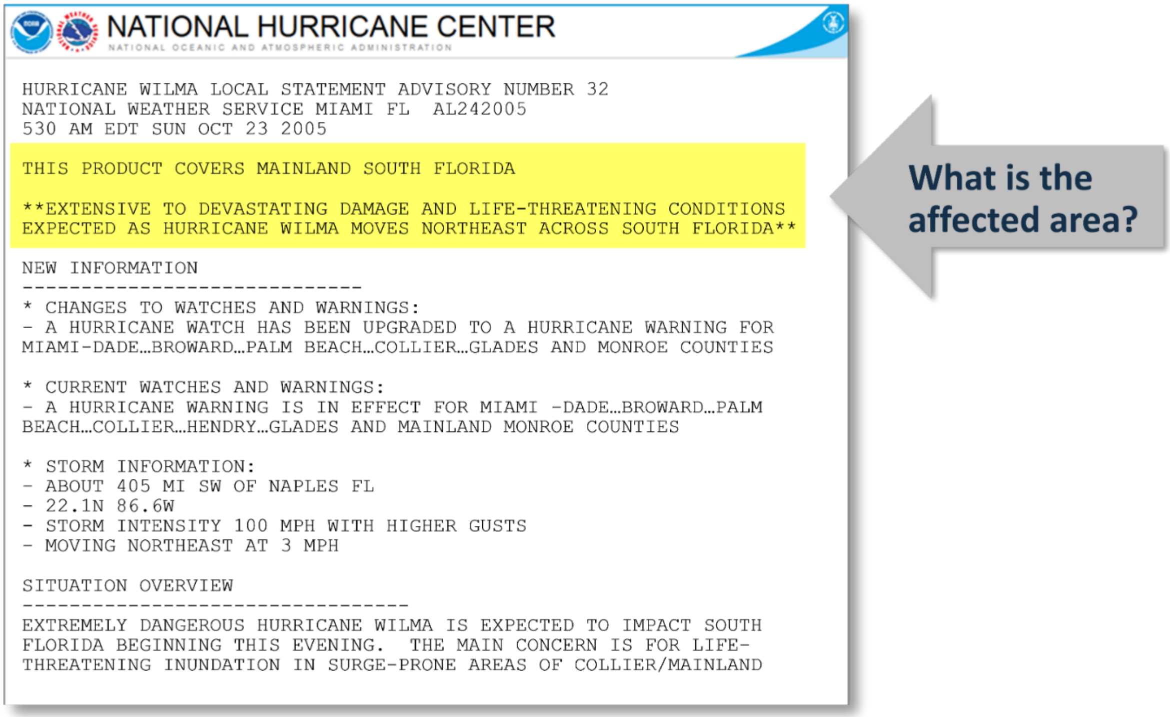
SITUATION OVERVIEW

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

Hurricane Local Statements are text products that provide information on potential hurricane impacts at the local level. WFOs 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 81: Hurricane Local Statements: Where is affected?



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

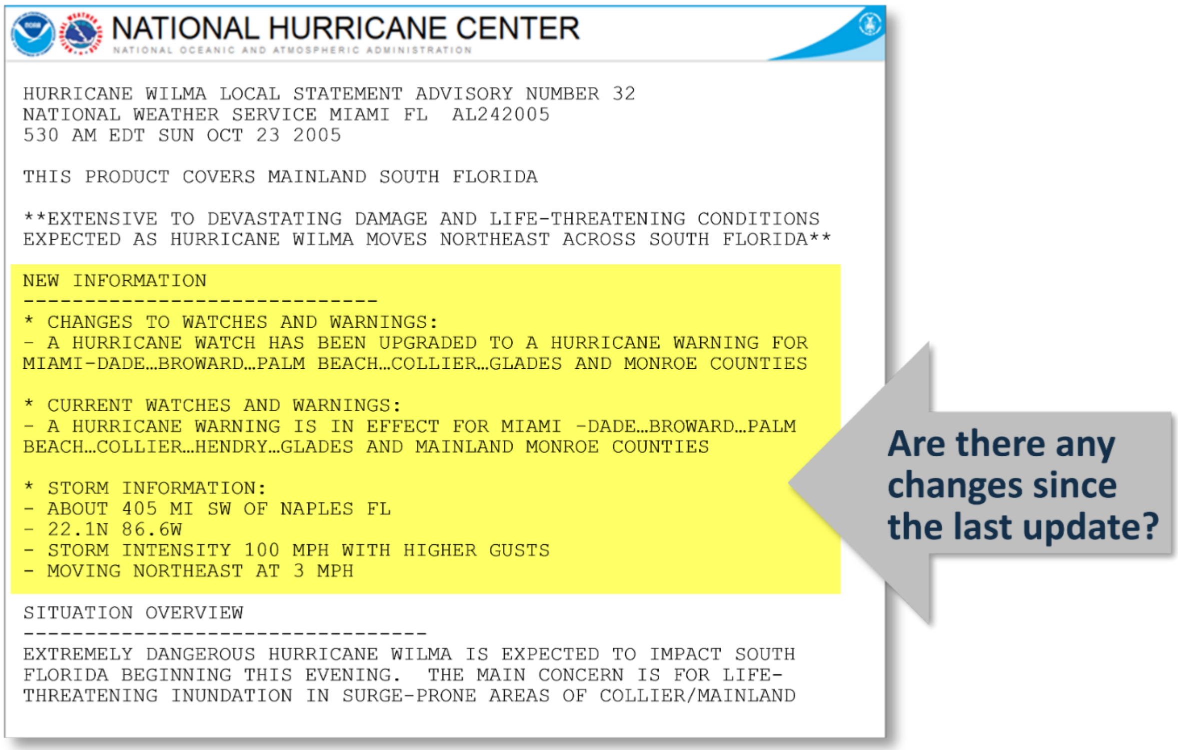
EXTREMELY DANGEROUS HURRICANE WILMA IS EXPECTED TO IMPACT SOUTH FLORIDA BEGINNING THIS EVENING. THE MAIN CONCERN IS FOR LIFE-THREATENING INUNDATION IN SURGE-PRONE AREAS OF COLLIER/MAINLAND

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 82: Hurricane Local Statements: Any changes?



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 83: NWS Email Briefings & Webinars

Most NWS Weather Forecast Offices (WFOs) and River Forecast Centers (RFCs) issue routine briefings for hazardous weather.

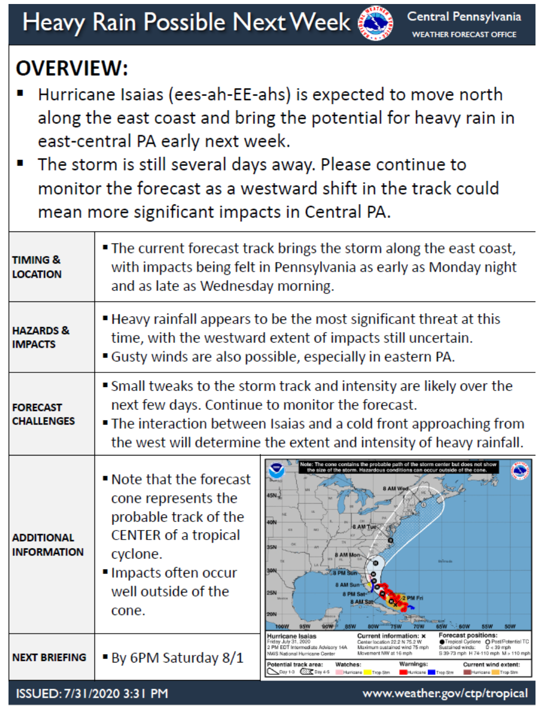
These briefings provide information on:

- Timing and Location of Hazards
- Range of Outcomes
- Expected Impacts
- Relevant Forecast Graphics
- Watches/Warnings/Advisories
- Forecast Challenges / Uncertainty / Confidence Levels
- Additional Information

Offices send briefing information to core partners.

- EMs, other public safety officials, school officials, etc.

Contact your WFO and RFC to ask about being added to their email/webinar briefing list!



Key Points

In addition to Hurricane Local Statements and Watches/Warnings, WFOs provide routine briefings on tropical cyclones that complement the NHC advisories and products. These products tend to have more graphics and/or present the potential threats in a more organized way.

Visual 84: Post-Storm Reports

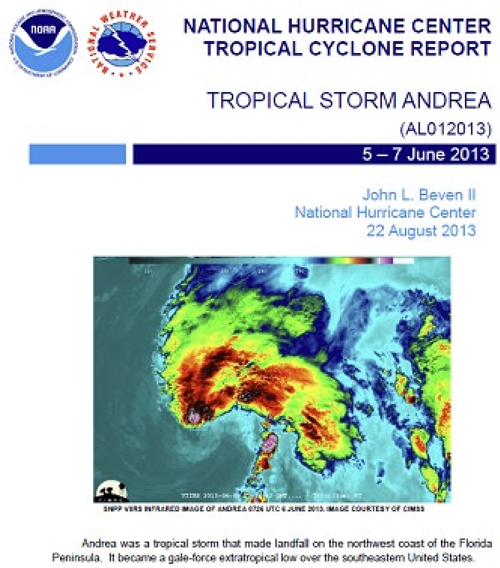
Post-storm reports address:

- What information is available after the storm?
- Where can I find summary information?

Key Points

After a storm, there are several sources of information that summarize impacts.

Visual 85: Tropical Cyclone Reports



NATIONAL HURRICANE CENTER
TROPICAL CYCLONE REPORT

TROPICAL STORM ANDREA
(AL012013)
5 – 7 June 2013

John L. Beven II
National Hurricane Center
22 August 2013

SNPP VIIRS INFRARED IMAGE OF ANDREA 0726 UTC 6 JUNE 2013. IMAGE COURTESY OF CIMSS

Andrea was a tropical storm that made landfall on the northwest coast of the Florida Peninsula. It became a gale-force extratropical low over the southeastern United States.

Summary Report

Available on the NHC website weeks to months after storm.

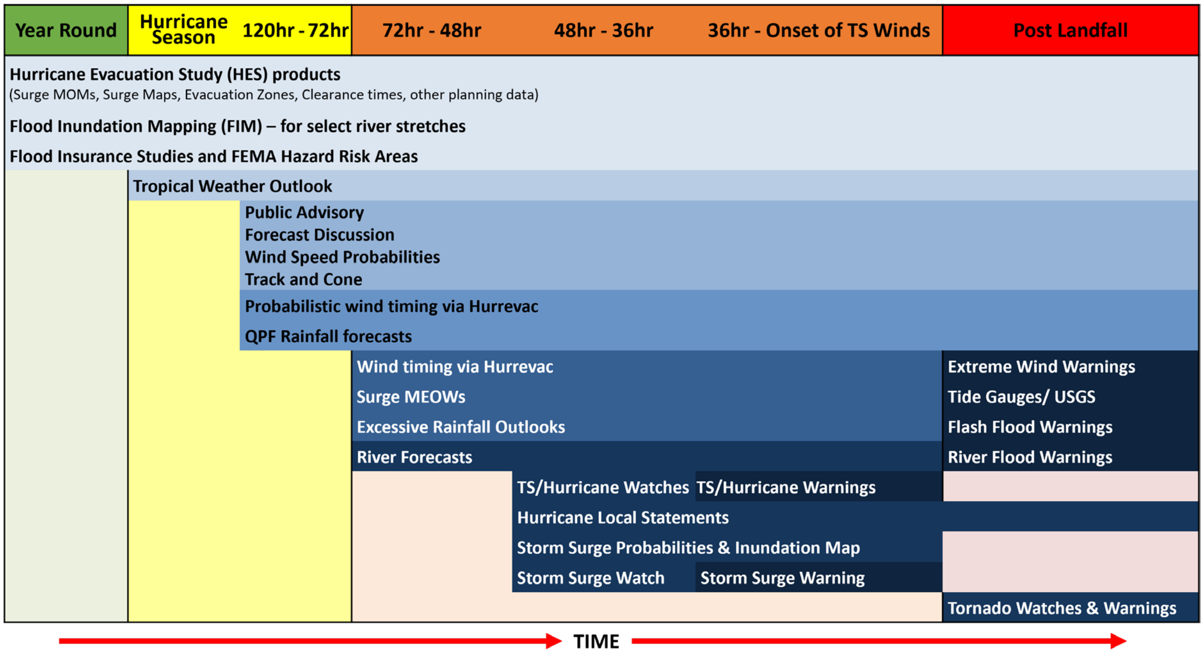
Provides a complete summary report for every Atlantic and East Pacific storm.

- Final track, intensity, and size information
- Damage and casualty figures
- Forecast critique

Key Point

The NHC’s Tropical Cyclone Reports (TCRs) contain comprehensive information on each storm, including synoptic history, meteorological statistics, casualties, and damages, and the post-analysis best track (6-hour positions and intensities). These reports are written after a tropical cyclone event has ended and all pertinent data have been gathered and analyzed. Once completed, the TCRs are posted to the archive section of the NHC website.

Visual 86: NWS Products –When is Key Info Available

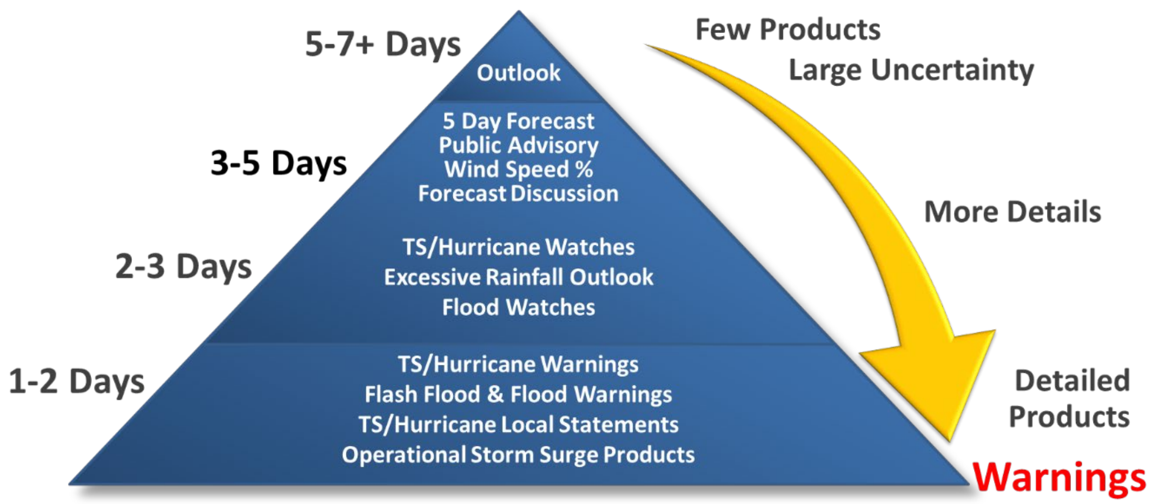


Key Points

This visualization helps to communicate when certain forecast products are available, providing a quick reference for decision-makers.

Blue-sky/steady-state products are available year-round, for example. During hurricane season, and especially when there is an active threat, more products become available as a threat nears.

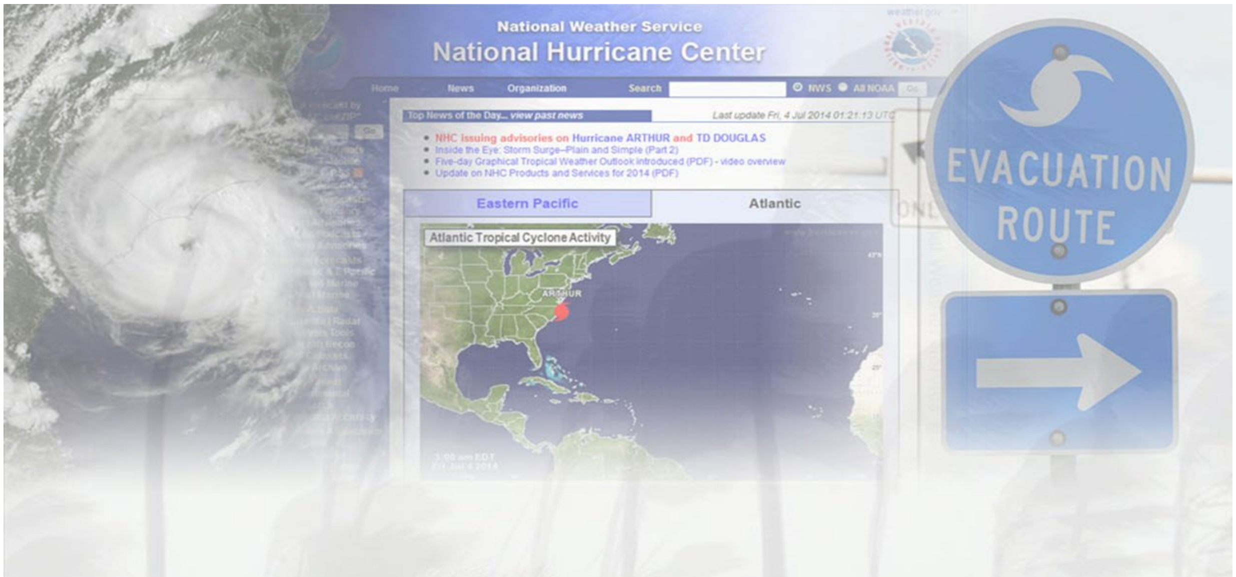
Visual 87: Tropical Cyclone NWS Products Timeframe



Key Points

This is a recap of the general timelines of when various products are available, and the level of detail and uncertainty at each point along the timeline.

Visual 88: 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.

Unit 3: Understanding Forecast Uncertainty

Visual 1: Understanding Forecast Uncertainty

Unit 3:

Understanding Forecast Uncertainty

Key Points

Unit 3 covers forecasting errors and the inherent uncertainty that exists with tropical cyclone 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

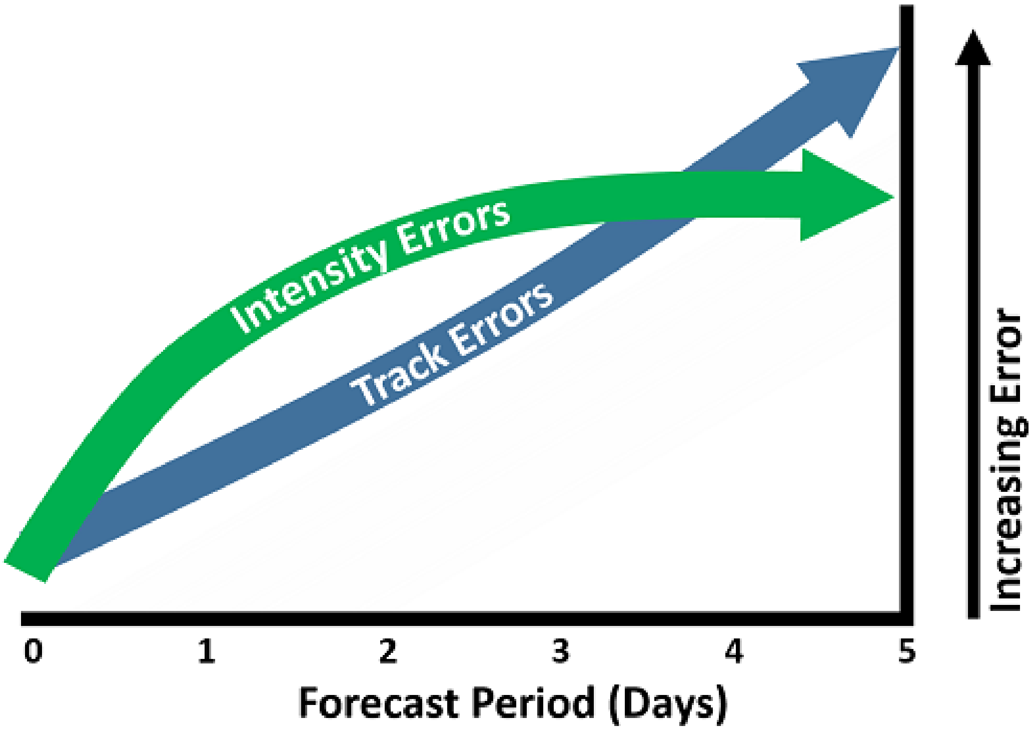
At the end of this unit, you should be able to:

1. Explain the meaning of "uncertainty" as it relates to NHC forecasts.
2. Explain what "59% chance of TS-force winds" (or similar probability) means.
3. Discuss the challenges inherent to rainfall and inland flooding forecasting.

Key Points

Review and take note of Unit 3 objectives.

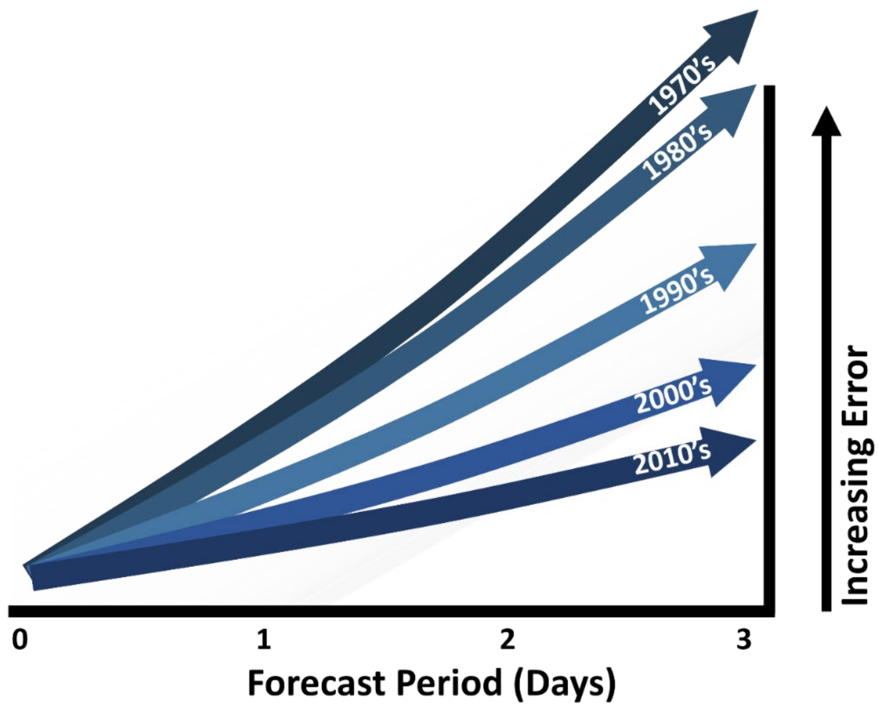
Visual 3: Forecast Errors



Key Points

We cannot predict the future 100% accurately all of the time. As good as the National Weather Service (NWS) is, there is still considerable uncertainty in the lead-up to the event.

Visual 4: Forecasts are Improving, But Not Perfect



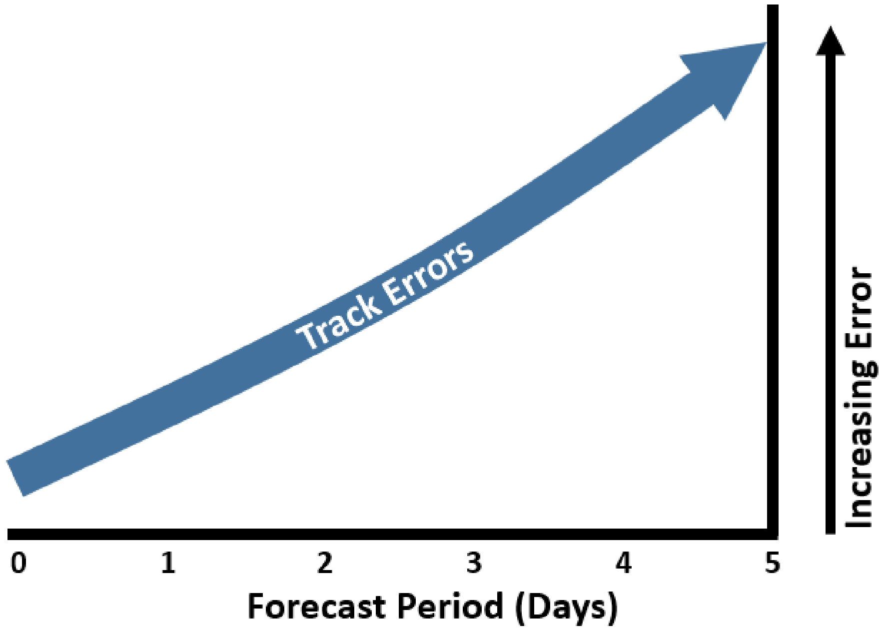
Key Points

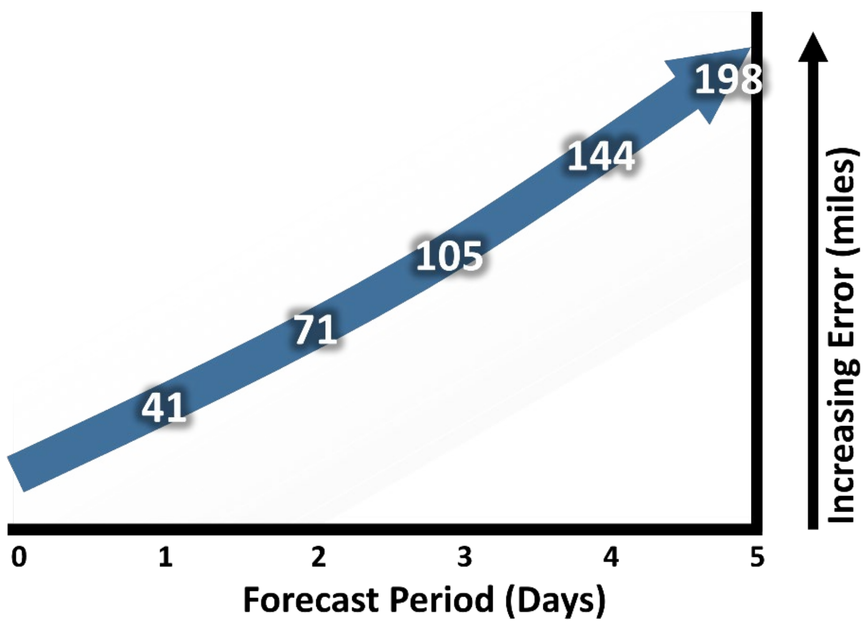
Due to increased knowledge of tropical cyclones, improved technology, and more accurate computer models, significant improvements have been made in tropical cyclone track forecasting over the past several decades. Although we have made big improvements, today's forecasts will always contain some uncertainty.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

Visual 5: NHC 5-Year Averages: Track Errors

Track Errors

- Increase 40 miles (35 nautical miles(**nm**)) per day





Key Points

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

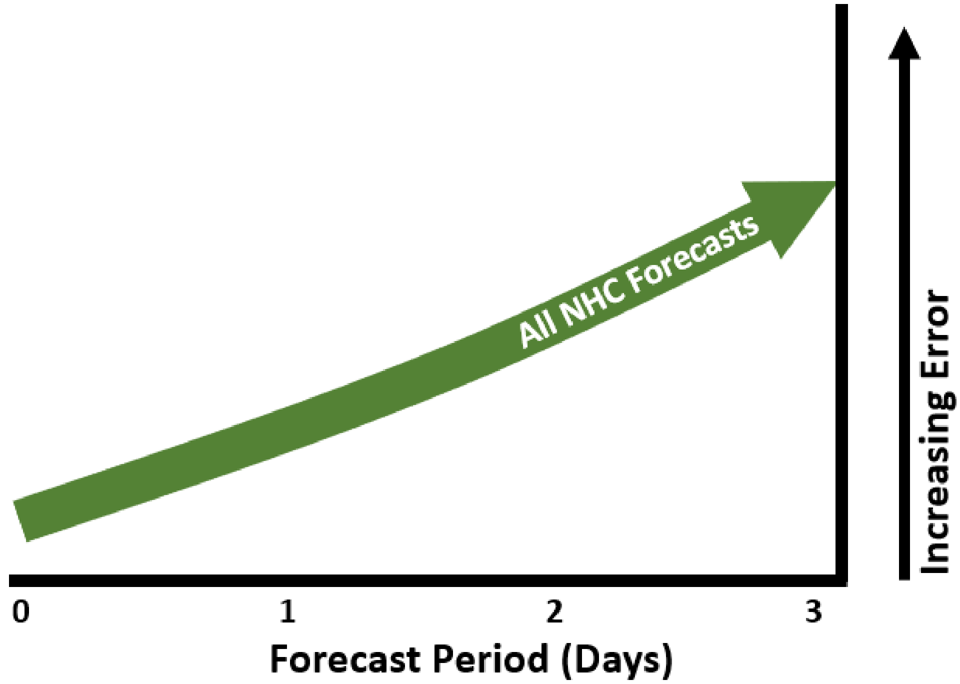
On average, the NHC track forecast errors increase by about 40 miles per day:

- Day 1 average track error: 41 miles per day
- Day 2 average track error: 71 miles per day
- Day 3 average track error: 105 miles per day
- Day 4 average track error: 144 miles per day
- Day 5 average track error: 198 miles per day

Visual 6: Track Errors – All NHC Forecasts

All NHC Forecasts (for all types of tropical cyclones)

- Track errors increase about 35–40 miles per day



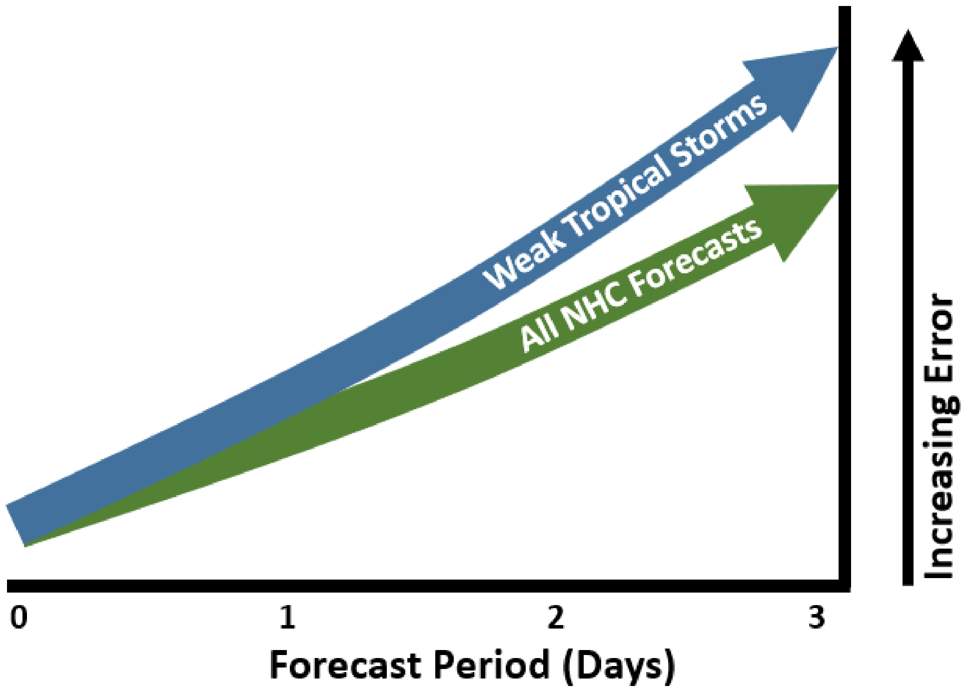
Key Points

On this slide, we're looking at the average of all NHC track errors combined ("weak" systems plus "strong" systems). This provides us a baseline for looking at the trends on the following two slides.

Visual 7: Track Errors – Weak TS

"Weak" Tropical Cyclones (Tropical Depressions and Tropical Storms)

- Track errors increase about 40–45 miles per day.



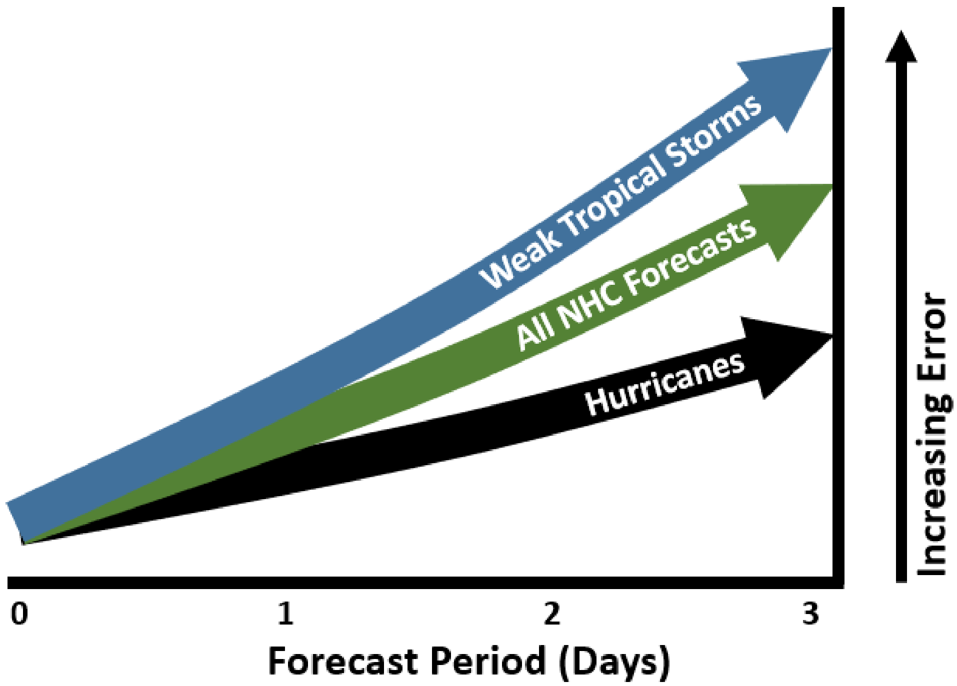
Key Points

NHC track forecasts are typically less accurate for "weaker" tropical cyclones (tropical depressions and tropical storms). Prediction models have a harder time with weaker systems.

Visual 8: Track Errors – Hurricane

"Strong" Tropical Cyclones (Hurricanes)

- Track errors increase about 25–30 miles per day.



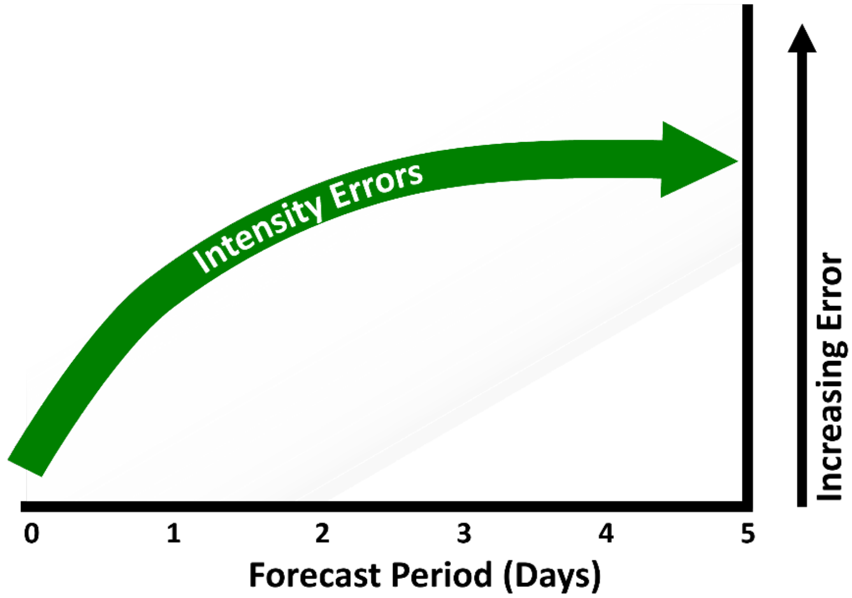
Key Points

NHC track forecasts are typically more accurate for stronger tropical cyclones (hurricanes) .

Visual 9: NHC 5-Year Averages: Intensity Errors

Intensity Errors

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



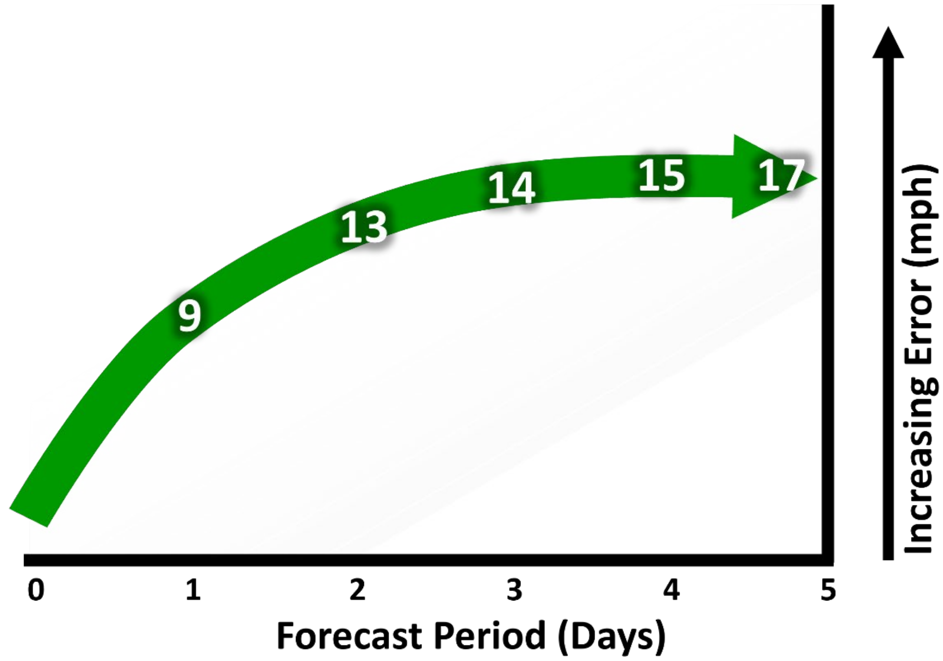
Key Points

Intensity errors increase for the first 2–3 days and then level off at about 15 knots (kt.) or about one Saffir-Simpson Hurricane Wind Scale category. Intensity forecasts level off because intensity forecasting is a more bound problem than track forecasting. For example, the intensity of a tropical cyclone is between about 30 to 150 kt., so one can only be so incorrect.

Visual 10: Intensity Errors Over 5 Days

Intensity Errors

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



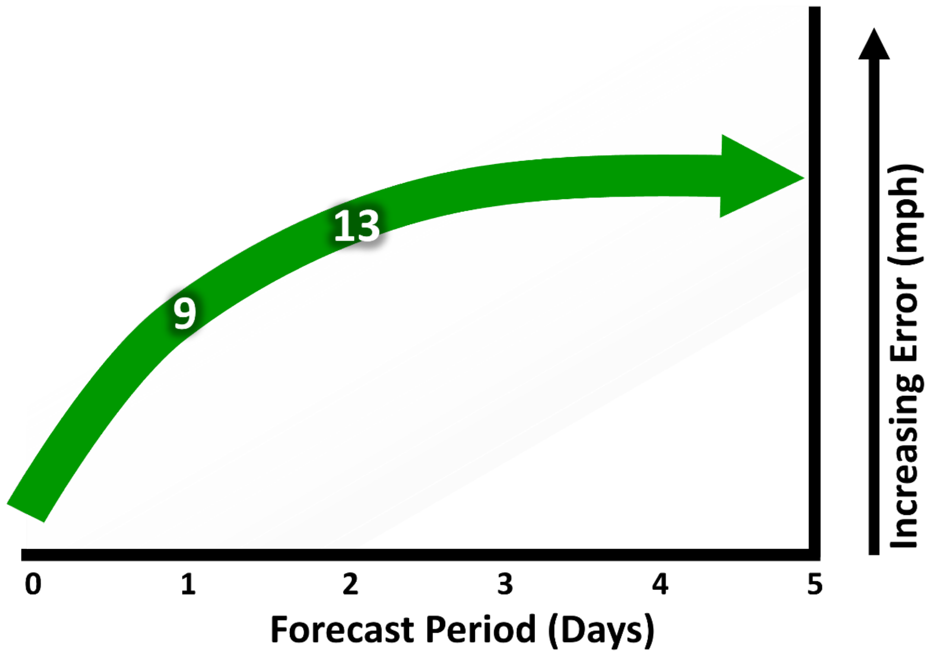
Key Points

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.

Visual 11: Intensity Errors Over 48 Hours

Intensity Errors

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



Key Points

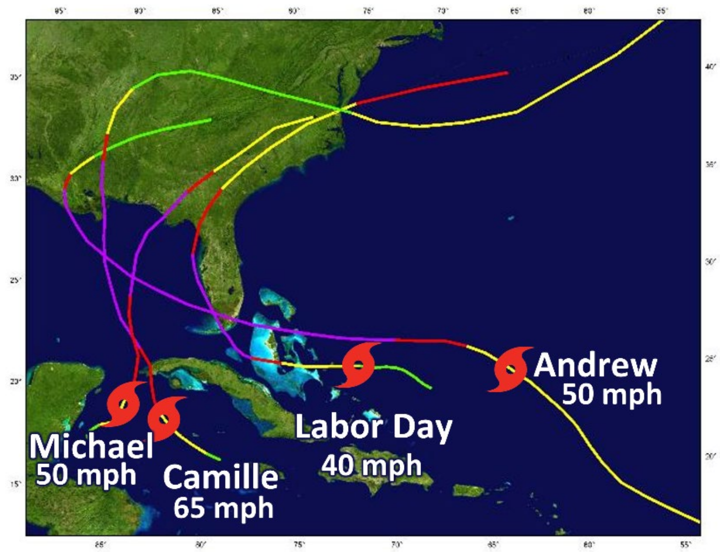
These numbers are on the order of about one Saffir Simpson category. This is good illustration of why it’s good for EMs to prepare for a storm one category higher. This is particularly important for people living in areas where storms can rapidly intensify, such as along the Gulf or the Southeast. Rapid intensification is believed to be less of a problem in the Mid-Atlantic or Northeast, where storms are usually weakening and undergoing or nearing extratropical transition when they move that far north.

Visual 12: Rapid Intensification

- Increase in the maximum sustained winds of at least 30 kts (35 mph) in a 24-hour period.

Where were these Category 5 hurricanes 3 days before landfall?

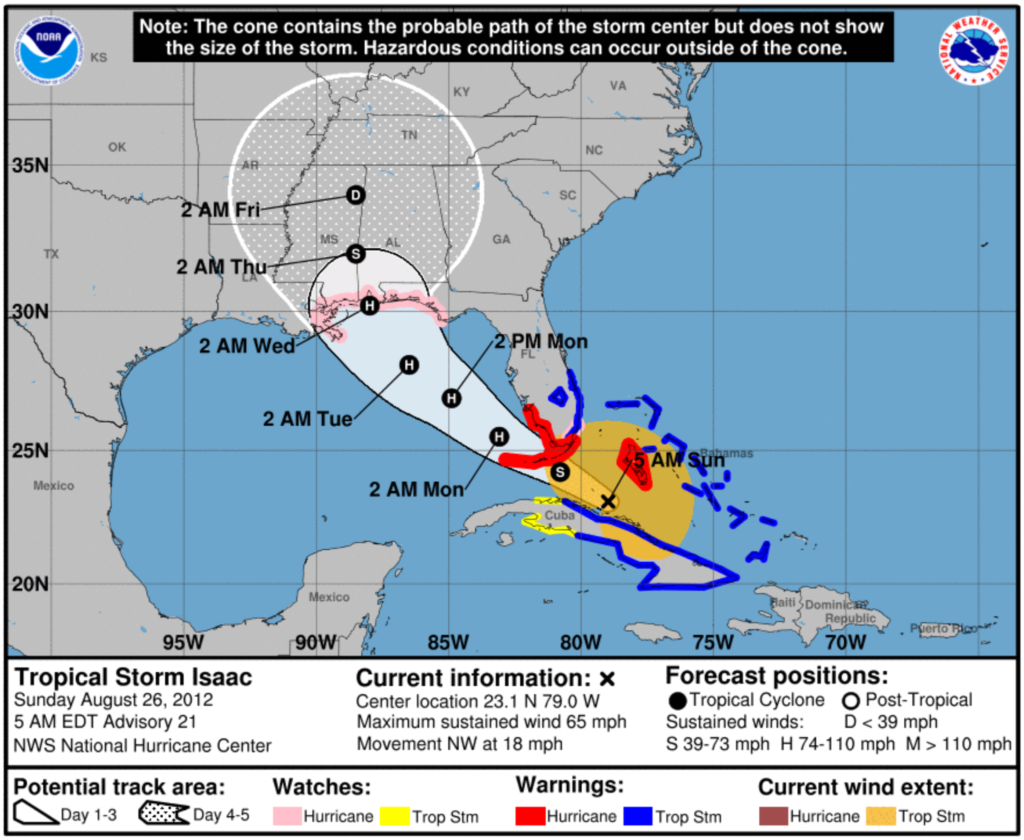
- Labor Day (1935)
- Camille (1969)
- Andrew (1992)
- Michael (2018)
- Ian (2022)
- Lee (2023)



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.

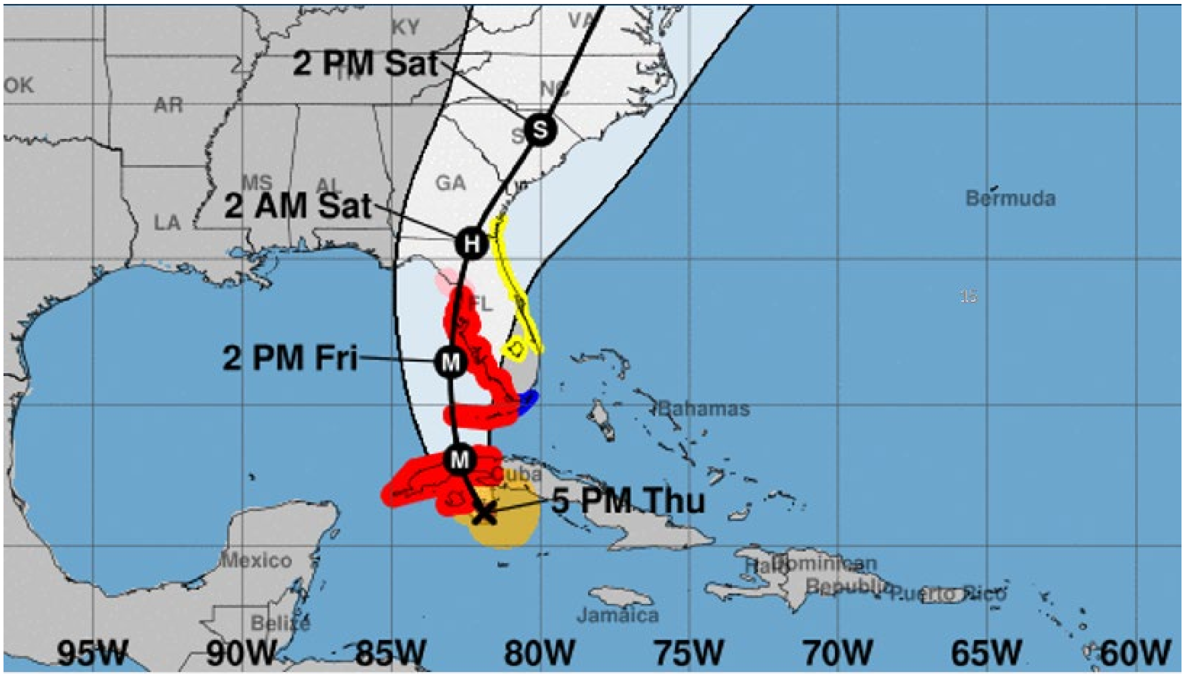
Visual 13: Forecast Error Cone - Probable Track, Watches, Warnings



Key Points

The Forecast Error Cone ("The Cone Graphic") is usually what the general public thinks of when they think of hurricane forecasts. But what information is actually conveyed by this product, and what levels of uncertainty does it account for?

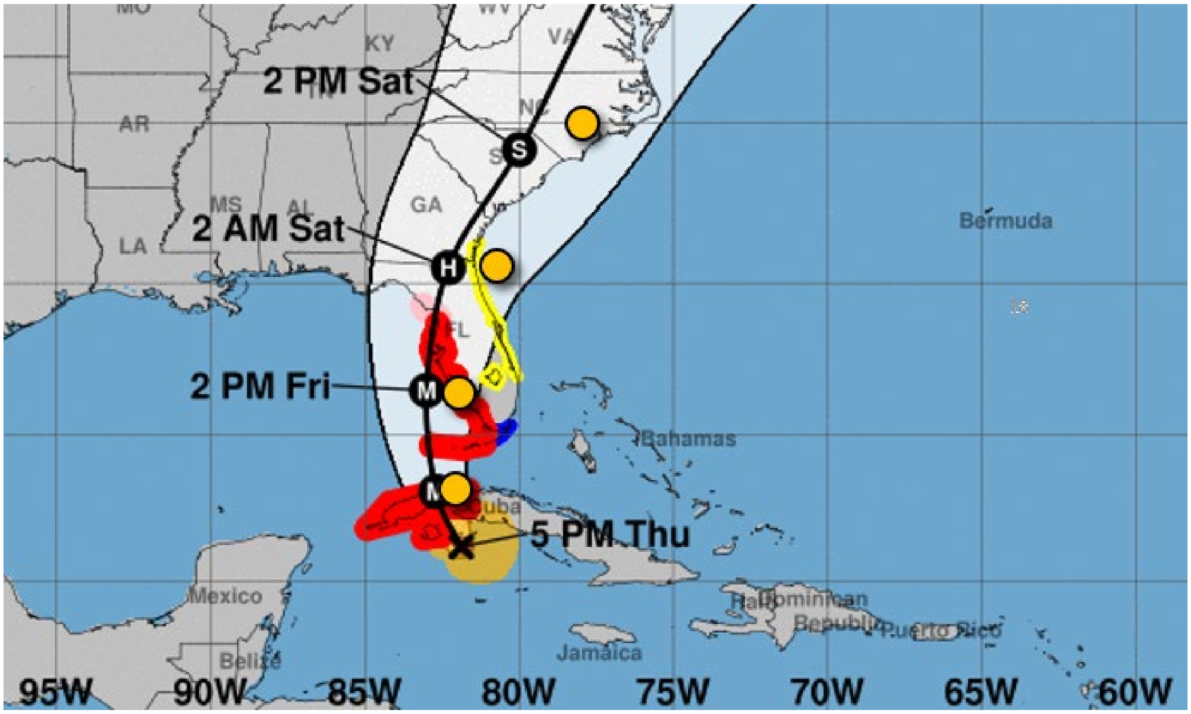
Visual 14: Don’t Focus on the Skinny Black Line



Key Points

This graphic shows the forecast track of Hurricane Charley (2004) about 24 hours before it made landfall in southwest Florida. In this case, the track forecast was relatively good (the errors were less than average). But given the storm’s angle of approach, Charley made landfall farther south along the Gulf Coast of Florida than anticipated. Notice, however, that the area was under a Hurricane Warning, so residents should have been prepared. The Cone is often misinterpreted as a deterministic product when it’s actually a probabilistic graphic.

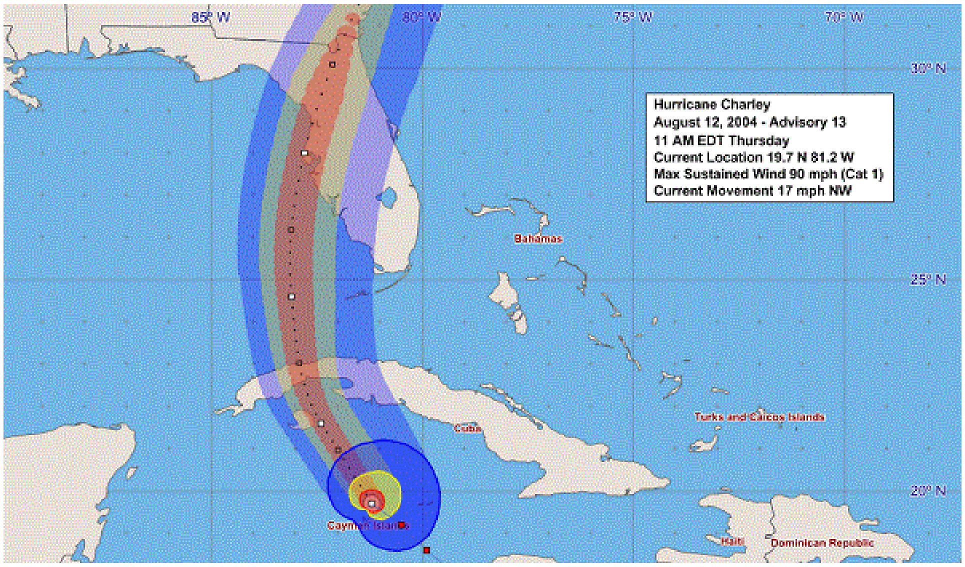
Visual 15: Forecast vs. Observed



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. The yellow dots represent the actual path of the storm. Note their placement to the east of the forecast track (as 24 hours before landfall), but still within the error cone.

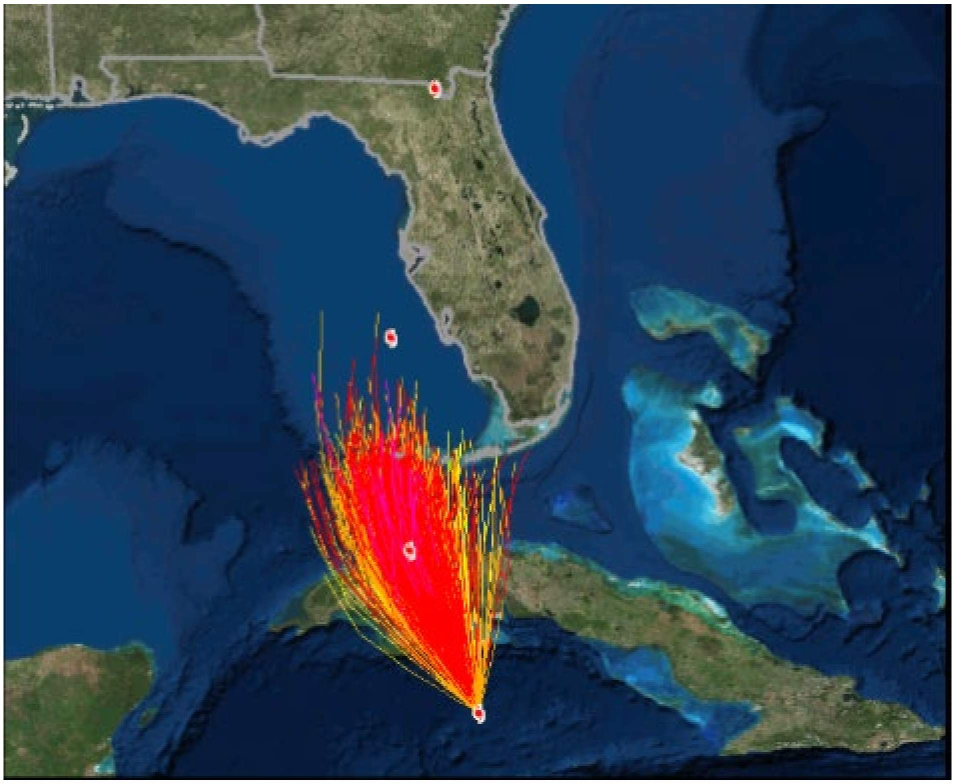
Visual 16: Hurricane Charley



Key Points

Here is the deterministic forecast wind swath for Hurricane Charley about 24 hours before landfall. The red area was where the deterministic forecast placed the hurricane-force winds, while the yellow and blue areas represent the strong tropical storm and tropical storm-force winds, respectively. Since the deterministic forecast follows the official NHC track forecast (the skinny black line), it placed the hurricane-force winds over Tampa versus Fort Myers (where they actually occurred).

Visual 17: Would Alternate Scenarios Help?



Key Points

This visual is an animation that shows 1,000 tracks around the NHC official forecast for Hurricane Charley (demarked the 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 18: What Does 59% Chance Mean?

Key Points

With a 59% chance of rain, you might not bring your umbrella. With a 59% 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 vs. getting hit by a car.

Visual 19: How Are Windspeed Probabilities Generated? (1 of 3)

More scenarios

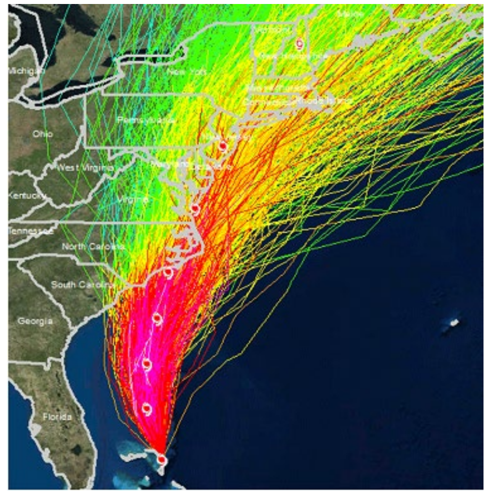
1,000 realistic alternative scenarios are created.

- Official NHC forecast
- Historical NHC 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.

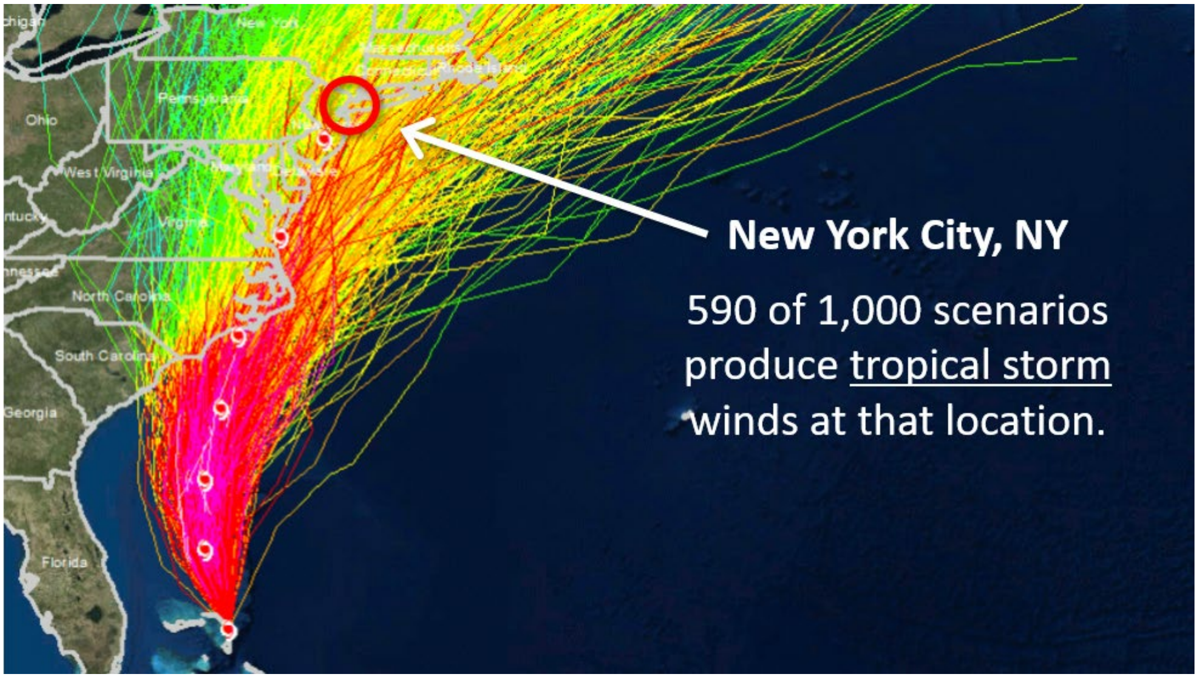
To arrive at the numbers we give as probabilities, we generate 1,000 realistic alternative scenarios based on data from the:

- 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 20: How Are Windspeed Probabilities Generated? (2 of 3)

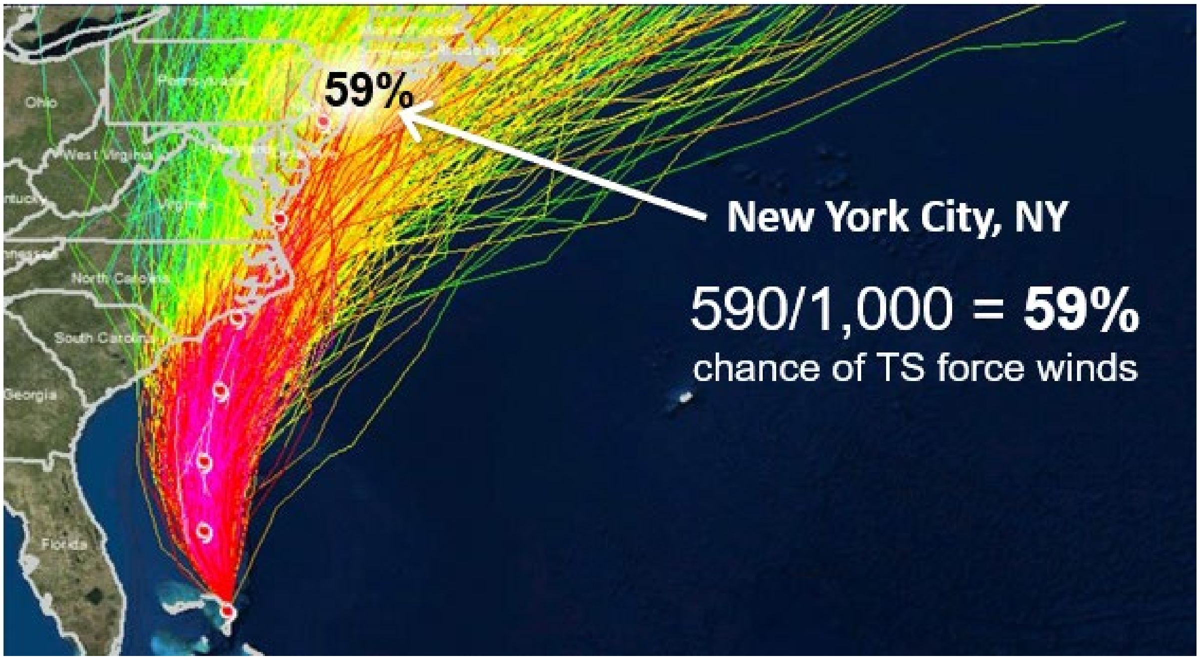


Key Points

As an example, let's consider the probability for the specific location of New York City, New York.

- 590 of 1,000 scenarios created produced tropical storm-force winds for New York City. To obtain a probability, the following formula is used:
- 590/1000 = 59% chance of tropical storm-force winds
- Therefore, the forecast for New York City is that they have a 59% chance of experiencing tropical storm-force winds.

Visual 21: How Are Windspeed Probabilities Generated? (3 of 3)



Key Points

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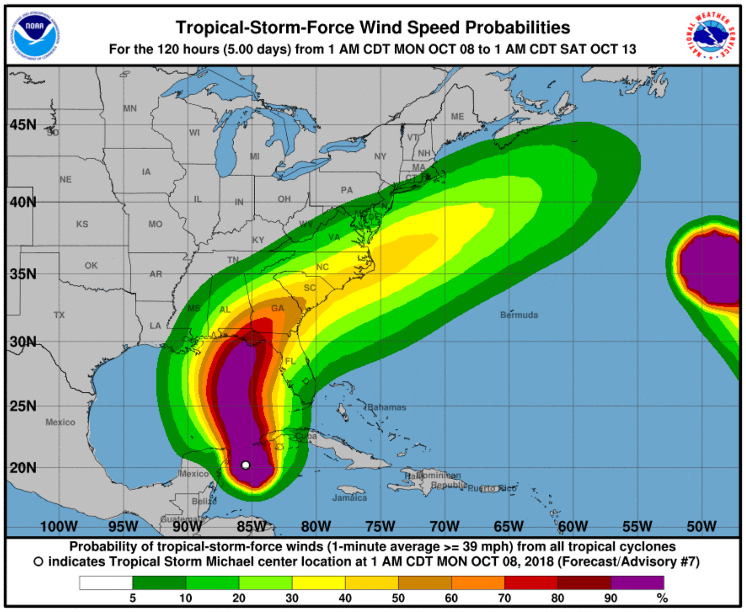
- 590/1000 = 59% chance of tropical storm-force winds
- Therefore, the forecast for New York City is that they have a 59% chance of experiencing tropical storm-force winds.

Visual 22: 5-Day Cumulative Graphic: TS-Force



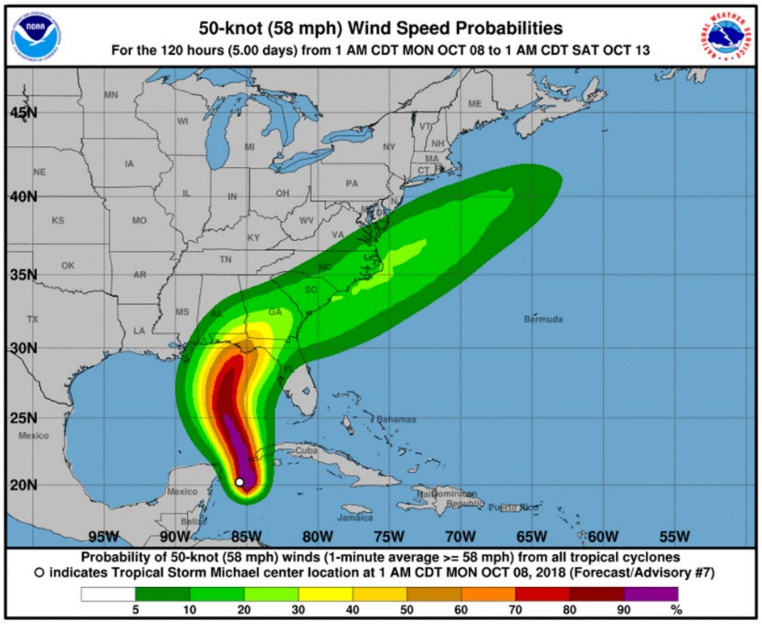
Location-specific Probabilities

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

Key Points

The **Wind Speed Probability Graphic** is a better-organized representation of the "spaghetti" versions seen in previous visuals. The percentage chance of each level of wind intensity is color-coded for and mapped for clear and quick legibility. The probabilities above are for the possibility of tropical storm-force winds.

Visual 23: 5-Day Cumulative Graphic: 58 mph



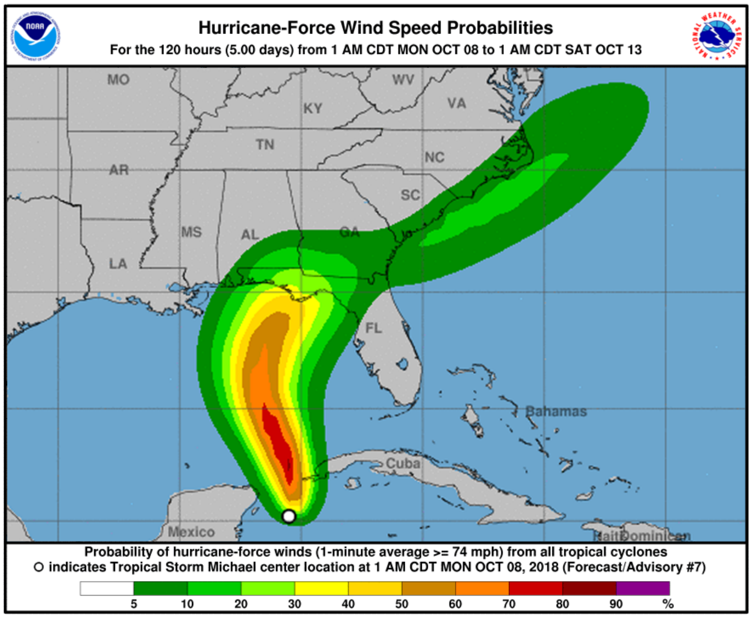
Location-specific Probabilities

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

Key Points

This version of the Windspeed Probability Graphic focuses on the chances of "strong" tropical storm-force winds (58–73 mph).

Visual 24: 5-Day Cumulative Graphic: Hurricane-Force



Location-specific Probabilities

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

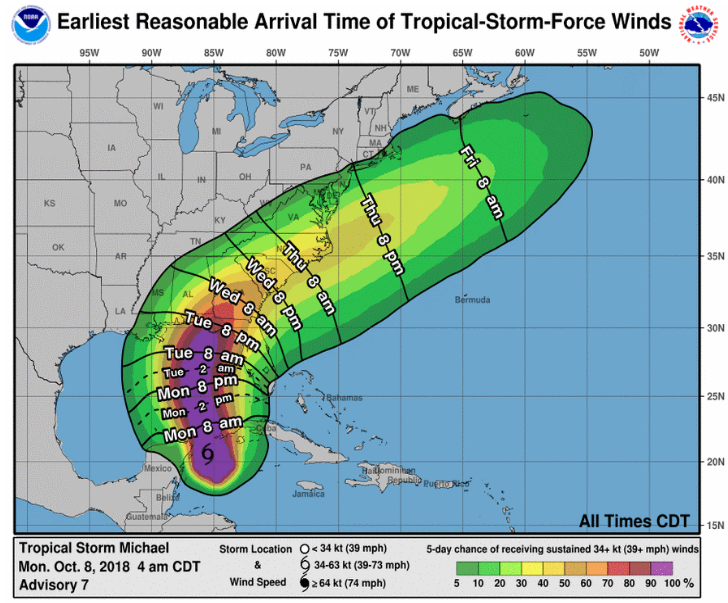
Key Points

This version of the Windspeed Probability Graphic focuses on the chances of hurricane-force winds.

Visual 25: Earliest Reasonable Onset of TS Winds

Earliest Reasonable

- 10% chance of onset (Most conservative timing)
- Black Contours: Arrival time of TS winds
- Color fill: 5-day cumulative TS probabilities



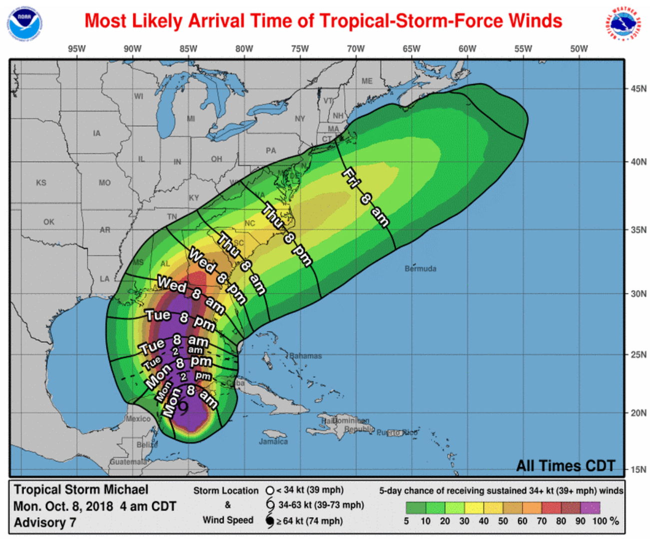
Key Points

Earliest Reasonable onset of tropical storm-strength winds is the point in time for which only 10% of the generated windspeed probability tracks will arrive earlier. If the 1,000 simulations were each a runner in a race, then Earliest Reasonable means 100 runners arrive before this time, 900 runners arrive afterwards.

Visual 26: Most Likely Onset of TS Winds

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

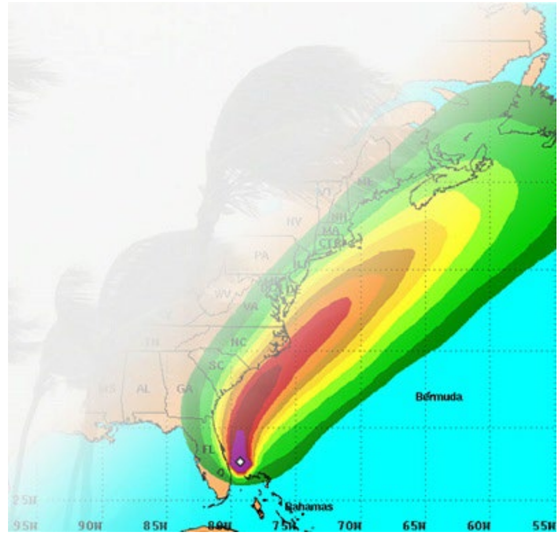


Key Points

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

Visual 27: Wind Speed Probabilities – Summary

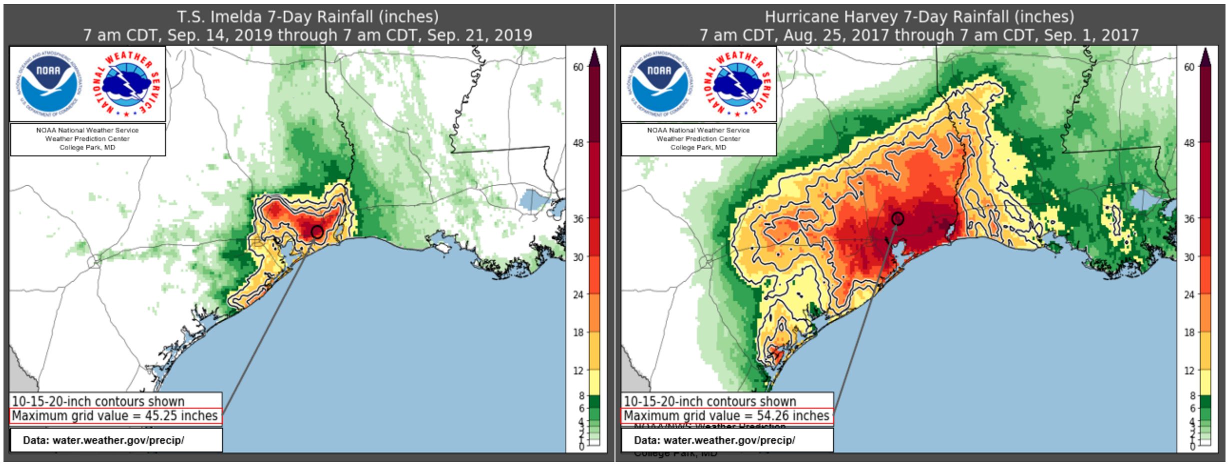
- NHC’s forecasts are improving, but errors remain.
  - Error cone is not the cure for skinny black line.
- Wind speed probabilities
  - Likelihood of tropical storm and hurricane winds
  - Onset timing of wind hazards
- Incorporates track, intensity, and size uncertainty
  - Includes weakening due to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



Key Points

This visual shows a summary of the windspeed probability section.

Visual 28: Rainfall Predictability Challenges

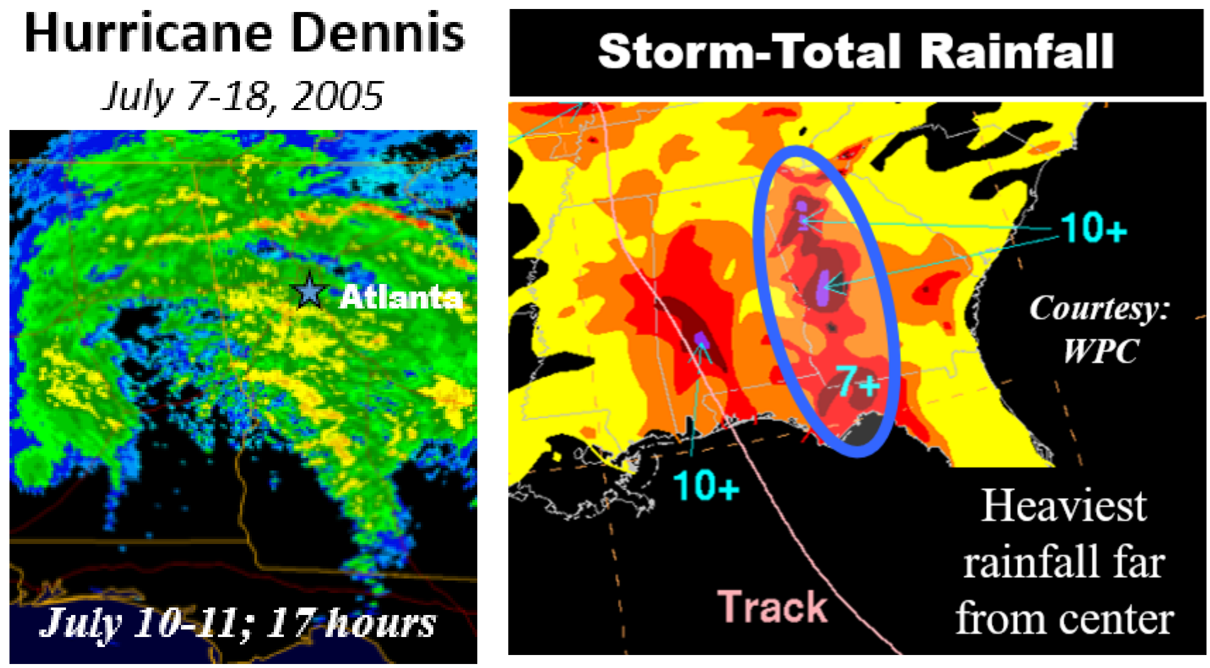


- Small, less organized storms can produce localized extreme rainfall maxima.
- Slow storm motion remains a factor.
- Less lead time and placement can make a big difference in impacts.
- Extreme events at this scale can be more obvious at longer lead times, but remember placement error.

Key Points

Both “weak” storms and “strong” storms can produce high volumes of rainfall. Notice that Tropical Storm Imelda (2019) on the left and Hurricane Harvey (2017) on the right both produced localized rainfall above 40 inches, even though Hurricane Harvey was a much “stronger” storm.

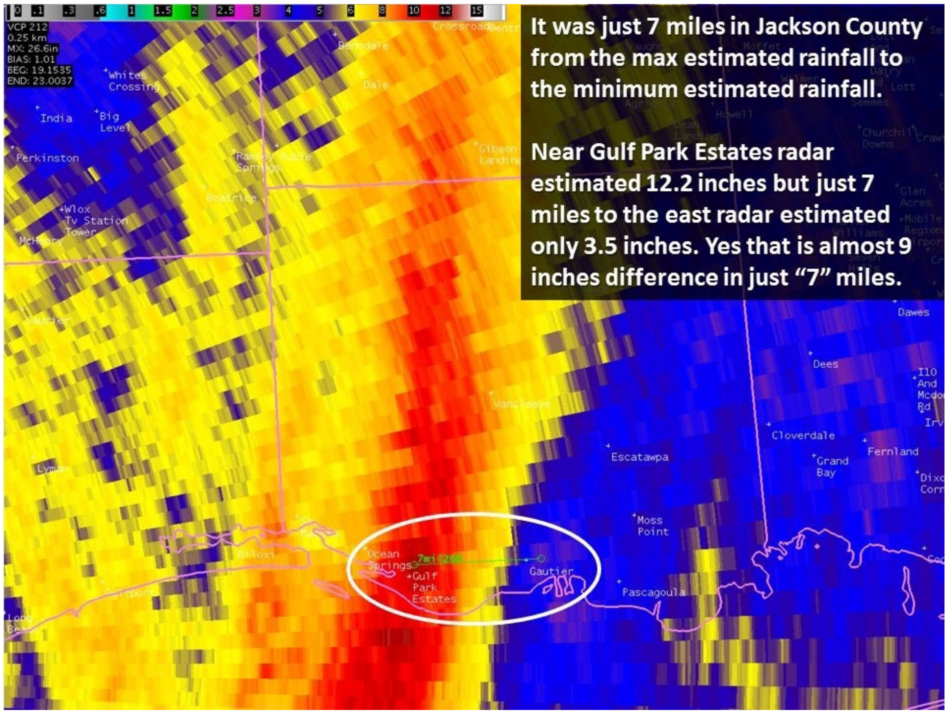
Visual 29: Placement of Persistent Rain Bands?



Key Points

The animation on the left shows how there was a persistent rain band on the front-right/right of the storm as it passed west-northwest through Alabama and Mississippi, leading to high rainfall accumulation over in Georgia.

Visual 30: TS Cindy (2017) Forecast Challenge

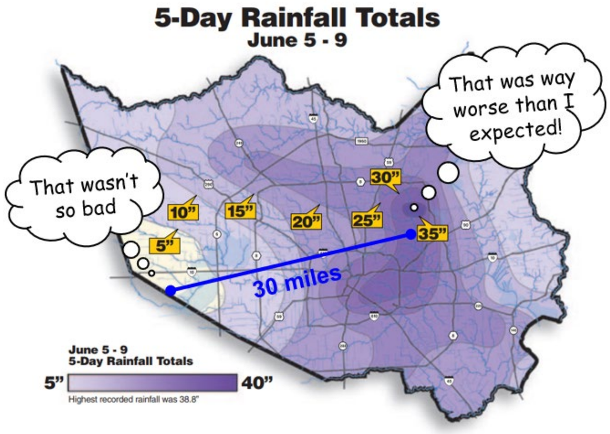


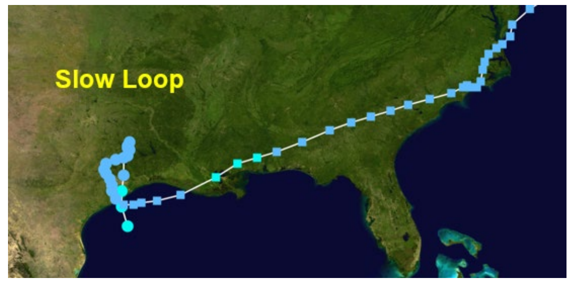
Key Points

Heavy rain often falls in "bands" and can mean sharp gradients in recorded rainfall. You saw this example from Tropical Storm Cindy (2017) in Unit 1. There were 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 31: Messaging Issues

Extreme rain gradients in banding in slow-moving, disorganized storms present messaging issues.





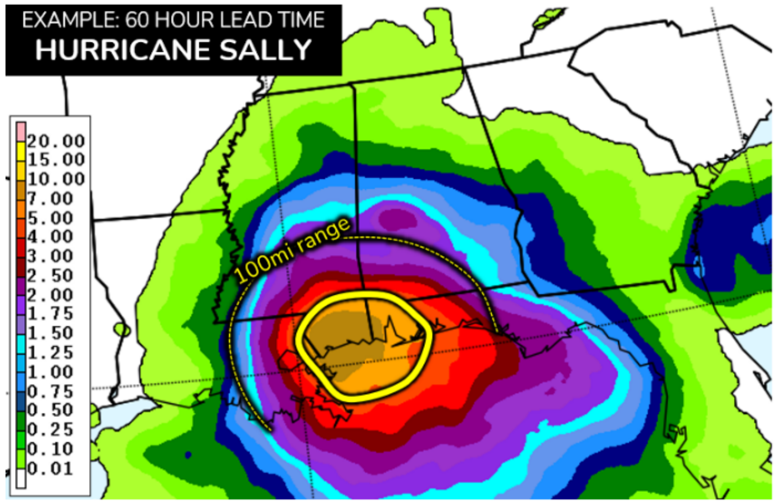
Key Points

Tropical Storm Allison (2001) produced a huge range of rainfall across the Houston metro area: more than 2 feet of rain fell in just 12 hours on the northeast side of Houston. Meanwhile, only 30 miles away, there were areas that saw little to no significant rainfall. If you don't know ahead of time which location will get the extreme rainfall and exactly how extreme it will get, how will that complicate messaging?

Visual 32: Rainfall Forecast Error

Lead Time	Avg. Error
12 hours	55 miles
36 hours	71 miles
60 hours	98 miles
84 hours	137 miles
108 hours	170 miles

2016-2021 Displacement Error of 2" Rainfall Forecast Contour

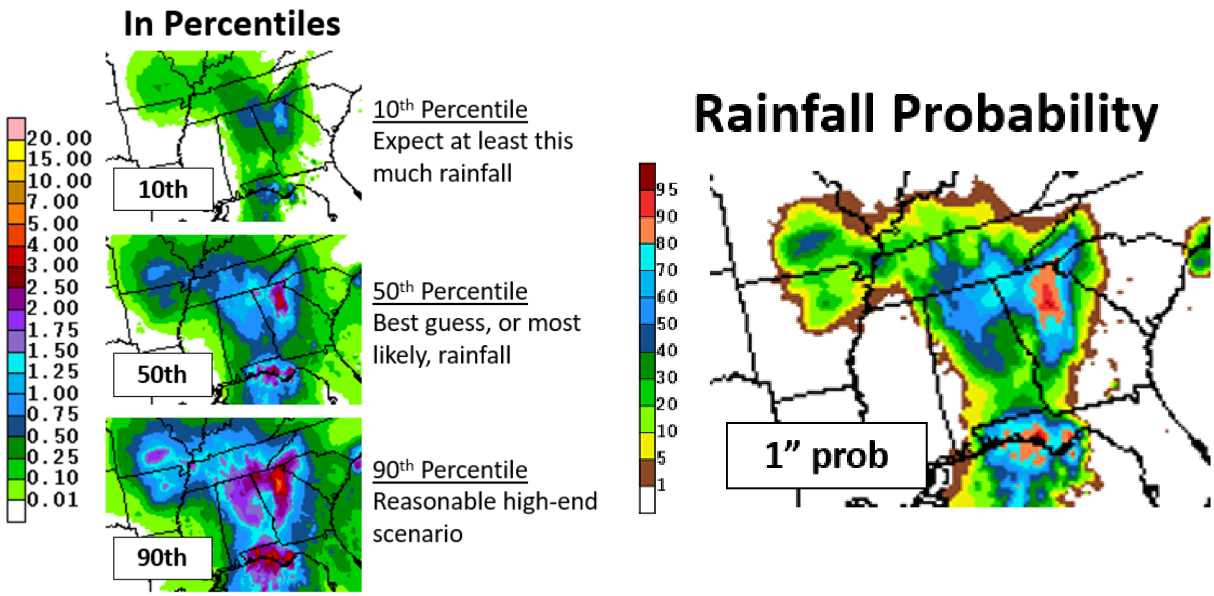


Key Points

The rainfall forecast is the best guess, but as with the NHC track forecast, it's important to consider that the heaviest amounts may be displaced from what you see.

Using the image on the right, the heaviest rain is forecast in southern Mississippi and southern Alabama. However, using the average error provided by the table on the left for the 60-hour lead time, southeast Louisiana and the Florida Panhandle could also see the heaviest rain.

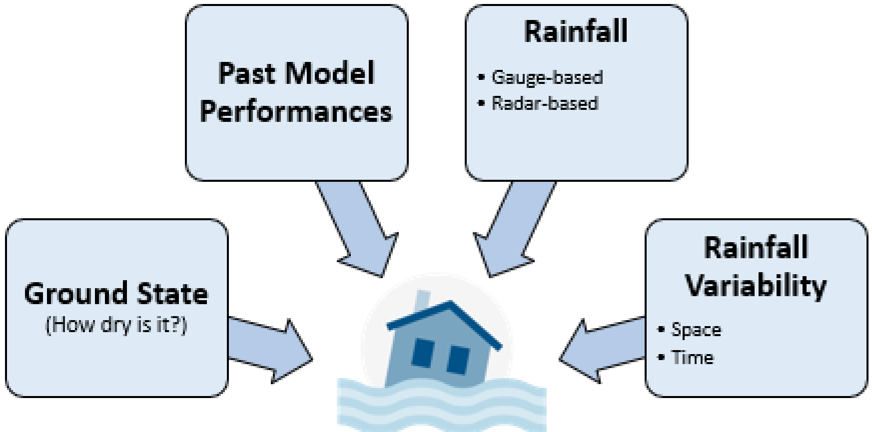
Visual 33: Probabilistic Rainfall Forecasts



Key Points

Caution: 90th percentile rainfall values may not always accurately depict a reasonable potential storm maximum. Always refer to the official Tropical Cyclone Advisory text product for the localized maximum rainfall expectations from forecasters.

Visual 34: Flooding Forecast Considerations



Key Points

The Flooding Forecast Considerations directly relate to the hydrologic forecast process:

1. Modeling how much rain gets into the river (Rainfall to Runoff)
2. Modeling how fast water gets to the river gauge (Unit Hydrograph)
3. Modeling how fast upstream water arrives at the gauge (Routing)
4. Translating water ***volume*** into water ***height*** (Rating)

Visual 35: Ensemble Forecasting

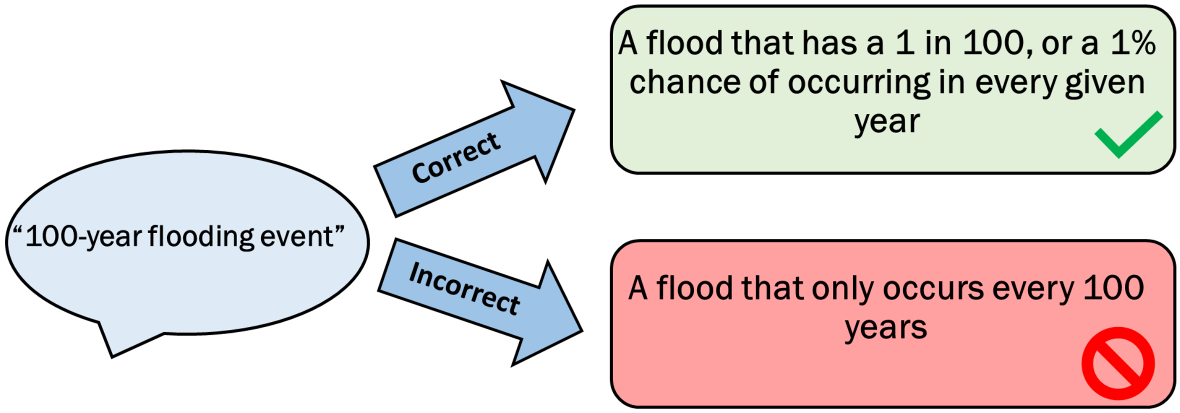
NAEFS River Ensemble Forecast on Sat. Aug 28, 2021; 4-5 days before Hurricane Ida's remnants arrived (Recreated from the official product)

River	City, ST	10%	30%	50%	70%	90%
Lehigh River	Lehighton, PA	12.2	8.7	6.6	5.2	5.1
Delaware River	Tocks Island, NJ	25.2	15.1	11.3	7.8	7.7
Delaware River	Riegelsville, PA	28.1	21.4	13.6	8.4	8.2
Delaware River	Washington Xing, NJ	19.1	13.8	8.7	3.6	3.1
Schuylkill River	Pottstown, PA	18.1	11.7	7.7	4.3	3.8
Schuylkill River	Philadelphia, PA	13.1	10.3	8.7	7.3	6.6
Brandywine Creek	Chadds Ford, PA	13.0	7.6	5.2	3.9	2.7
Neshaminy Creek	Langhorne, PA	16.2	8.3	5.6	3.7	2.6
Conococheauge Creek	Fairview, MD	15.3	10.0	6.2	3.6	2.5
Potomac River	Shepherdstown, WV	24.1	14.7	9.6	5.7	3.9
Monocacy River	Frederick, MD	21.1	9.3	6.9	4.8	2.7

Key Points

- 50% Exceedance (50th percentile) = equal chances of lower or higher crest (aka "Most Likely")
- 10% Exceedance (10th percentile) = reasonable worst-case scenario
- Relying exclusively on the 50% Exceedance would have put Emergency Managers far behind.
- Emergency Managers should always consult the reasonable worst-case scenarios (10% and 30% exceedance in this case).

Visual 36: Recurrence Intervals



Technical term: Annual Exceedance Probability (AEP)
A 100-year rainfall event ≠ 100-year flood

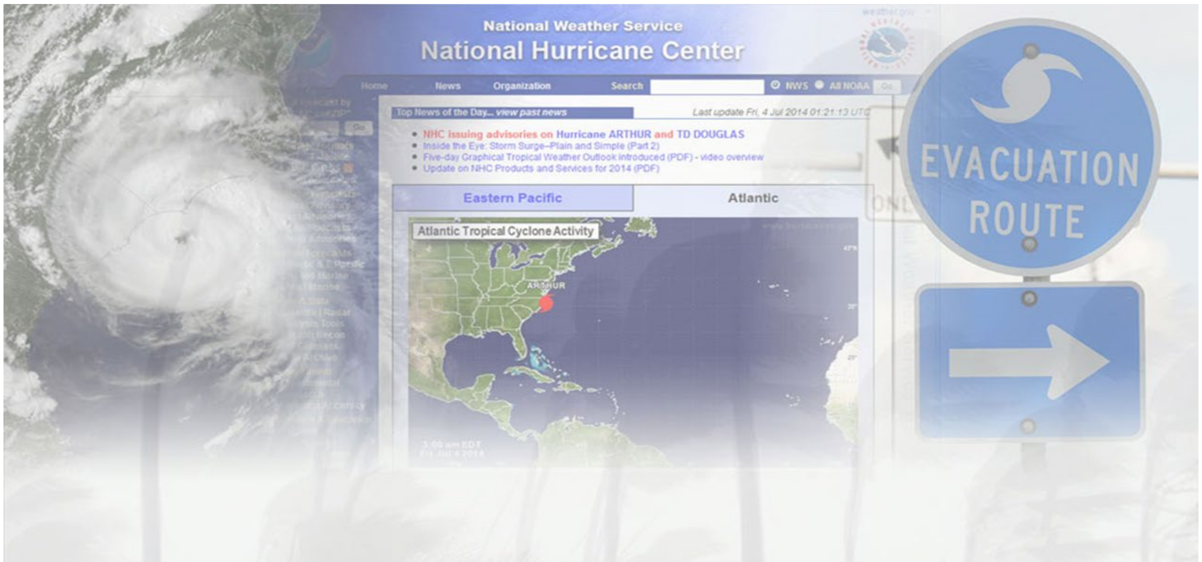
Note:
500-year flooding event = 2% chance every year
1000-year flooding event = .1% chance every year

Key Points

The terminology is key – a "100-Year Flood" does not mean that it can occur only once every 100 years, but that there is only 1% chance of it happening in any given year (meaning it is *statistically likely to occur within a period of 100 years*). Many of these figures are being revised as data is more reliably collected within the past few decades.

Also note that flood events and rainfall events are not related. A 100-year rainfall event might not result in a 100-year flooding event and vice versa.

Visual 37: Questions /Comments?



Key Points

In this unit, you learned about the underlying uncertainty inherent to forecasting and how to interpret that when reading various NWS products.

Unit 4: Inland Hurricane Preparation in Practice

Visual 1: Inland Hurricane Preparation in Practice

Unit 4:

Inland Hurricane Preparation in Practice

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 4 Objectives

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

1. Compare the challenges of coastal and inland Emergency Managers.
2. Discuss the available planning resources to assist inland EMs in evacuation decision making.
3. Describe available flood inundation support tools.
4. Identify the purpose of the Hurricane Liaison Team.

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. Review and take note of Unit objectives.

Visual 3: NWS IDSS & FEMA HLT

NWS Impact-Based Decision Support Services (IDSS) & FEMA Hurricane Liaison Team (HLT) address:

- Confidence? Contingencies?
- What is the forecast/evacuation timing?
- Can we get a briefing?

Key Points

The FEMA Hurricane Liaison Team and NWS Impact-Based Decision Support Services are here to help.

Visual 4: NWS Impact-Based Decision Support Services (IDSS)

IDSS connects NWS forecasts and Warnings to decision makers on the local, state, and Federal levels to save lives and property.

IDSS includes:

- Remote support with forecast advice through various means (such as phone calls, email or online webinars).
- On-site support at an Emergency Operations Center.
- On-site support at an incident or event (such as NWS deployment to a wildfire).

Key Points

One of the ways that you will receive direct support from the NWS and HLT is through on-site support or remote support from Weather Service personnel. This can be personnel from your local WFO or NWS Regional headquarters. You can invite them into your ranks (EOCs and/or ICP) or coordinate with them remotely. “Support” comes in many forms.

Visual 5: Hurricane Liaison Team (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.

Key Points

In addition to the Local NWS, the HLT can help facilitate communications and forecast information. The initial idea for the HLT arose in early 1990's and was successfully proven during response to the 1995 Hurricane Season. It became formal in 1996 by FEMA Director upon request of the Governor of Florida and the Director of National Hurricane Center.

Visual 6: HLT 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 7: Rapid Communications

Partnership between the NWS and FEMA

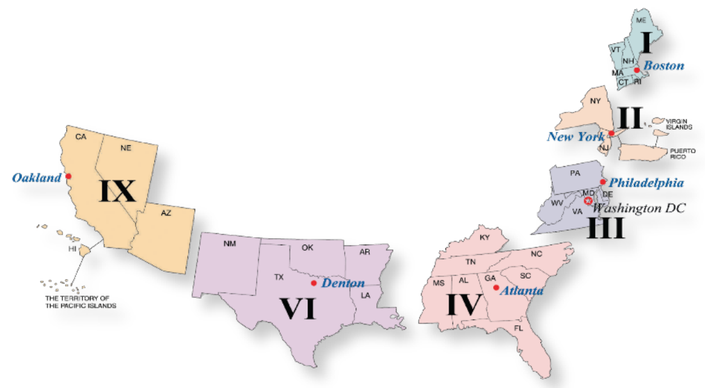
- FEMA Hurricane Program Managers
- FEMA Reservists
- FEMA Liaison to NWS National Water Center
- NWS meteorologists and hydrologist

Key Points

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 8: Regional Hurricane Program Managers (RHPMs)

- Technical Knowledge
- State/Local Relationships
- Deploy to NHC

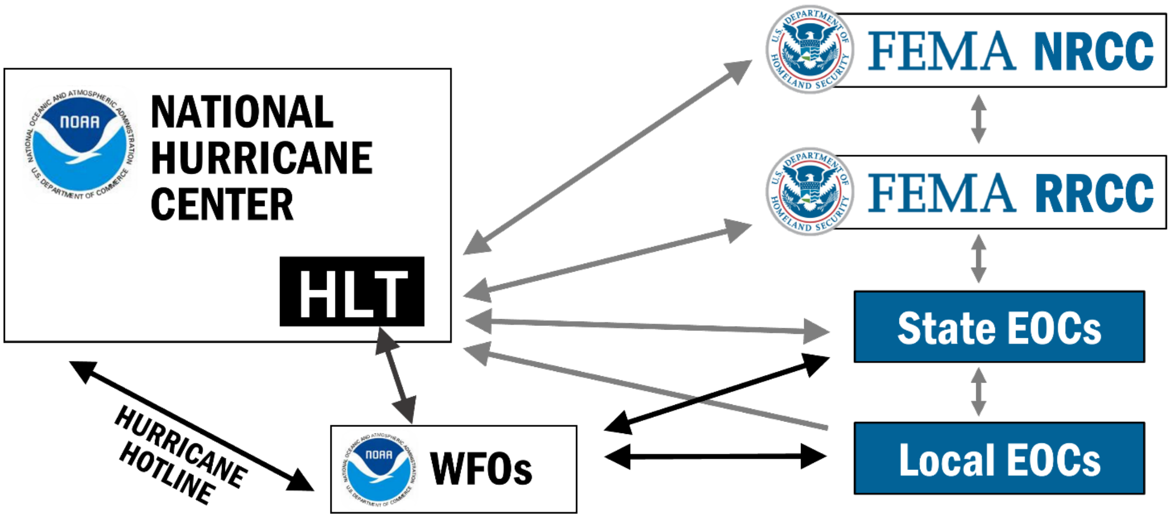


Key Points

Each hurricane-prone FEMA Region has a Regional Hurricane Program Manager (RHPM). These technical experts are familiar with their specific region and work during "blue skies" or non-disasters to build relationships and deploy to the National Hurricane Center in Miami as needed during incidents that threaten their region to provide support.

Regional Hurricane Program Managers are located in FEMA Regions I, II, IV, VI, and IX/Pacific Area Office. The FEMA NHP office is located in FEMA HQ in Washington, DC.

Visual 9: Communication Flowchart



Key Points

The HLT office is embedded within the National Hurricane Center. The HLT communicates directly with FEMA HQ, FEMA Regions, and the states. They also coordinate with other NWS entities.

Visual 10: HLT 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 use of NHC forecasts and predictive modeling.
- Provide NHC visibility on state and local protective actions.
    - Improve messaging.

Key Points

This is a review of what the Hurricane Liaison Team does during events.

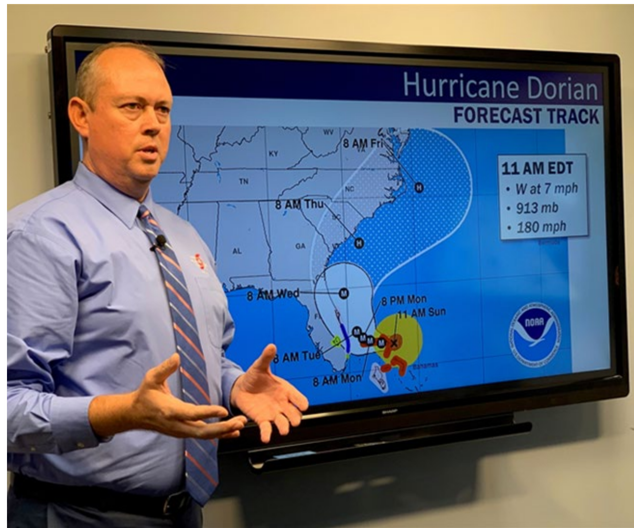
Visual 11: Responsibilities (cont.)

Facilitate two-way communications

- Between the NHC and EMs
- Common forecast picture
- Relay EM issues to improve NWS/NHC messaging

Video/Teleconferences

- NHC/NWS
- FEMA and other Federal Agencies
- Emergency Operations Centers (EOCs)



Key Points

A full suite of telecommunications equipment is located in the HLT office to communicate with FEMA HQ.

Visual 12: State Meteorologists & Hurricane Programs

- In addition to NWS and FEMA HLT, your state emergency management agency may also have a State Meteorologist or Climatologist, a State Hurricane Program Manager, or State Hurricane Lead.
- These individuals often work closely with NWS and FEMA.
- They are excellent resources for state-specific tropical threat analysis and plans.

Key Points

Many states have their own in-house meteorologist, or a program lead who is focused on hurricanes and/or other weather threats. These individuals are often fantastic resources for tropical-related planning and may be able to provide state-specific tropical threat analysis. They work very closely with both FEMA and the NWS.

Visual 13: Discussion 1: Evacuations

Activity Time: 10 minutes

Goal: Discuss the evacuation challenges that are:

- Unique to **coastal** EMs/decision-makers.
- Unique to **inland** EMs/decision-makers.

Directions:

- Pair up with a neighbor.
- Fill out the chart in the Unit 4 Discussion Handout.
- Prepare to share with class.

Student Manual

Goal: Discuss the evacuation challenges that are:

- Unique to **coastal** EMs/decision-makers.
- Unique to **inland** EMs/decision-makers.

Pair up with a neighbor.

Fill out the chart in the handout.

Time: 10 minutes (5 minutes to discuss, 5 minutes to share out)

Discussion Steps:

1. Listen to instructor’s directions.
2. Ask questions if clarification is needed.
3. Discuss the question in your pairing.
4. Be prepared to share out with the class.

Visual 14: Coastal vs. Inland EM Challenges 1

Coastal EM Challenges/Advantages	Inland EM Challenges/Advantages
Advantage: Longer lead-time and there is enough forecast confidence to enable evacs far in advance of the storm.	Disadvantage: Flash Floods may provide little-to-no lead time. There is rarely enough confidence to enable evacs far in advance of the storm. Mainstem river flooding will have slightly more lead time, but still may prove difficult. Mainstem river forecasts will have greater confidence than flash flooding.
Advantage: Evacs occur prior to onset of hazards.	Disadvantage: Evacs could occur *during* hazardous weather, posing threats to both motorists and first responders. May be harder to communicate evac orders if communications infrastructure is impacted.

Key Points

Emergency Managers have different sets of challenges for evacuation planning depending on if they are more coastal or inland. The table across these three slides helps to provide some examples of the differing perspectives that EMs face. This slide covers the topics of lead time and the relation of evac time to onset of hazardous conditions.

Visual 15: Coastal vs. Inland EM Challenges 2

Coastal EM Challenges/Advantages	Inland EM Challenges/Advantages
Disadvantage: Larger-scale evacuations (100,000s, if not millions, of evacuees), who may need to travel significant distances to get to safety/comfort. “Shadow evacuees” will contribute significantly to the evacuating pop.	Advantage: Smaller-scale evacs (at least relative to coastal evacs), and evacuees may not need to travel far to get to safety/comfort. Few, if any, “shadow evacuees.”
Advantage: Predetermined surge evacuation zones, which can be communicated to the public during Blue Sky.	Disadvantage: Not many inland communities have pre-established evac zones beyond FEMA Flood Hazard Areas (which may not cover all of the flood-prone in an extreme flood event).

Key Points

Emergency Managers have different sets of challenges for evacuation planning depending on if they are more coastal or inland. The table across these three slides helps to provide some examples of the differing perspectives that EMs face. This slide covers the topics of size of evacuations and evacuation zones.

Visual 16: Coastal & Inland EM Challenges 3

Coastal EM Challenges/Advantages	Inland EM Challenges/Advantages
Advantage: Regularly updated Hurricane Evacuation Studies (HESs), including recalculated evac clearance times.	Disadvantage: There are HES-like studies for inland EMs, but they don't quite offer the same suite of tools.
Same: widespread severe impacts	Same: widespread severe impacts

Key Points

Emergency Managers have different sets of challenges for evacuation planning depending on if they are more coastal or inland. The table across these three slides helps to provide some examples of the differing perspectives that EMs face. This slide covers the topics of available planning resources and level of impacts.

Visual 17: Evacuations for Inland Communities

Basic Inland Evacuation Considerations:

- What areas are most susceptible to inland flooding?
- What structures will withstand the winds (if strong enough winds extend far enough inland)?
  - Need to evacuate mobile homes?
  - Structural integrity of shelter roofs?
- Community/neighborhood isolation (aka "evacuation islands")?
- Resiliency of critical infrastructure?

Key Points

Evacuation considerations for inland communities are not the same as those for coastal communities. Flooding profiles, community resilience and available resources, and ability for the population to evacuate in short timeframes all contribute to how an inland EM approaches the need and nature for an evacuation.

Visual 18: Evacuations for Inland Communities 2

Inland Evacuation Timing Considerations

- Onset of hazards
- Time of day
- Ongoing Weather Hazards
- Response Time/Evacuation Departure Time (i.e., the amount of time it will take a household to respond to the evac order)
- Traffic management considerations

Key Points

This all assumes the storm/flood provides enough lead time. Many flash flood evacuations will be short fused.

Visual 19: Evacuation Decision Considerations

Protective Action Decisions within a jurisdiction are frequently made by an elected official.

- Define ultimate authority.
- Consensus from other elected officials.
- Verification by local ordinance or state code.

Key Points

Evacuations are frequently made by elected officials, not just by Emergency Managers. It is important to understand their decision criteria, their authority, and their abilities/obligations when it comes to evacuations.

Visual 20: Regional Considerations

Evacuation decisions by one jurisdiction **may** affect others.

- Inland evacuations tend to be smaller scale compared to coastal evacuations.
- Evacuees typically don't need to leave the town, county, or state. But there are exceptions…

Will evacuees in your jurisdiction have to go to shelters in other jurisdictions?

What are the host jurisdiction considerations?

Blue Sky and Dark Sky coordination with those jurisdictions?

Key Points

Decisions in one jurisdiction may impact neighboring or surrounding jurisdictions both in terms of evacuees into that jurisdiction or influencing evacuation decisions in that jurisdiction. EMs should be coordinating with neighboring jurisdictions in Blue and Dark Sky conditions to ensure that impacts are mitigated or acceptable.

Visual 21: Important Inland Planning Factors

Widespread infrastructure impacts that could be medium to long term include:

- **Major and secondary roads** flooded, washed out and/or impacted by mudslides/debris. Seemingly unpredictable and random pattern to the impacts.
- **Key bridges** may be washed away by the floodwaters and/or debris.
- **Power outages** caused by flooding of grid facilities.
- **Water and sewer disruptions,** including for critical facilities (e.g., hospitals).

Key Points

Impacts to infrastructure could have a medium- or long-term impact on evacuation and response. If roads are flooded and washed away, how will people travel to safe locations, or how can relief supplies make it to affected populations/critical locations? Will power outages render facilities inoperable? Will water or sewer disruptions impact critical facilities or shelters?

Visual 22: Important Inland Planning Factors (cont.)

- The importance of air operations given potential for severe disruption of roadway networks.
- Widespread HAZMAT threats.
- Major and potentially long-term impacts to agriculture.

Key Points

Continuing from the previous slide, how do impacts to infrastructure limit your jurisdiction's capacities or change the nature of risks?

Visual 23: Discussion 2: Vulnerable Facilities/ Populations

Time: 3–5 minutes

Goal: Build a list of (1) vulnerable facilities and (2) populations that need to be accounted for in inland flooding planning.

Directions:

- Pair up with a neighbor.
- Fill out the chart in the Unit 4 Discussion Handout.
- Prepare to share with class.

Student Manual

Goal: Build a list of (1) vulnerable facilities and (2) populations that need to be accounted for in inland flooding planning.

Pair up with a neighbor.

Fill out the chart in the handout.

Time: 10 minutes (5 minutes to discuss, 5 minutes to share out)

Discussion Steps:

1. Listen to instructor's directions.
2. Ask questions if clarification is needed.
3. Discuss the question in your pairing.
4. Be prepared to share out with the class.

Visual 24: Vulnerable Facilities

- Hospitals
- Assisted Living and Nursing Homes
- Critical Infrastructure
- Public Safety Facilities
- Industrial Facilities
- Tourist and Recreation Areas
- Mobile Homes

Key Points

The number and extent of the vulnerable facilities within a jurisdiction impact the complexity of planning for evacuations. Facilities can be vulnerable as a function of their population (nursing homes) or by their sturdiness (mobile homes) or their function (industrial facilities). Each needs to be treated differently as they have different risks. Consider how you would plan for the safety of not just the individuals but the facility itself in the case of an evacuation.

Visual 25: Vulnerable Populations

Socioeconomic Status	• Below Poverty • Unemployed • Income • No High School Diploma
Household Composition & Disability	• Aged 65 or Older • Aged 17 or Younger • Civilian with a Disability • Single-Parent Households
Minority Status & Language	• Minority • Speak English "Less than Well"
Housing & Transportation	• Multi-Unit Structures • Mobile Homes • Crowding • No Vehicle • Group Quarters

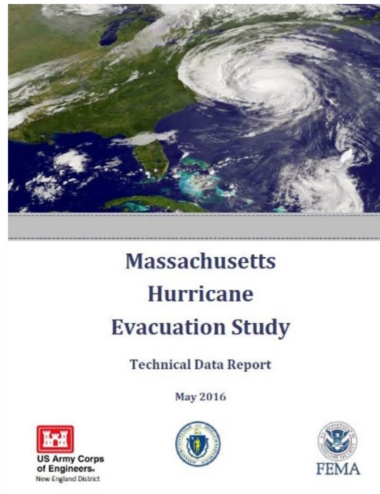
Key Points

Check with your state/tribal/local Department of Health and/or Human Services for any additional categories that they actively track. This is not an exhaustive list.

Visual 26: Hurricane Evacuation Study (HES)

- What will be wet and what stays dry?
- Who/what will be affected in your community?
- What is the public thinking?
- What are your shelter needs?
- Where is traffic going to back up?
- Evacuations from storm surge risk
- Predominantly focused on storm surge, currently no inland flooding equivalent

Inland EMs have other resources at their disposal.



Key Points

The Hurricane Evacuation Study (HES) provides several analyses that can help answer questions for a coastal/tidal community (specifically for storm surge threats). There are other resources that an EM can use to have similar information to inform freshwater evacuation planning; however, they may not be as comprehensive as an HES.

An HES provides a critical set of evacuation and response information to SLTT Emergency Managers in hurricane-prone areas to guide their hurricane evacuation planning. An HES has 5 key components:

- Hazard Analysis
- Vulnerability Analysis
- Behavioral Analysis
- Shelter Analysis
- Transportation Analysis

Visual 27: Discussion 3: Planning Resources

Time: 3–5 minutes

Goal: In the absence of an HES for inland EMs, what resources are you aware of in your jurisdiction/states that you can use to answer these same questions?

- Determine the extent, severity, location, and duration of hazards.
- Identity areas/neighborhoods that would need to evacuate in a given scenario.
- Identify vulnerable populations/facilities.
- Estimate shelter needs.
- Assess evacuation elements (routes, timing).

Directions:

- Pair up with a neighbor.
- Fill out the chart in the Unit 4 Discussion Handout.
- Prepare to share with class.

Student Manual

Goal: Identify the resources that an inland EM would use to answer the same questions found in an HES. How would you:

- Determine the extent, severity, location, and duration of hazards?
- Identity areas/neighborhoods that would need to evacuate in a given scenario?
- Identify vulnerable populations/facilities?
- Estimate shelter needs?
- Assess evacuation elements (routes, timing)?

Pair up with a neighbor.

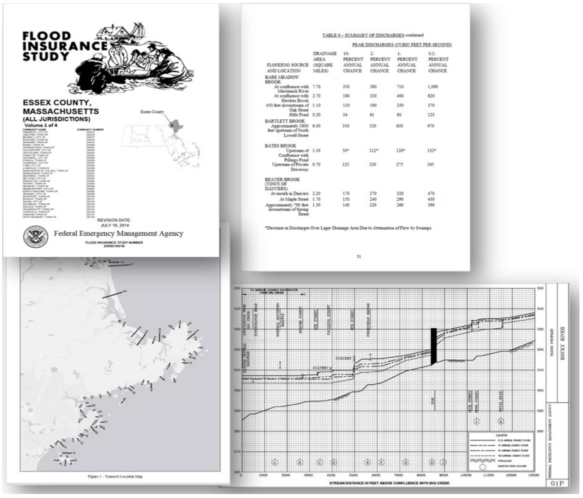
Fill out the chart in the handout.

Time: 10 minutes (5 minutes to discuss, 5 minutes to share out)

Discussion Steps:

1. Listen to instructor's directions.
2. Ask questions if clarification is needed.
3. Discuss the question in your pairing.
4. Be prepared to share out with the class.

Visual 28: Flood Insurance Study (FIS)



A compilation and presentation of flood hazard areas along rivers, streams, coasts, and lakes within a community.

A **Flood Insurance Study (FIS)** includes:

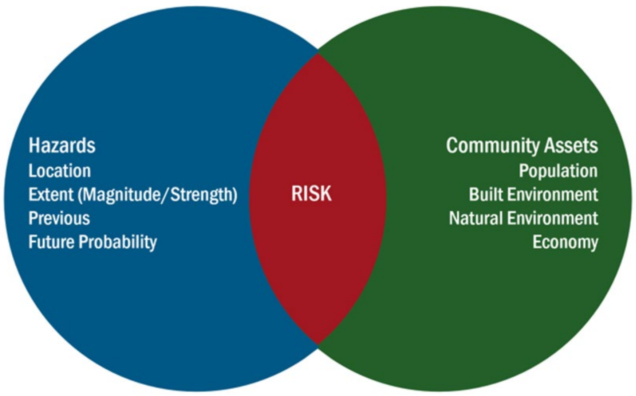
- Cross-sections
- Coastal transects
- Riverine flood profiles
- H&H engineering

The results of the FIS are shown on FEMA's flood maps called **Flood Insurance Rate Maps (FIRMs)** and in the accompanying description of the study called an FIS report.

Key Points

A Flood Insurance Study (FIS) is a compilation and presentation of flood risk data for specific watercourses, lakes, and coastal flood hazard areas within a community that is completed for the National Flood Insurance Program (NFIP). An FIS report contains detailed flood elevation data in flood profiles and data tables.

Visual 29: Hazard Mitigation Plans

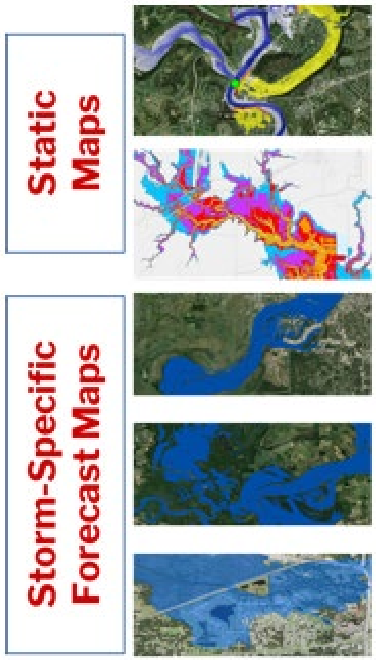


- Hazard mitigation planning reduces loss of life and property by minimizing the impact of disasters.
- State, tribal, and local governments identify natural disaster risks and vulnerabilities that are common in their area.
- Develop long-term strategies for protecting people and property from similar events.
- Mitigation plans are key to breaking the cycle of disaster damage and reconstruction.
- Updated every 5 years and required to receive hazard mitigation grant funding.

Key Points

Hazard Mitigation Plans (HMPs) are at the state, tribal, and local levels. Thousands of jurisdictions have HMPs, and a current overview can be found at the FEMA Hazard Mitigation Planning website (https://www.fema.gov/emergency-managers/risk-management/hazard-mitigation-planning/status).

Visual 30: Overview of NWS Flood Inundation Mapping (FIM) Options



NWS Advances Hydrologic Prediction Service FIM (AHSPS FIM) – High-resolution static maps. Shows both extent and depth of possible flooding at various crest heights. Only covers >1,000 miles of rivers. (Available now).

NWS Flood Categorical FIM (CatFIM) – Static maps that cover ~30,000 miles of rivers. Shows likely special extent (but not depth) of flooding at various flood stage categories ("major," "moderate," "minor," etc.). (Available Spring 2024 for select basins in PA, NY, WV, OH, TX).

River Forecast Center FIM (RFC FIM) – Storm-specific forecast maps showing approximate flooding extent over next 3–5 days based on the RFC forecast for the upstream gauge. Will cover ~110,000 miles of rivers when fully implemented. (Available now for select basins in PA, NY, WV, OH, TX).

National Water Model FIM (NWM FIM) – Storm-specific forecast maps showing the NWM's best approximation on possible flooding extent in the next 5 days along all streams and river based on latest weather model data and antecedent conditions. Will cover ~3.4 million miles of rivers when fully implemented. (Available now for select basins in PA, NY, WV, OH, TX).

National Water Model Latest Analysis FIM (AnA FIM) – NWM's best approximation storm-specific forecast map on current flooding extended based on latest rainfall observations and streamflow data. Will update every 1.5 hours. Will cover ~3.4 million miles of rivers when fully implemented. (Available now for select basins in PA, NY, WV, OH, TX).

Key Points

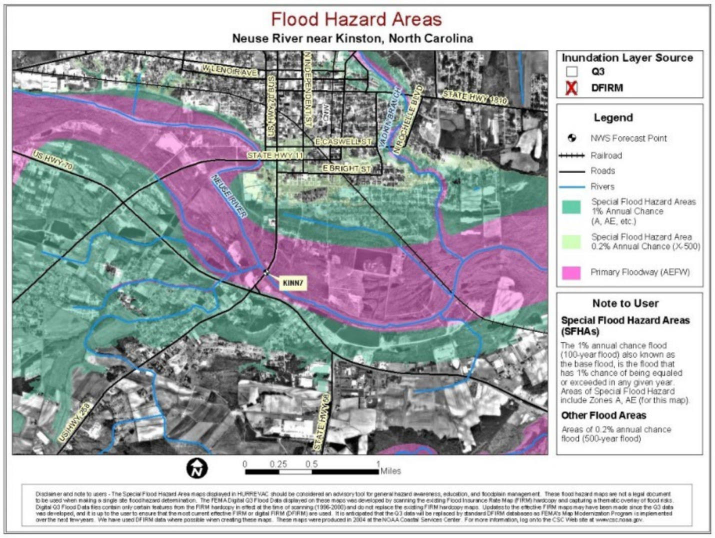
Flood Inundation Mapping (FIM) is one of the best operational planning tools for Emergency Managers. FIMs are predominantly focused on freshwater flooding. The following pages will focus on each type of FIM in more detail.

Generally, there are two broad types of FIMs:

- Static Maps: Maps that are available all of the time and stay the same regardless of the specific storm at hand.
- Storm-specific Forecast Maps: Maps that are only available when there is a possible flooding threat, will only show information based on the storm at hand, and will change as the situation evolves.

NWS is not the only agency to produce FIMs. Other NOAA agencies, U.S. Geological Survey, U.S. Army Corps of Engineers, and even some states have their own FIMs or FIM-like tools. Some of the NWS FIMs include FIMs produced by other agencies. Given time constraints, this course will only focus on the NWS FIMs.

Visual 31: FEMA Flood Hazard Area Mapping



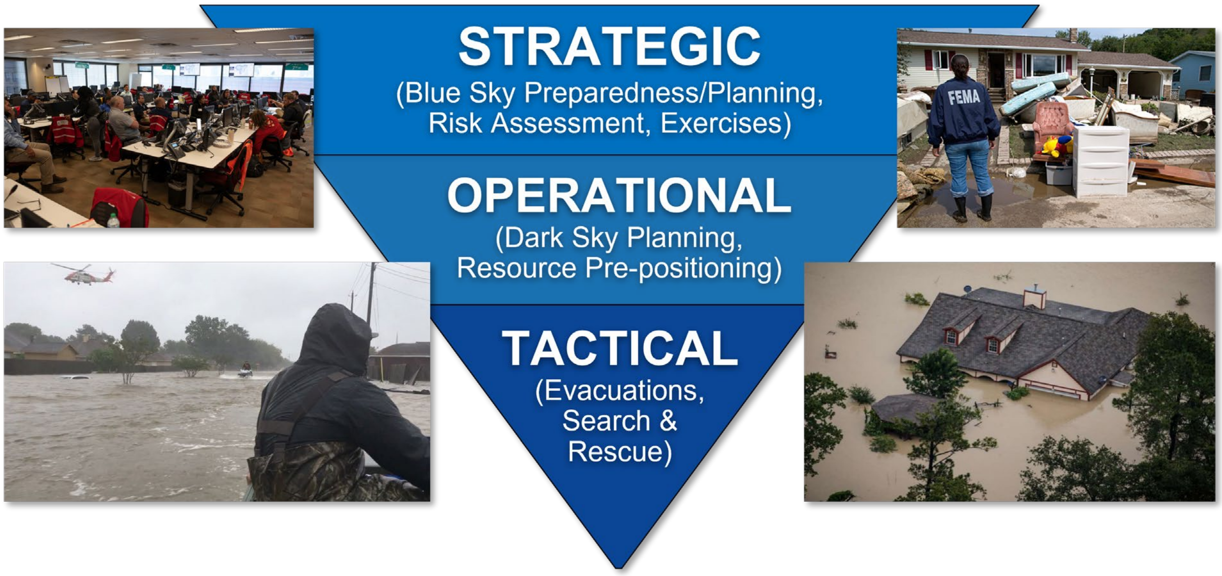
Flood Hazard Areas

- Map shows special flood hazard areas.
- Overlay of local features.
- Can be applied for GIS use.
- Created for flood insurance purposes; less useful than the NWS Flood Inundation Mapping (FIM) tools for response purposes.

Key Points

Special Flood Hazard Areas (SFHA) are those within a community that have a special flood, mudflow, or flood-related hazard and are communicated through a Flood Hazard Boundary Map or a Flood Insurance Rate Map. There are various Zones of the SFHA, corresponding to different levels of hazard. However, these hazard areas are not the equivalent of evacuation zones. They're harder to communicate to the public in a dark sky scenario. They're also created for insurance purposes, with a greater emphasis on flood risk exposure and frequency. In contrast, evacuation zones are typically drawn based on hazard exposure and potential severity, and often factor in human constructs (i.e., the desire to use specific streets as boundaries to simplify hazard communications, or over-zoning to avoid "evacuation islands," etc.).

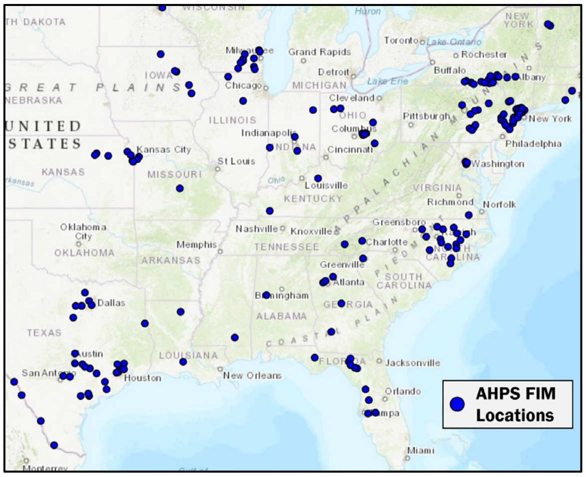
Visual 32: Possible Uses of FIMs



Key Points

When fully operational, FIMs will have a variety of useful emergency management applications. In the early stages of the FIM rollout, the most useful application will likely be utilizing the static map options for blue sky activities. The ability to use the storm-specific FIMs effectively for dark sky purposes (especially evacuation decision-making) will heavily depend on the type of flooding threat and the specific FIMs available for the location in questions.

Visual 33: NWS FIM Options – AHPS FIM



- Static map (i.e., not storm-specific) that's always available via the **Advanced Hydrologic Prediction Service (AHPS) website (hence "AHPS FIM")**. The name will likely change when AHPS becomes the National Water Prediction Service (NWPS) in the near future.
- Currently operational.
- Shows both depth and spatial extent of possible flooding at various crest heights.
- Most detailed FIM available for emergency managers.
- However, covers less than 1,000 miles of rivers.

Key Points

- AHPS FIM depicts both river flood inundation extent and depth for a range of river flood levels, including each of the flood categories defined at a stream gauge location.
- AHPS FIM uses high-resolution elevation data and accounts for many built structures, such as bridges, levees, and flood walls.
- Most AHPS FIM maps were created through interagency cooperative projects, including local, state, regional, and Federal agencies.
- Given the level of effort, the AHPS FIM is the best-available option for EMs. However, because of the level of effort required, the AHPS FIM is only available for select parts of the country. Most Emergency Managers will not have access to an AHPS FIM.
- The name of this FIM will likely change when AHPS transitions to the National Water Prediction Service (NWPS). However, it will not be called "NWPS FIM" because the other NWS FIMs also will be accessible via NWPS.

Visual 34: AHPS FIM Demo 1

Instructor-Led Demo of Inundation Mapping Tool

Activity Time: 5 minutes

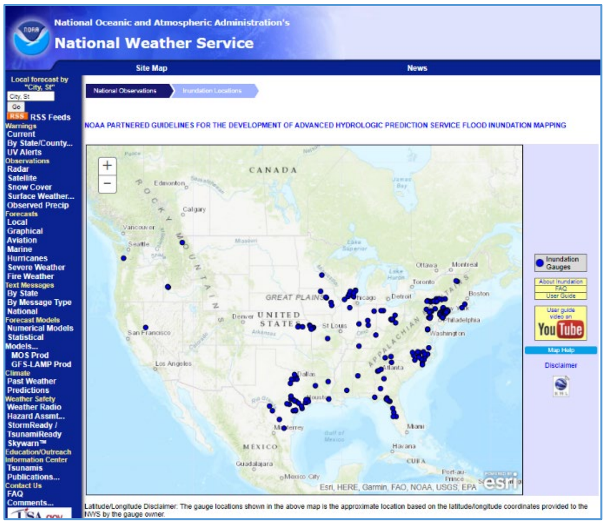
Goal: Explore the AHPS FIM Tool (https://water.weather.gov/ahps/inundation.php)

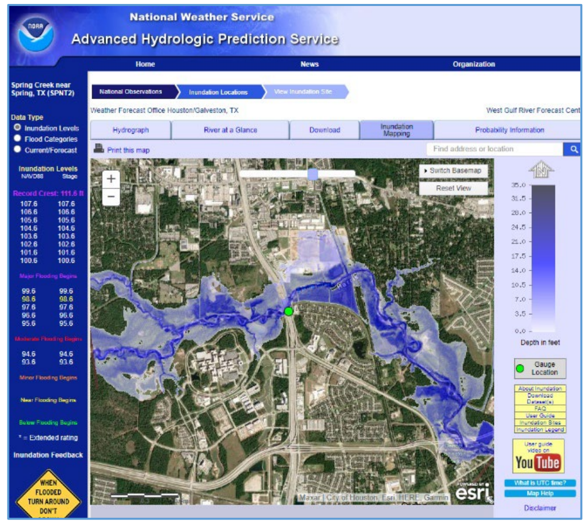
1. Layout of the interface
2. Locations of key information
3. How to set inundation levels/map features

Key Points

This is a quick demonstration of how to access the Advanced Hydrologic Prediction Service (AHPS) Flood Inundation Mapping (FIM) tool. While different than the other FIMs, the AHPS FIM demo helps provide a general idea of how any type of FIM can be applied for response planning and operations purposes.

Visual 35: AHPS FIM Demo 2

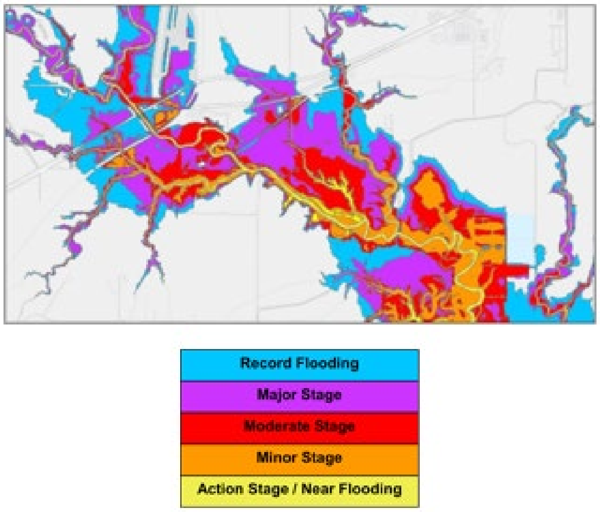




Key Points

- Currently, NWS provides access to detailed flood maps at about 180 RFC forecast points across the country through the Advanced Hydrologic Prediction Service (AHPS).
- So, at these locations, a user can zoom in and look at a detailed flood map, looking at what the potential impacts are for minor, moderate, and major river flooding, and sometimes up to record levels. At these locations, you've got a couple miles of river segment to look at.

Visual 36: NWS FIM Options – Categorical FIM (CatFIM)

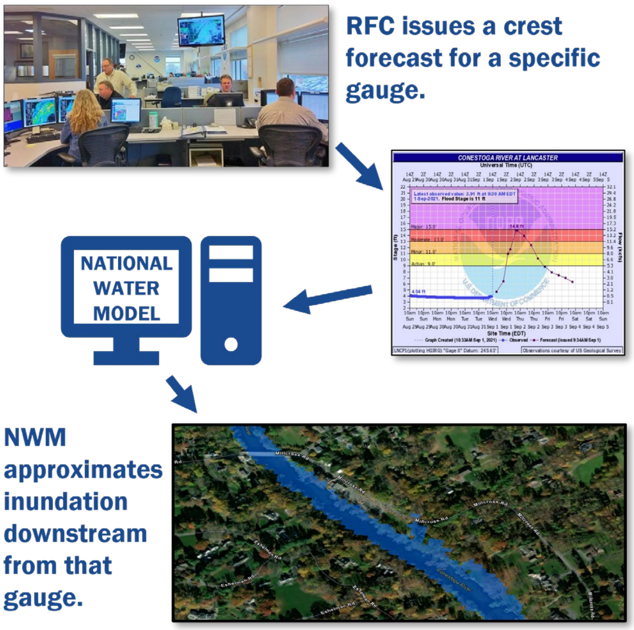


- Static map (i.e., not storm-specific) that will be always available via NWPS.
- Shows spatial extent of possible flooding at specific **flood stage categories (hence "Cat" FIM)**.
- ~30,000 miles of rivers are covered.
- Will be available as an experimental (non-operational) product for select parts of the country, starting in Spring 2024.

Key Points

- Where available, in select parts of the country, refer to Categorical FIM ("CatFIM") to preview flood inundation extents at each flood category defined at a stream gauge location: Action Stage, Minor Stage, Moderate Stage, Major Stage, and Record Flood.
- In addition to each of the flood categories, CatFIM is also available at 1-foot increments spanning from Action Stage to 5 feet above Major Flood.
- Verification efforts are ongoing to compare CatFIM output with flood reports and other documentation from prior floods. CatFIM will not be produced for locations that do not have a USGS-documented datum accuracy of +/- 1 foot.

Visual 37: NWS FIM Options – RFC FIM

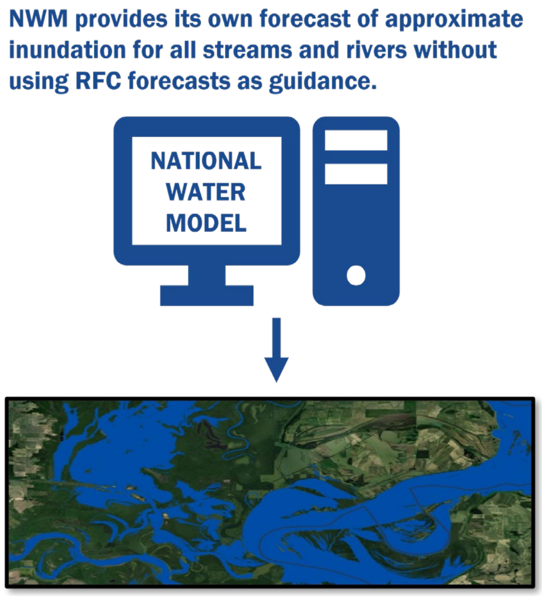


- Forecast map (storm-specific) shared via NWPS when there's a potential for flooding. Looks out 3–5 days (depending on the RFC).
- Shows spatial extent of possible flooding based on the **River Forecast Center's (RFC's)** crest forecast for the upstream gauge site. It's the National Water Model's (NWM's) best approximation for inundation using the upstream RFC forecast.
- ~110,000 miles of rivers are covered.
- Most useful for river flooding threats, but not flash flooding.
- Available as an experimental (non-operational) product for select part of the country over the next few years. Will be available for everyone by October 2026.

Key Points

- RFC FIM is a storm-specific map, based on the highest river level (often the crest) from the latest forecasts issued by NWS RFCs.
- The National Water Model (NWM) uses the RFC forecast at a specific forecast site/gauge and then provides a best approximation of the flooding extent downstream of that forecast point. This process is sometimes called "routing flow" or "replace and route."
- RFC FIM is updated within approximately 1 hour of the latest river forecast update. The flood inundation extent may change with each update, so be sure to compare the RFC FIM to the latest RFC forecast.
- RFC FIM is only available for larger rivers that have RFC forecast points.

Visual 38: NWS FIM Options – NWM FIM

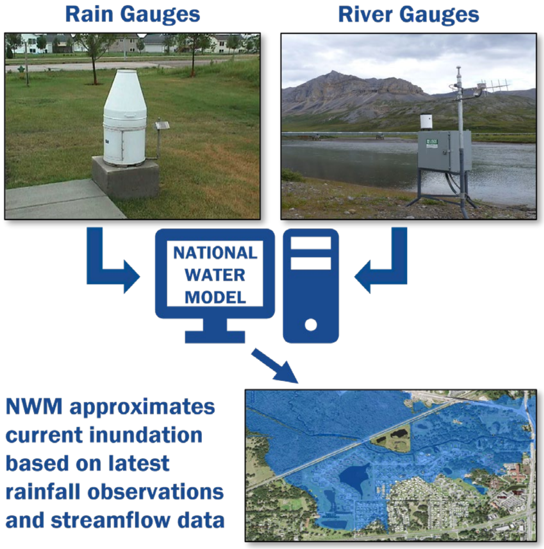


- Forecast map (storm-specific) shared via NWPS when there's a potential for flooding. Looks out 5 days.
- Shows the **National Water Model's (NWM's)** best approximation on future flooding extent for all streams and rivers based on latest weather model data and antecedent conditions.
- ~3.4M miles of rivers are covered (expands far beyond the geographic scope of the RFC FIM).
- Better for flooding on smaller rivers, streams, creeks (i.e., those without a forecast gauge site). But it's not a human-derived forecast and may have greater than normal uncertainty.
- Available as an experimental (non-operational) product for select parts of the country over the next few years. Will be available for everyone by October 2026.

Key Points

- NWM FIM is a storm-specific map, available for nearly every stream, including smaller tributaries, streams, and creeks without stream gauges.
- Currently, NWM FIM is updated once every 6 hours, using a single weather model for precipitation inputs. There are plans to use a "blend" of multiple models instead. There is no human forecaster interaction with NWM output. Therefore, NWM FIM and RFC FIM flood extents may differ, even at the same location.
- NWM FIM is best used to signal the possibility of flooding along smaller rivers, streams, and creeks where no other FIM type is available.

Visual 39: NWS FIM Options – Latest Analysis (Ana) FIM



- "Nowcast" map that is storm-specific, shared via NWPS when there is active flooding. Updated every 1.5 hours. It's not a "forecast" FIM; instead, it's the **"latest analysis" (AnA) FIM.**
- Shows the National Water Model's (NWM's) best approximation on current flooding extent for several streams and rivers based on latest observed rainfall and streamflow data.
- ~3.4M miles of rivers are covered (expands far beyond the geographic scope of the RFC FIM).
- Better for flash flooding on smaller streams.
- Available as an experimental (non-operational) product for select parts of the country over the next few years. Will be available for everyone by October 2026.

Key Points

- Similar to NWM FIM, Latest Analysis FIM is a storm-specific map, available for nearly every stream, including small streams and tributaries without stream gauges.
- Latest Analysis FIM updates every 1.5 hours and is best used to show current river flood conditions, using near real-time stream gauge data and estimates of observed precipitation.
- There is no direct human interaction with Latest Analysis FIM output. Reports or documentation of observed flooding are not directly incorporated into the output.

Visual 40: NWS FIM Options – Days 4–7+ Pre-Flood (and "Blue Sky" Planning)

- **"What-If" Planning**
  - **Ex:** What if Vestal, New York, reaches Major Flood? Which properties are at risk of river flooding?
    - **AHPS FIM** (where available); otherwise, use **CatFIM**
- **Monitor river ensembles**
  - **Ex:** What are the chances of Major Flooding? Where might we see the worst flooding?
    - Look at **AHPS FIM** or **CatFIM** for inundation at locations where flooding is of greatest concern.
    - **NWM FIM** for guidance along smaller rivers, streams, and creeks.

Upper Susquehanna Basin

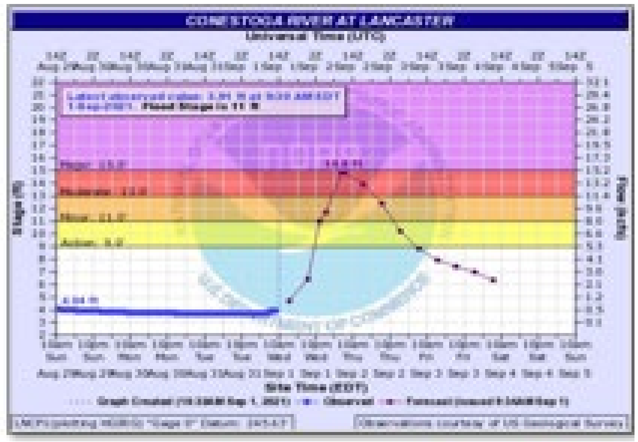
			Exceedance Level (ft.)					Flood Levels (ft.)			
StationID	River	City,State	10%	30%	50%	70%	90%	Action	Minor	Mod	Major
UNDN6	Susquehanna River	Unadilla, NY	13.6	8.9	7.8	7.3	5.8	9.0	11.0	13.0	14.5
RCKN6	Unadilla River	Rockdale, NY	11.8	8.4	7.4	6.5	5.8	8.0	11.0	12.0	13.0
BAIN6	Susquehanna River	Bainbridge, NY	21.0	13.0	11.1	9.2	6.7	13.0	15.0	20.0	22.0
WSRN6	Susquehanna River	Windsor, NY	19.8	13.1	11.6	9.8	7.6	13.0	17.0	19.0	20.5
CKLN6	Susquehanna River	Conklin, NY	17.4	11.5	10.0	8.4	6.5	10.0	12.0	15.0	20.0
CRTN6	Tioughnioga River	Cortland, NY	10.3	7.2	6.2	5.8	4.9	7.0	8.0	10.0	12.5
CINN6	Otselic River	Cincinnatus, NY	7.2	4.8	4.0	3.5	2.8	8.0	9.0	10.5	11.5
SHBN6	Chenango River	Sherburne, NY	9.9	7.7	6.2	5.0	3.6	6.5	8.5	9.5	10.6
GNEN6	Chenango River	Greene, NY	14.9	11.0	8.7	6.9	5.3	11.0	13.0	15.0	18.0
CNON6	Chenango River	Chenango Forks, NY	11.0	8.5	7.0	6.2	5.3	8.0	10.0	12.6	14.0
BNGN6	Susquehanna River	Binghamton, NY	15.3	11.0	9.0	7.6	5.8	12.0	14.0	15.0	18.0
VSTN6	Susquehanna River	Vestal, NY	24.1	17.1	14.1	11.8	9.3	15.0	18.0	21.0	27.0
OWGN6	Susquehanna River	Owego, NY	14.8	13.9	13.8	13.6	13.5	29.0	30.0	32.0	33.0
WVYN6	Susquehanna River	Waverly NY (Near), PA	16.3	11.0	9.0	7.3	5.8	12.0	13.0	16.0	20.0
LDYN6	Tioga River	Lindley, NY	8.5	7.7	7.2	6.9	6.0	14.0	17.0	20.0	22.0
WCRN6	Canisteo River	West Cameron, NY	9.6	8.1	7.1	6.1	5.3	11.0	17.0	18.0	21.0

Key Points

- Refer to the static/non-storm-specific FIM types (AHPS FIM and CatFIM) to become familiar with potential flood impacts before the next flood event approaches.
- River forecast ensembles can provide river flood outlooks by location up to several days in advance. For example, if river forecast ensembles signal high chances for Major Flooding, you can refer to AHPS FIM and CatFIM to preview the potential river flood inundation at specific locations, days before the flood hits.

Visual 41: NWS FIM Options – Days 1–3 Pre-Flood

- **Forecast confidence is increasing.**
  - Move towards deterministic forecasts.
- **NWS River Forecasts are available**
  - **Ex:** River forecasts show widespread Moderate to Major Flooding.
    - Look at corresponding crest height on **AHPS FIM** (where available).
    - Elsewhere, look at **RFC FIM.**
    - **NWM FIM** for smaller streams.
- **What if flooding is worse than predicted?**
  - **Ex:** What if river flooding is XX feet higher than predicted? What if a Moderate flood goes to Major?
    - Look at 1-ft intervals on **AHPS FIM**; **CatFIM.**

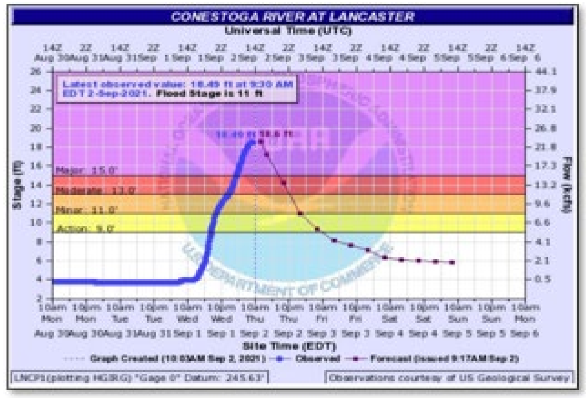


Key Points

- RFC FIM and NWM FIM are storm-specific and only available when there is a potential for flooding within up to 5 days.
- For rivers with RFC forecast points, refer to the corresponding RFC FIM. NWM FIM can provide forecast inundation along smaller rivers, streams, and creeks, which do not have RFC forecast points.
- For “what if” contingency scenarios, compare the RFC river forecast and corresponding RFC FIM to the range of AHPS FIM and CatFIM inundation levels, if available.

Visual 42: NWS FIM Options – While Flooding is Ongoing

- **Consult NWS River Forecasts for crest.**
  - Look at corresponding crest height on **AHPS FIM** (where available).
  - Elsewhere, look at **RFC FIM.**
- **What if flooding is worse than predicted?**
  - **Ex:** How much higher can river flooding get before the water treatment plant is inundated?
    - **AHPS FIM; CatFIM**
- **For small streams/flash flooding:**
  - Look at current conditions on **AnA FIM.**
  - **NWM FIM** can show where additional rises might be expected.
  - **NWM FIMs** are not recommended for larger rivers where **AHPS FIM** or **RFC FIM** is a



Key Points

- Look for the flood crest timing on forecast hydrographs or in the text of Flood Warnings.
- Refer to the Latest Analysis FIM for current flood conditions along any stream. If rivers are expected to rise, refer to RFC FIM and NWM FIM for the latest maximum inundation extent forecast.
- For "what if" contingency scenarios, compare the forecast hydrograph and corresponding RFC FIM to the range of AHPS FIM and CatFIM inundation levels, if available.

Visual 43: NWS FIM Example – Hurricane Ida (2021)

Inundation crosses Millcross Road, as indicated by NWS CatFIM

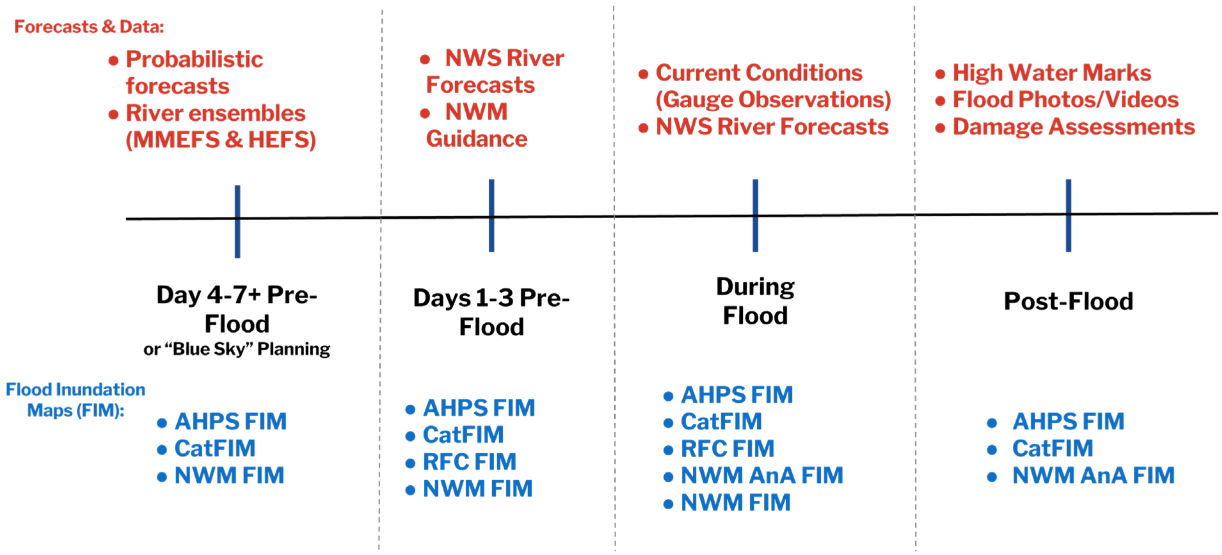
Lancaster, PA - NWS CatFIM

Flooding along Millcross Road in Lancaster, PA after Ida, Sept 2021

Key Points

- The primary goal for all NWS FIMs is to serve as a tool to support decision making that protects lives and property during river flood events.
- These experimental maps represent the NWS' best approximation of inundation extent based upon modeled river discharge. FIMs should only be used for improved understanding of where areas may be inundated from floodwaters.
- To achieve nationwide spatial coverage, FIMs incorporate some assumptions and limitations, which affect map accuracy. Therefore, the maps are subject to revision, and actual areas that could become flooded may differ from the areas shown on the maps. Continuous map verification and improvement efforts are underway, along with routine map updates.
- Never hesitate to reach out to your local NWS Weather Forecast Office or NWS River Forecast Center if you have questions about FIMs. The FEMA Hurricane Liaison Team and State Meteorologists can also provide guidance and support if NWS is unavailable.

Visual 44: NWS FIM Use Before, During, and After a Flood Event



Key Points

This chart is a way to visualize the timeline outlined in the previous pages.

Visual 45: FIM Considerations

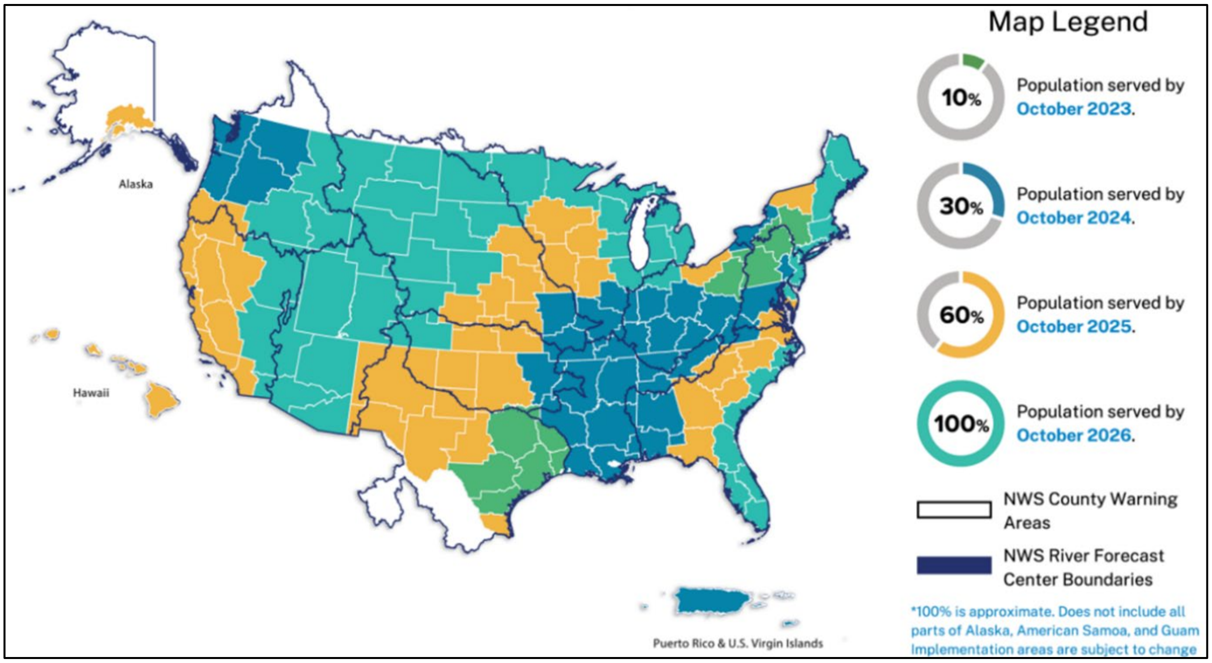
Key Points

How you, as an Emergency Manager, use FIMs will depend on your level of understanding and ability to fit them into your planning and operations. Here are some important considerations:

1. The official NWS forecast hydrographs are still crucial to flood preparedness and response. Human-created forecasts are still generally higher quality than raw computer model output.
2. Know the limitations of the FIM you are evaluating. Ask yourself if the map accurately represents the current rainfall and hydrologic forecasts.
3. FIMs can be overwhelming for decision-makers. You can’t pinpoint every single impact. The key is to locate critical impacts (i.e., roads, bridges, critical infrastructure, etc.). A best practice is to use a critical infrastructure layer, in conjunction with existing NWS impact statements in the Watch/Warning text and the impacts table on the AHPS page for the gauge location.
4. Focus on neighborhood-level accuracy and not on a single street or house level. All FIMs have uncertainty and we have to be careful with over/underestimating the potential impacts.
5. Lastly, don’t forget to watch out for local structures that may or may not be accounted for (i.e., levees, culverts, etc.). These can impact the quality of the map in question.

Never hesitate to reach out to your local NWS Weather Forecast Office or NWS River Forecast Center for guidance on FIM usage. The FEMA HLT and State Meteorologists are also available to provide guidance and support if NWS in unavailable.

Visual 46: NWS FIM Rollout



Key Points

The FIM products will be rolled out gradually. This map shows which NWS Weather Forecast Office forecast/warning area will have access to it in which year. By October 2026, Emergency Managers in nearly all of the United States will have access to the FIM.

Visual 47: Dam Hazards

Dam failure threat level terminology can vary between dam operators, which can easily cause confusion.

- Work with your dam operators in blue sky to understand their processes and language.

Dam inundation flood analysis (hasty analysis program used by some WFOs).

Exercises!

Key Points

Make sure that the terminology used in describing dam threats is understood or translated to a common language since terms vary between dam operators. It is important to understand the terms and processes that operators use so that planning and response efforts are appropriately executed.

Visual 48: Operational Timeframe

- Understand pre-existing conditions, hazard related or infrastructure/facilities.
- Ensure internal and external communication channels are open.
- Realize the operational timeframe.
- Anticipate staffing issues that may impact the activation.

Key Points

Think through the operational considerations specific to your jurisdiction.

Visual 49: Execution Plan/Checklist/Timeline

Comprehensive guide to direct hurricane preparedness and decision-making for both pre-season and impending hazards.

Decisions and Actions are effective if they are based on:

- An understanding of tropical cyclones
- Hazards
- Community vulnerabilities
- Forecast products
- Good decision-making process

Public and private involvement is essential!

- Checklists are specific to each community.

Key Points

The Hurricane Readiness Checklist should be community-specific:

- The checklist should be time-sequenced.
- Identify responsible agencies or officials for each task.
- Evaluate priority of actions to be addressed.

Visual 50: Importance of an Execution Checklist/Timeline

- Prompts for timely action
- Supports decision-making accountability
- Structures documentation
- Ensures coordination and communication

Key Points

Review your jurisdiction's operational resources and checklists. Update them with the information and knowledge you gained from this course.

Visual 51: 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

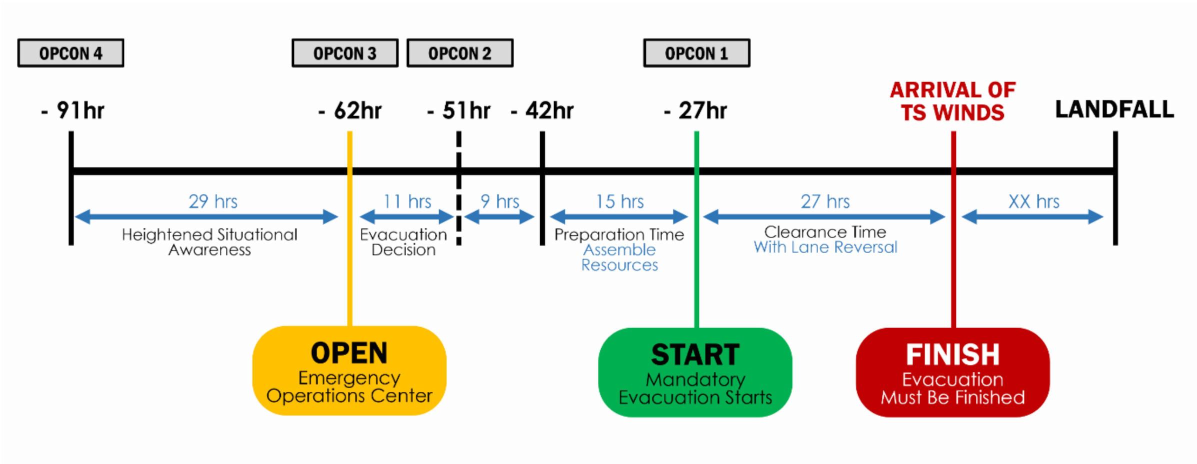
This is an example. Each jurisdiction will have different actions based on local operations. You can assign Priority levels, Personnel responsible, Status of the task, and when it was completed. It may seem laborious but well worth the while during a frantic emergency.

- 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 52: Timeline Example

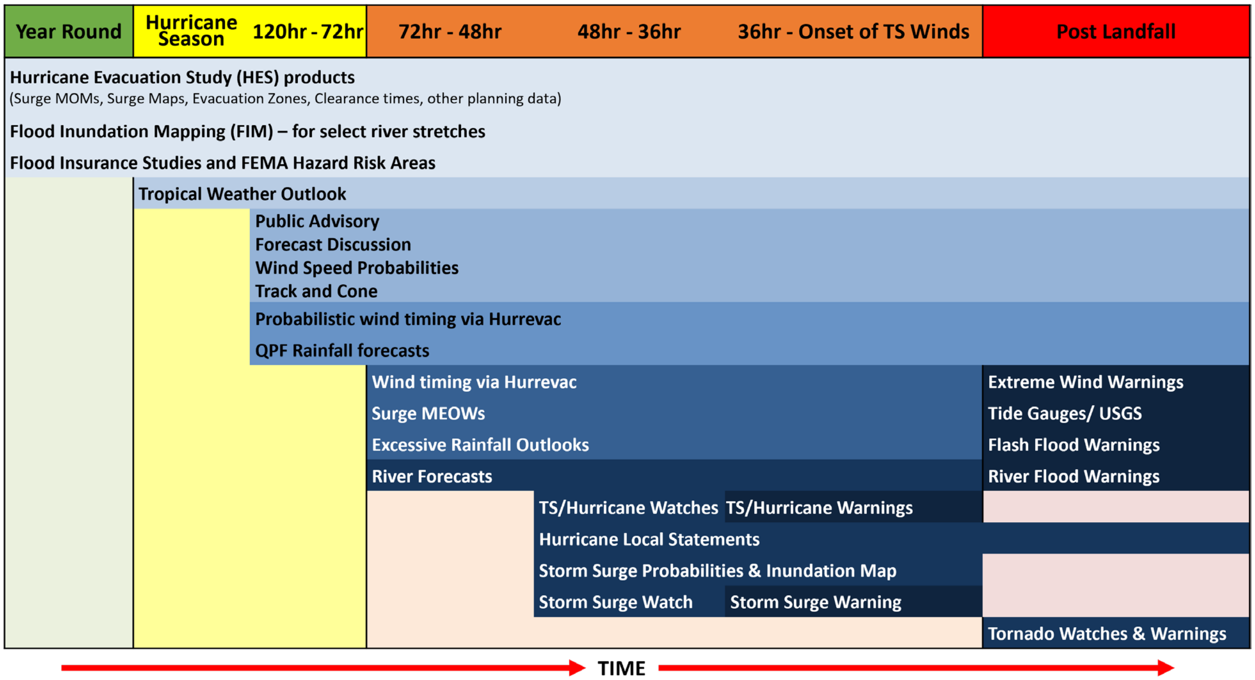


Horry County Evacuation Timeline for ABC Scenario

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 53: Forecast Product Timeline



Key Points

Decisions and actions on your execution timeline need to account for the types of forecast products/guidance (and levels of certainty) that will be available at specific points in the leadup to onset of hazards.

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

Visual 54: Resource Planning

Here are common items that are most likely to be needed during disasters:

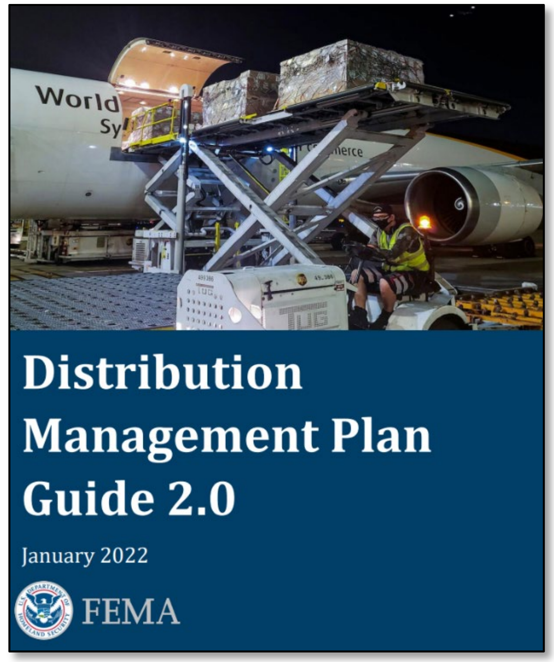
- Shelf Stable Meals
- Bottled Water
- Cots
- Blankets
- Infant Toddler Kits
- Medical Equipment/Supply Kits
- Tarps
- Blue Sheeting
- Generators
- Fuel

Key Points

Many communities have these items as part of shelter kits; however, do you know if your community has any gaps? It is vital for emergency preparedness that inventory is taken routinely to ensure that numbers keep up with population changes, expiration dates, or damage. Additionally, ensuring that the right types of equipment are available to run critical facilities with plenty of fuel is important to ensure the community continues to have access to needed services.

Visual 55: Resource Planning (cont.)

- Prior to the storm, have a plan on how you're going to acquire critical resources, and identify specific sources.
- Communicate any remaining resource gaps to stakeholders.
- There are several logistical planning resources for Emergency Managers.



Key Points

Working together to evaluate gaps in the level of logistics you are responsible for is key in understanding the logistics chain. Once you understand your own organization's gaps, you can work up, down, and laterally to begin to find ways to fill those gaps. Information gathered through a Logistics Capability Assessment Tool 2 or LCAT2 can inform plans and procedures in resource planning. The data can also be used to develop exercises to go through plans under tropical cyclone conditions.

Visual 56: HURREVAC

Hurricane tracking and decision support tool

- Tropical Weather Outlook
- Tropical Cyclone track and historical error cone
- Wind probabilities and deterministic wind fields
- Tropical Storm Wind Time of Arrival
- Rainfall Forecasts and Excessive Rainfall Outlooks
- Significant River Flooding Outlooks
- Observed and forecast flood stages along rivers (although less functionality and info than on AHPS website).

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.

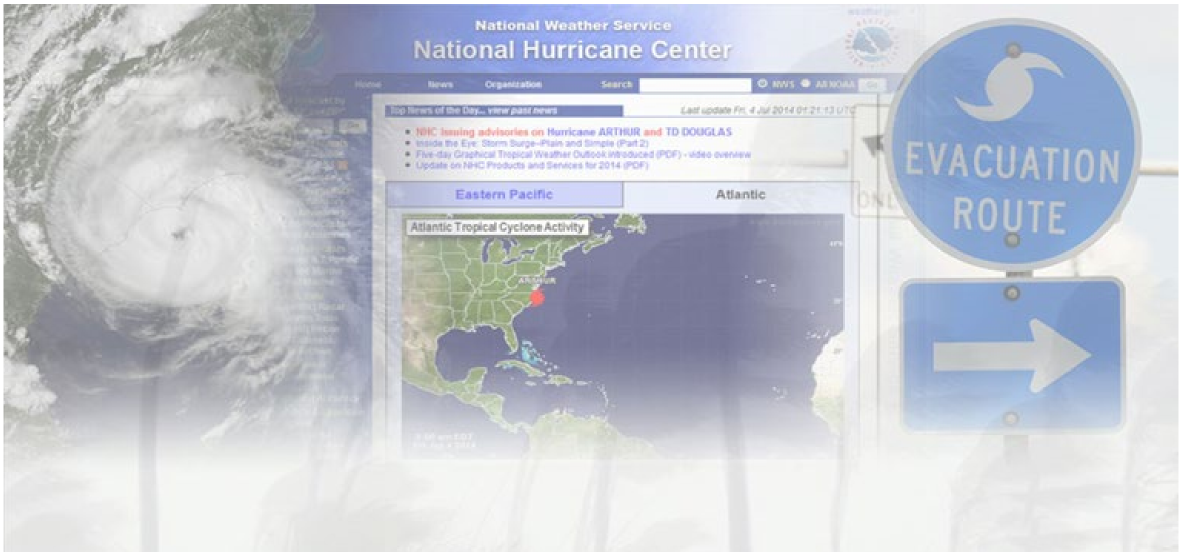
Visual 57: Brief Course Review

- No such thing as “just a Tropical Storm.”
- Forward speed matters for inland impacts.
- Plan for tornadoes as bands come ashore, especially in the right-front quadrant of the tropical cyclone away from the center.
- The NWS and NHC have numerous products that are useful for Emergency Managers to understand TC hazards (i.e., FIM, Public Advisory, etc.) in addition to other products such as Hurrevac that aid in evacuation planning and response.
- The weaker the tropical cyclone, the less certainty about the track.
- High Risk days for excessive rainfall/flash flooding are historically fatal and costly, but also don’t let your guard down if you’re in the Moderate Risk.
- Inland flooding situations can change rapidly.
- HLT is here to help!

Key Points

- Review the key course takeaways above, and remember that the HLT is here to help, and one of many resources that you all can utilize when tropical cyclones threaten.

Visual 58: Questions/Comments



Visual 59: Final Examination

Time: 30 minutes

Activity: Complete final exam.

Student Manual	You have 30 minutes to complete the final examination. You must receive a passing grade of at least 75% to pass this course.