# HURRICANE READINESS
## *L-311*

FEMA

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## HURRICANE READINESS
### *Administrative Details*

FEMA

### ADMIN DETAILS

- **Course application – FF119-25-2**
  - Student Identification (SID) Number required
  - Include your email address
  - Sign the application

- **EMI Evaluation Form (scantron)**
  - Evaluate instruction and content
  - Provide comments and suggestions

- **EMI certificate**
  - Must attend the entire course to receive credit
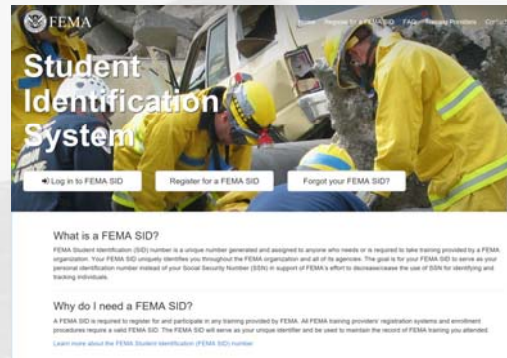  - EMI certificates will be sent via email

## HURRICANE READINESS
*Administrative Details*

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### STUDENT IDENTIFICATION (SID)

- **https://cdp.dhs.gov/femasid**

- **Select 'Register for a FEMA SID'**
  - Follow instructions and you will receive an email with your SID #

- **If you think you have an SID #**
  - Call 866.291.0696



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## HURRICANE READINESS
*Evaluations*

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### APPROPRIATE WORDING :)

- **"This has been the best learning experience!"**

- **"The instructors totally blew me away with their insightful knowledge and presentation skills."**

- **"I feel 1000% ready for the next hurricane threat."**

- **"You had me at hurricanes."**

## HURRICANE READINESS
*Evaluations*

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### STATE CODES

- Texas      49
- Louisiana      22
- Mississippi      29
- Alabama      02
- Florida      12
- Georgia      13
- South Carolina      45

- North Carolina      31
- Virginia      51
- Maryland      24
- DC      10

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## HURRICANE READINESS
*Evaluations*

FEMA

### STATE CODES

- Connecticut      08
- Delaware      11
- Maryland      24
- Maine      25
- Massachusetts      23
- New Hampshire      34
- New Jersey      35

- New York      38
- Pennsylvania      42
- Puerto Rico      43
- Virgin Islands      52
- Vermont      53

# HURRICANE READINESS
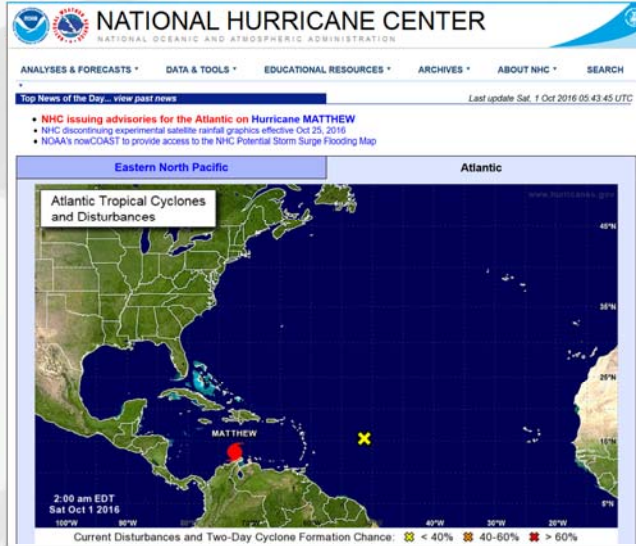## L-311

FEMA

**HURRICANE READINESS**
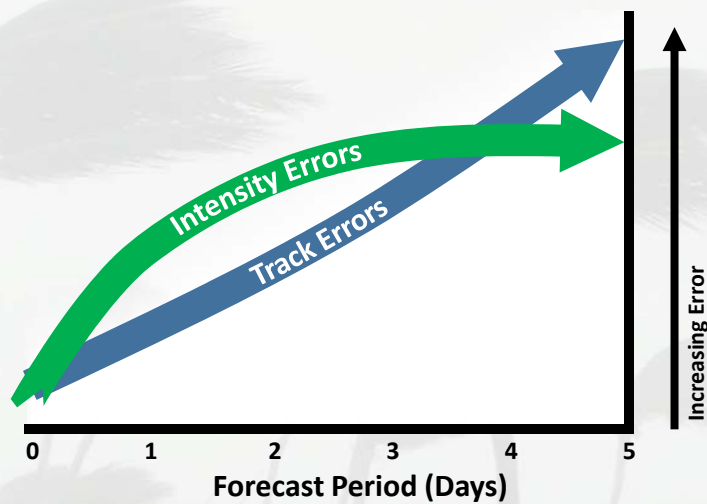*Hurricane Basics*

FEMA
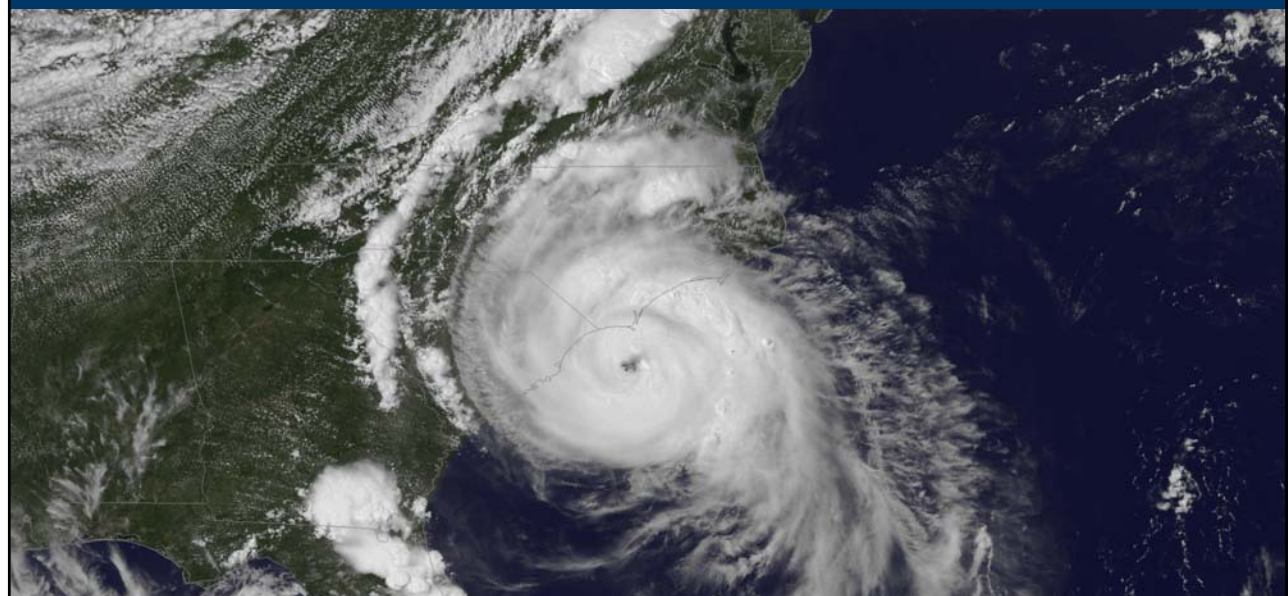
# HURRICANE READINESS
*There is a Storm. What's the Info?*

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# HURRICANE READINESS
*Forecast Uncertainty. What, Me Worry?*

FEMA

## HURRICANE READINESS
### *Making Better Decisions*

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## HURRICANE READINESS
### *A Short Course*

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### AGENDA

- **Hurricane Basics: Lifecycle, Climatology and Hazards**
  *830 am – 10 am*

- **There is a Storm. What's the info?**
  *1030 am – 12 pm*

- **Forecast Uncertainty. What, Me Worry?**
  *130 pm – 3 pm*

- **Making Better Decisions**
  *330 pm – 5 pm*

**HURRICANE READINESS**
*A Short Course*

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# UNIT ONE
## *Hurricane Basics*

**HURRICANE BASICS**
*Life Cycle. Climatology. Hazards.*

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## TROPICAL CYCLONES
### *Hurricane. Typhoon. Tropical Storm.*

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## TROPICAL CYCLONES

- **Large, long-lived low pressure system**
  (Can be hundreds of miles wide, lasting for days)

- **Forms over sub/tropical oceans**

- **No fronts attached**

- **Produces organized thunderstorm activity**

- **Has a closed surface wind circulation around a well-defined center**

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## TROPICAL CYCLONES
### *Classified by Maximum Wind Speed*

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– **Tropical Depression:  < 39 mph**

– **Tropical Storm:  39-73 mph**

– **Hurricane:  74 mph or greater**

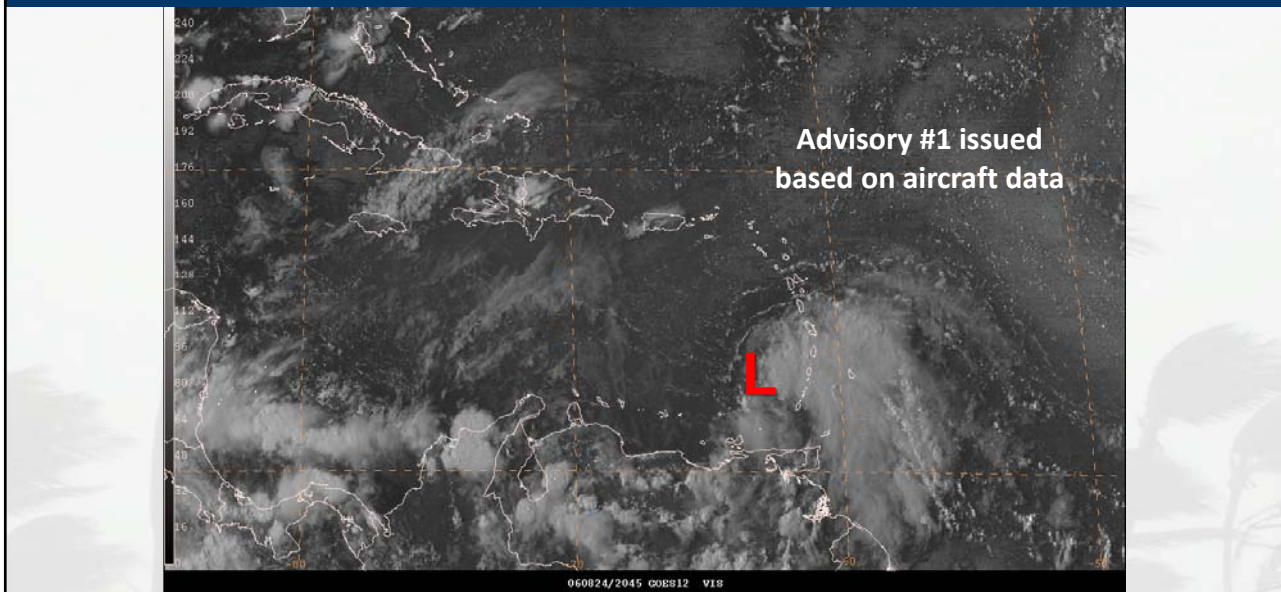  • *Major Hurricane:  111 mph or greater*
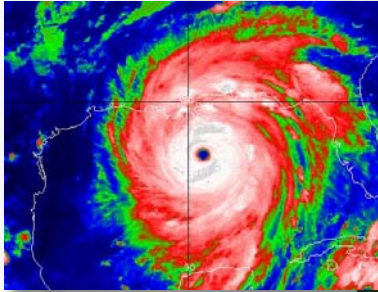
## TROPICAL CYCLONES
*Surface Circulation? Organized?*
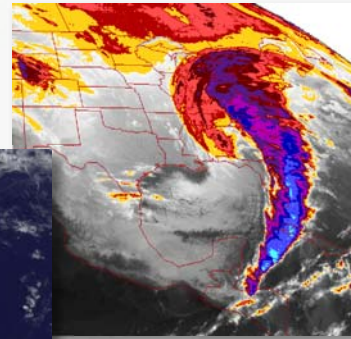
FEMA
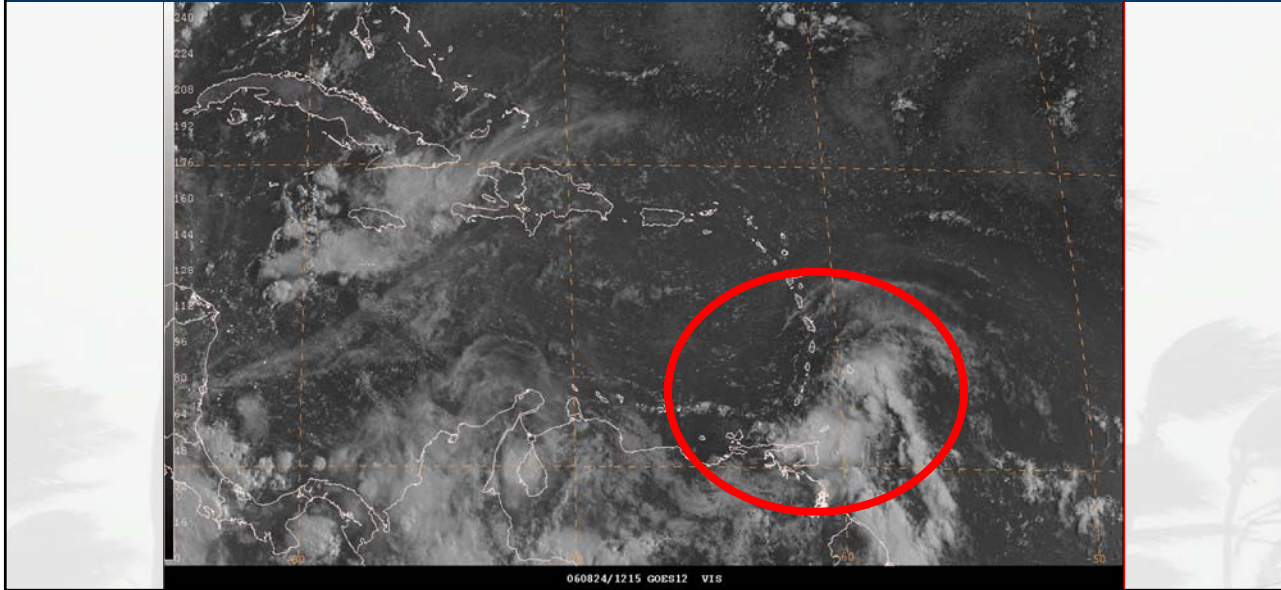


## TROPICAL CYCLONES
*Ernesto 2006*

FEMA



Advisory #1 issued
based on aircraft data

L

## CYCLONES
### *Tropical, Subtropical and Extratropical*
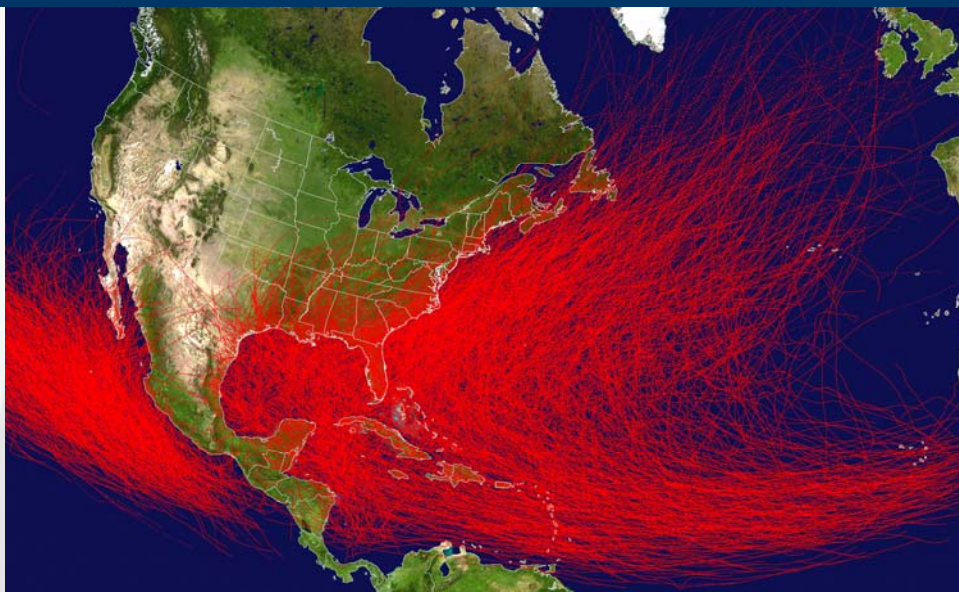
FEMA

Hurricane Katrina 2005
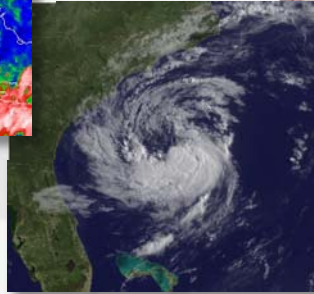
Subtropical Storm Ana 2015

March Superstorm 1993

## TROPICAL CYCLONES
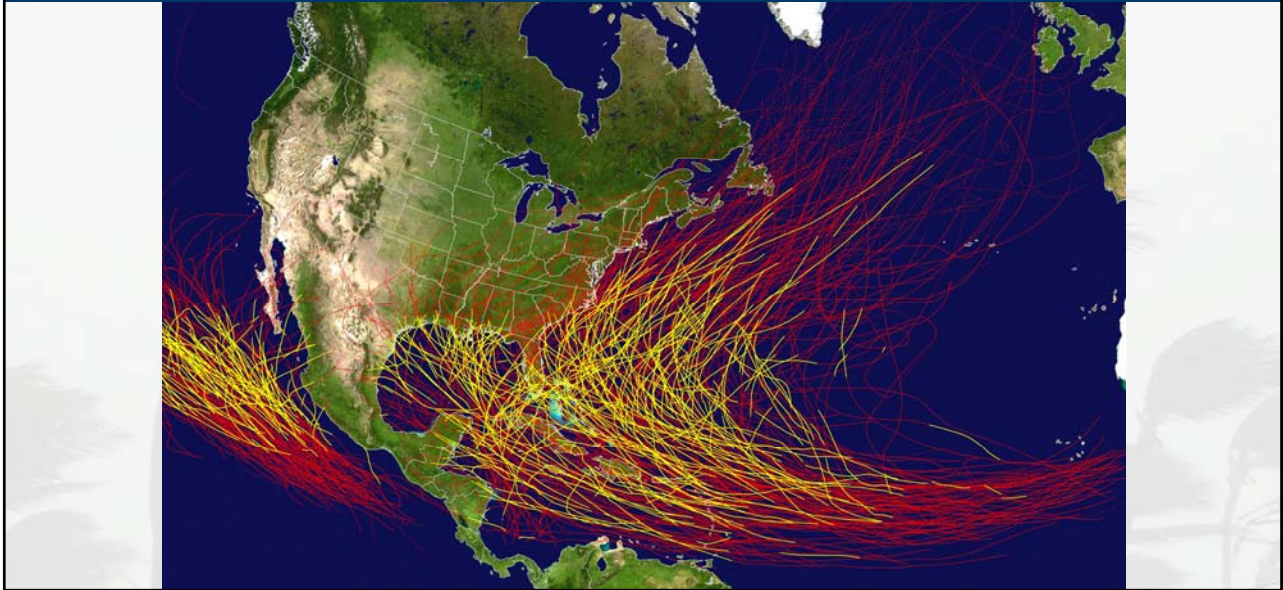### *Atlantic since 1851. Pacific since 1949.*

FEMA

## MAJOR HURRICANES
*Atlantic since 1851. Pacific since 1949.*
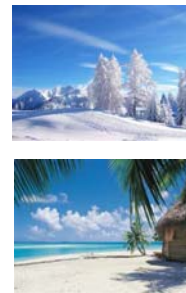
FEMA



## CLIMATOLOGY
*What do you know?*

FEMA

### QUIZ QUESTION
**What month has the most hurricane activity in the Atlantic?**

A. December
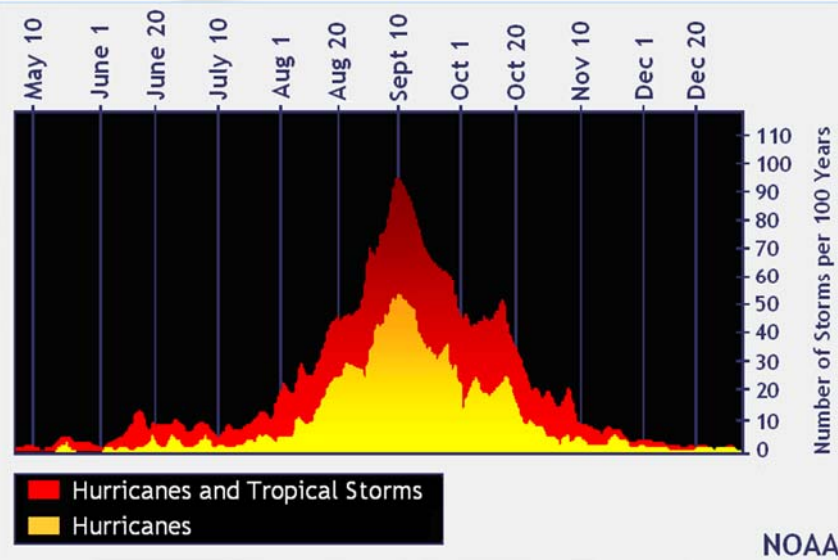
B. August

C. June

D. September

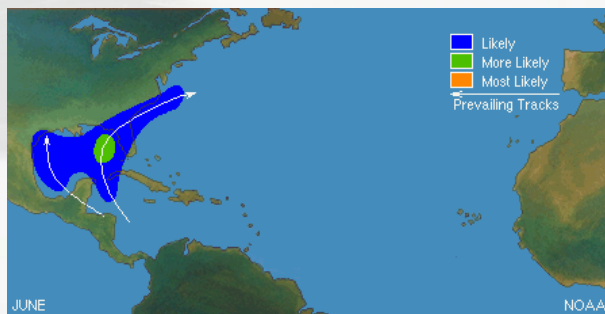## CLIMATOLOGY
*Atlantic Hurricanes & Tropical Storms*

FEMA



## CLIMATOLOGY
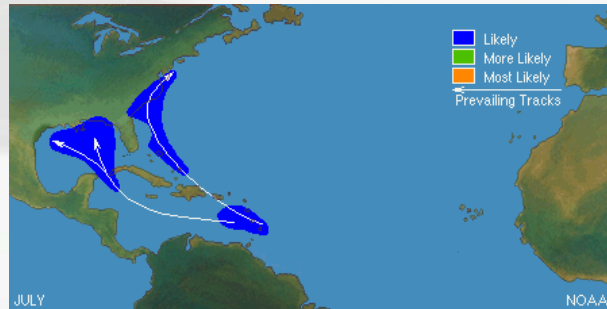*June Formation Areas*

FEMA



- **On average about 1 storm every other year.**
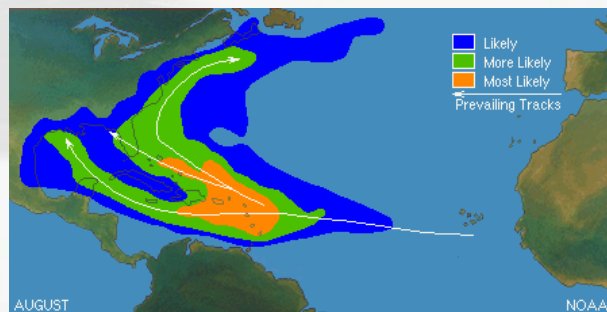- **Most June storms form in the NW Caribbean Sea or Gulf of Mexico.**

## CLIMATOLOGY
*July Formation Areas*

FEMA



- **On average about 1 storm every year.**
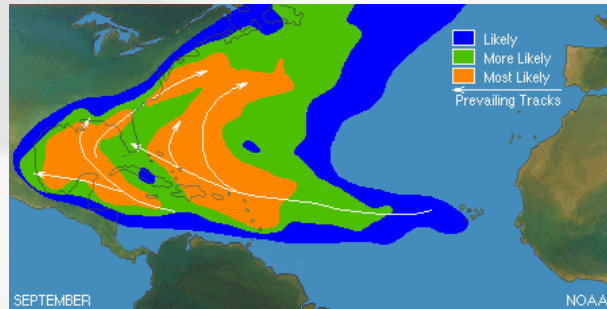- **July development areas spread east and covers the western Atlantic, Caribbean, and Gulf of Mexico.**

## CLIMATOLOGY
*August Formation Areas*

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- **On average about 2-3 storms form each year.**
- **The Cape Verde season usually begins in August.**
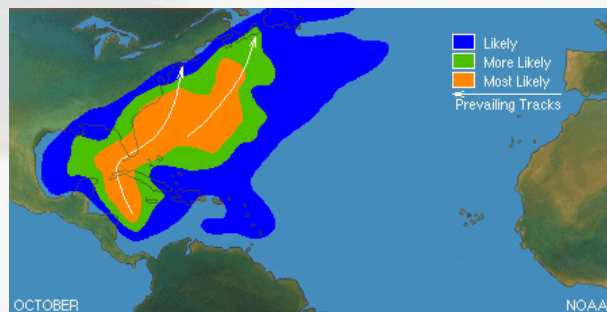
## CLIMATOLOGY
*September Formation Areas*

FEMA



- **September is the climatological peak of the season.**
- **Storms can form nearly anywhere in the basin; Long track Cape Verde storms.**

## CLIMATOLOGY
*October Formation Areas*

FEMA



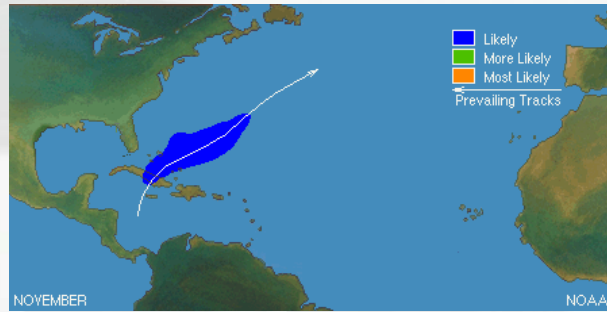- **Secondary peak of season in mid-October.**
- **Cape Verde season ends. Development area shifts back to the Gulf, Caribbean and western Atlantic.**

## CLIMATOLOGY
### *November Formation Areas*

FEMA



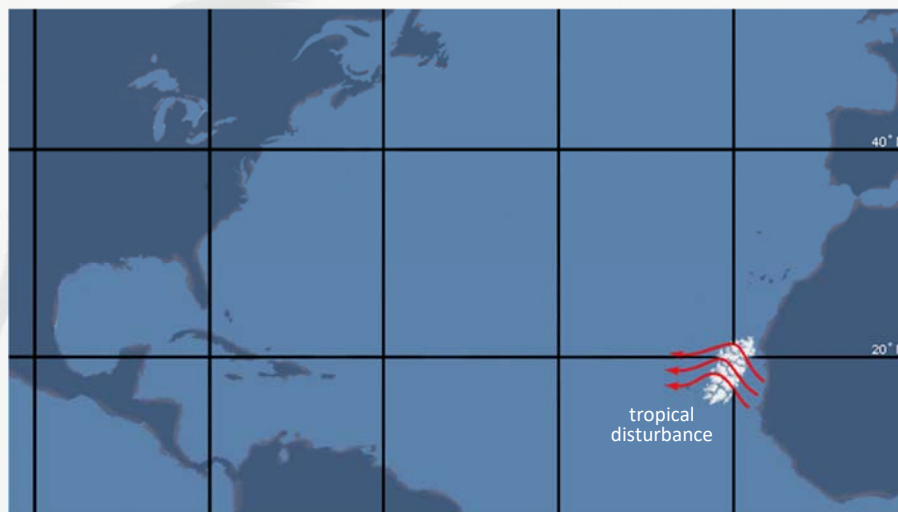- **On average about 1 storm ever other year.**
- **Storms that do form typically develop in central Caribbean or western Atlantic.**

## HURRICANE LIFECYCLE
### *Cape Verde Hurricanes*

FEMA

## HURRICANE LIFECYCLE
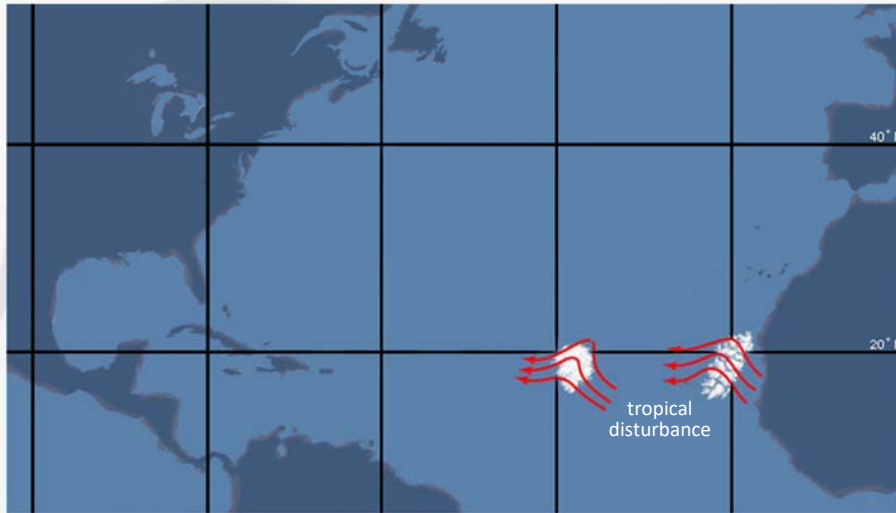*Cape Verde Hurricanes*

FEMA



## HURRICANE LIFECYCLE
*Cape Verde Hurricanes*

FEMA

**HURRICANE LIFECYCLE**
*Cape Verde Hurricanes*



**HURRICANE LIFECYCLE**
*Cape Verde Hurricanes*

3/26/2018

# HURRICANE LIFECYCLE
*Cape Verde Hurricanes*

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# HURRICANE LIFECYCLE
*Cape Verde Hurricanes*

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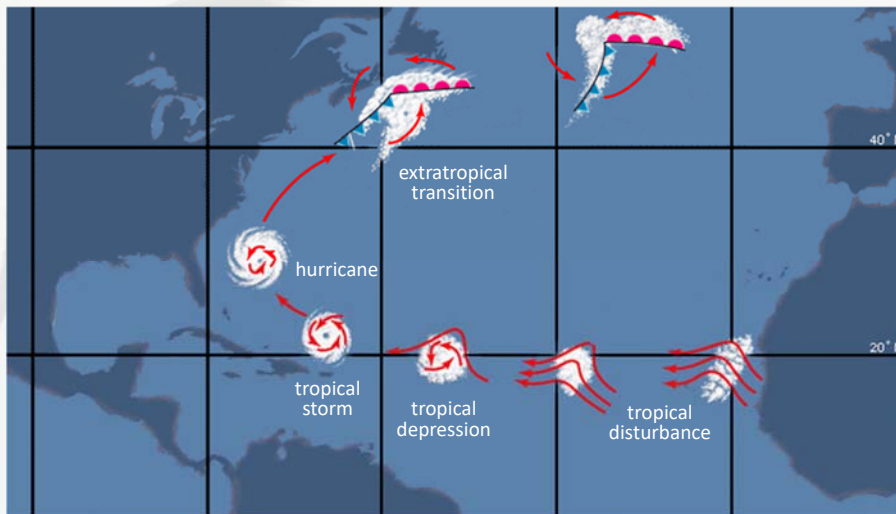
## HURRICANE LIFECYCLE
*Hurricane Bill (2009)*

FEMA
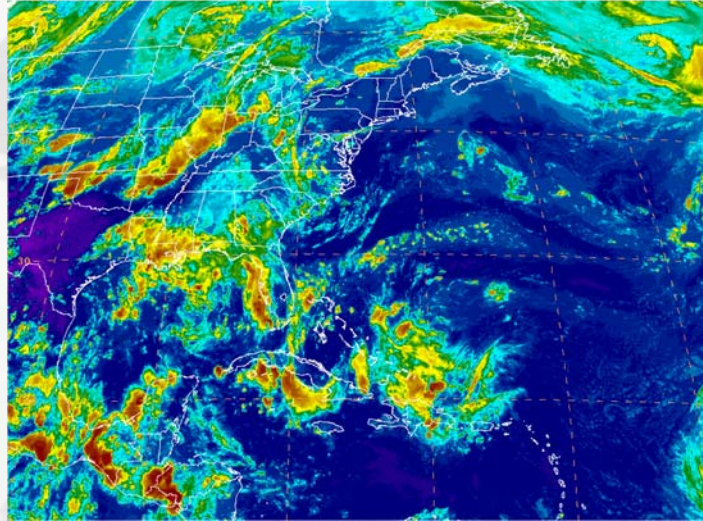


## HURRICANE FORECASTING
*What do you know?*

FEMA

### QUIZ QUESTION
Which of these are ingredients for hurricane development?
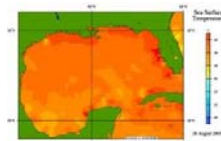


A. Warm Water
B. Cold Air
C. Lots of Moisture
D. Strong Winds Aloft
E. Icebergs

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## HURRICANE LIFECYCLE
### *Ingredients for Formation*

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| BUILDING BLOCKS | FUEL |
|---|---|
| 1) A pre-existing disturbance (vorticity or spin) | 4) Warm sea-surface temperatures (usually at least 80°F) |
| 2) Location several degrees north of the equator | 5) Unstable atmosphere (temperature goes down as you go up) |
| 3) Little change in wind speed and/or direction with height (vertical wind shear) | 6) High atmospheric moisture content (relative humidity) |

## HURRICANE FORECASTING
### *Pre-existing Disturbances*

FEMA

### DISTURBANCES

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

- **Decaying cold fronts**
  - Formation often near Gulf and SE States
  - Typically early or late season storms

- **Non-tropical lows and thunderstorm complexes**
  - Often subtropical systems

## HURRICANE FORECASTING
*Storm Motion and Track*

FEMA

### FORECASTING

- **Track forecast is usually controlled by large-scale weather features**
  - Cork in the stream analogy

- **Numerical computer models forecast track quite well**
  - Constantly upgrading model physics and resolution
  - Long ago surpassed statistical models in accuracy



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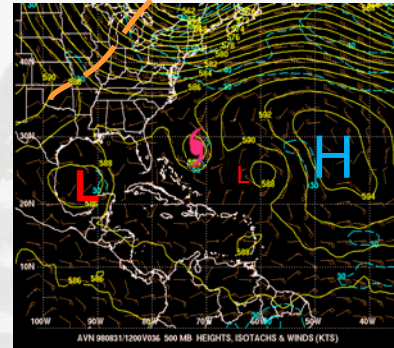
## HURRICANE FORECASTING
*Factors that Influence Intensity*

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### INTENSITY FACTORS

- **Upper Ocean Temperatures**
  *More heat favors a stronger storm*

- **Interaction with Land/Topography**
  *More land increases weakening*

- **Vertical Wind Shear**
  *Shear limits strengthening*

- **Moisture in Storm Environment**
  *Dry air can limit strengthening*

- **Structural Changes, Eyewall Replacement**
  *Difficult to forecast and not straightforward*

- **Interactions with other weather systems**

## HURRICANE FORECASTING
*One size does not fit all.*

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Charley
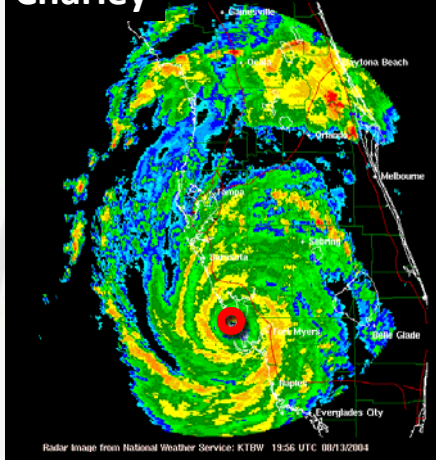

Wilma
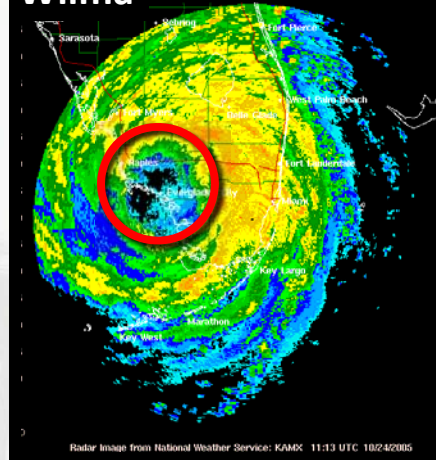
## HURRICANE HAZARDS
*What do you know?*

FEMA

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

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

## HURRICANE HAZARDS
*Water is responsible for vast majority*

FEMA

### FATALITIES
**U.S. tropical cyclone fatalities**
*– from 1963 - 2012*



Pie chart:
- Storm Surge 50%
- Rainfall-induced Flood 25%
- Surf 5%
- Offshore 5%
- Wind 5%
- Tornado 5%
- Other
- Unknown 5%

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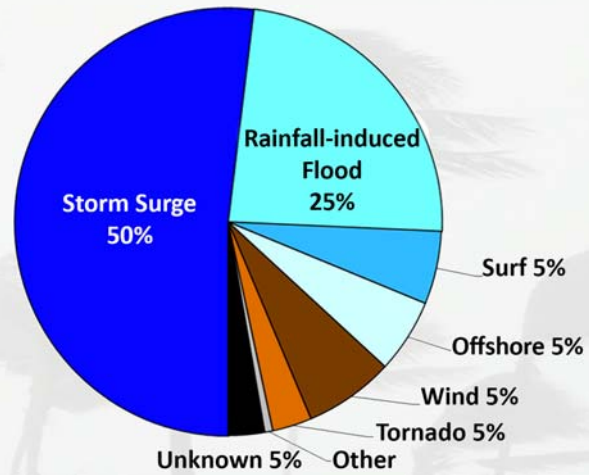
## HURRICANE HAZARDS
*Surge. Wind. Flood. Tornadoes. Waves.*

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Wind

Waves / Rip Currents

Tornadoes

Storm Surge

Inland Flooding
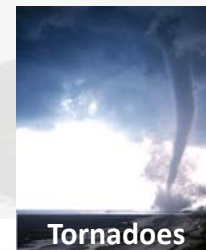
## HURRICANE WINDS
*Saffir-Simpson Scale*

FEMA

# SAFFIR-SIMPSON SCALE
- **Estimates wind damage**

| | | | MAJOR HURRICANES | | |
|---|---|---|---|---|---|
| **TROPICAL STORM** 39 – 73 mph (34 – 63 kt) | **CATEGORY 1** 74 – 95 mph (64 – 82 kt) | **CATEGORY 2** 96 – 110 mph (83 – 95 kt) | **CATEGORY 3** 111 – 129 mph (96 – 112 kt) | **CATEGORY 4** 130 – 156 mph (113 – 136 kt) | **CATEGORY 5** > 156 mph (> 136 kt) |
| Debby (2012) | Isaac (2012) | Ike (2008) | Katrina (2005) | Charley (2004) | Andrew (1992) |
| Allison (2001) | Claudette (2003) | Isabel (2003) | Wilma (2005) | Hugo (1989) | Camille (1969) |

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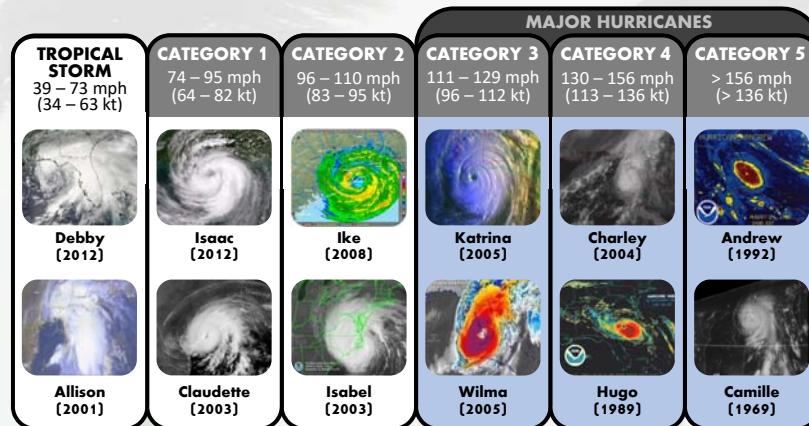
## HURRICANE WINDS
*Category 1 (74 – 95 mph)*

FEMA

# CATEGORY ONE
- **Some Damage**
  - Well-constructed frame homes could have roof damage.
  - Large branches of trees will snap and shallow-rooted trees may topple.
  - Damage to power lines and poles; Outages could last a few to several days

Humberto (2007) Southeast TX

Claudette (2003) Palacios, TX

Lili (2002) Louisiana
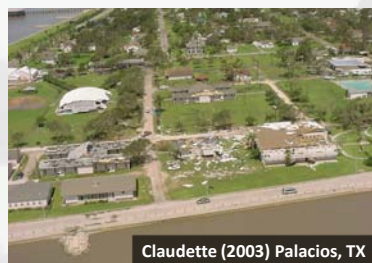
## HURRICANE WINDS
*Category 2 (96 – 110 mph)*

FEMA

# CATEGORY TWO

- **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 days to weeks.


Ike (2008) Houston, TX


Juan (2003) Halifax, NS


Wilma (2005) SE Florida

## HURRICANE WINDS
*Category 3 (111– 129 mph)*

FEMA

# CATEGORY THREE

- **Devastating Damage**
  - Well-built framed homes may incur major damage.
  - Many trees will be snapped or uprooted.
  - Electricity and water will be unavailable for several days to weeks.


Jeanne (2004) Cape Canaveral, FL


Rita (2005) Orange, TX


Rita (2005) Orange, TX

## HURRICANE WINDS
### *Category 4 (130 – 156 mph)*

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## CATEGORY FOUR

- **Catastrophic Damage**
  - Well-built framed homes can sustain severe damage.
  - Most trees will be snapped or uprooted and power poles downed.
  - Power outages will last weeks to possibly months.



Charley (2004) Punta Gorda, FL



Hugo (1989) Sullivans Island, SC



Ike (2008) Holguin, Cuba

## HURRICANE WINDS
### *Category 5 (>156 mph)*

FEMA

## CATEGORY FIVE

- **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.



Andrew (1992) Florida City, FL



Felix (2007) Nicaragua



Andrew (1992) South Dade, FL

## STORM SURGE
*Greatest potential for large loss of life.*

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**Hurricane Sandy (2012)**
**73 deaths**
**$65 billion damage**



**Hurricane Katrina (2005)**
**1200 deaths**
**$108 billion damage**

## STORM SURGE
*Storm Surge vs Storm Tide*

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

### STORM TIDE
The water level rise due to the combination of storm surge and the astronomical tide.



17 ft storm tide
15 ft Surge
2 ft normal high tide
Mean sea level
NOAA/The COMET Program
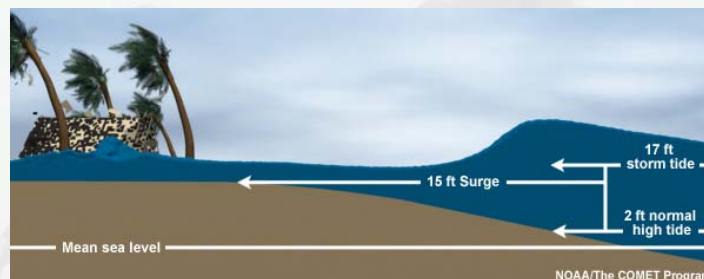
## STORM SURGE HISTORY
### Gulf Coast



Hurricane Katrina (2005)

Hurricane Georges (1998)

Hurricane Rita (2005)

Hurricane Ike (2008)

## STORM SURGE HISTORY
### Waveland, Mississippi



Kimberly and David King

# STORM SURGE HISTORY
## *Southeast*

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Hurricane Isabel (2003)


Hurricane Hugo (1989)


TS Fay (2008)


Hurricane Jeanne (2004)

# STORM SURGE HISTORY
## *Mid-Atlantic*

FEMA


Hurricane Isabel (2003)


Hurricane Isabel (2003)


Hurricane Sandy (2012)


Hurricane Sandy (2012)

## STORM SURGE HISTORY
### *New England*

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Hurricane Carol (1954)


Hurricane Irene (2011)


1938 Hurricane


Hurricane Sandy (2012)

## STORM SURGE
### *Factors Affecting Storm Surge*

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### STORM SURGE FACTORS

- **Intensity**
  *Stronger storm = More storm surge*

- **Size (Radius of Maximum Winds)**
  *Larger = More storm surge*

- **Forward Speed**
  *Slower storm = Storm surge farther inland*

- **Width and Slope of Shelf (Bathymetry)**
  *Gradual sloping shelf = More storm surge*

- **Angle of Approach**
  *Alters focus of storm surge*

## STORM SURGE
*What's the effect of intensity?*



## STORM SURGE
*What's the effect of size?*
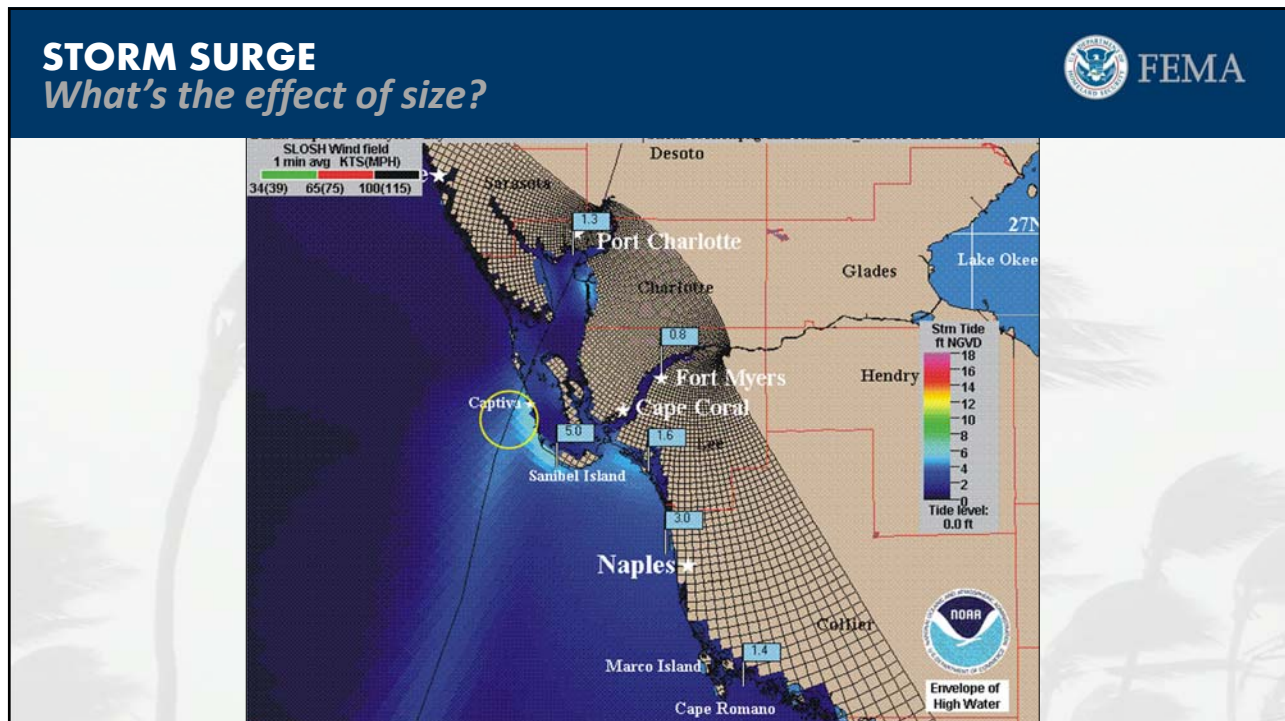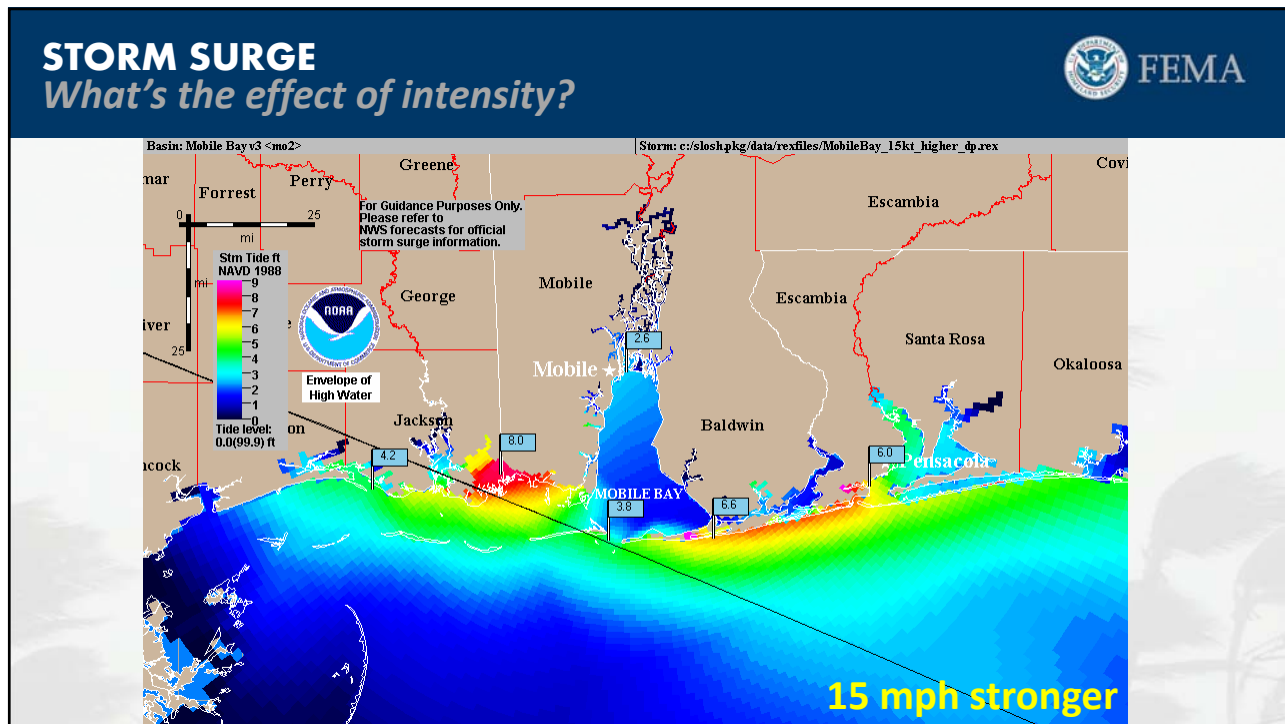
## STORM SURGE
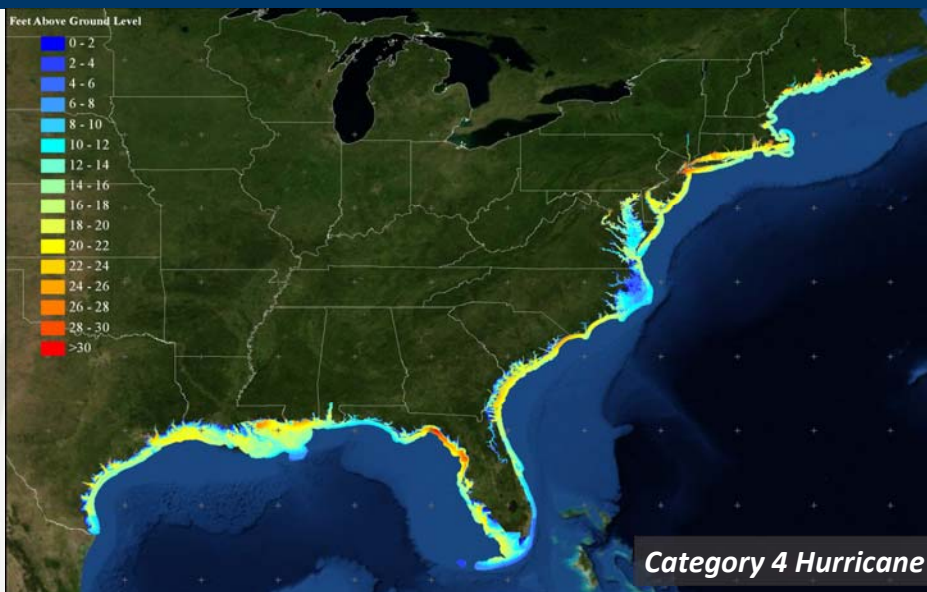*What's the effect of forward speed?*

FEMA
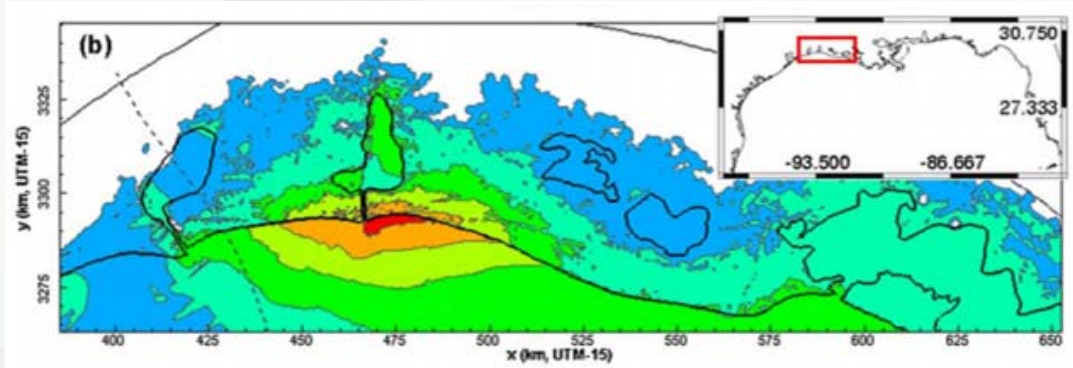


**Fast Speed (25 mph)**
- Higher maximum

## STORM SURGE
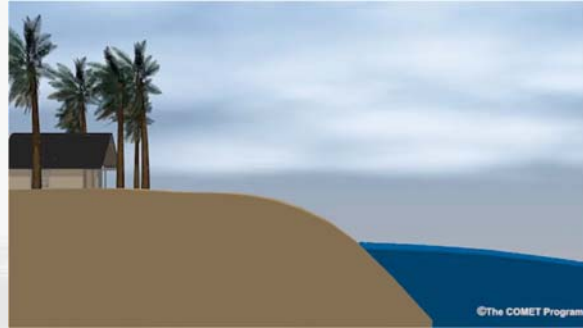*Location. Location. Location.*

FEMA



*Category 4 Hurricane*

# STORM SURGE
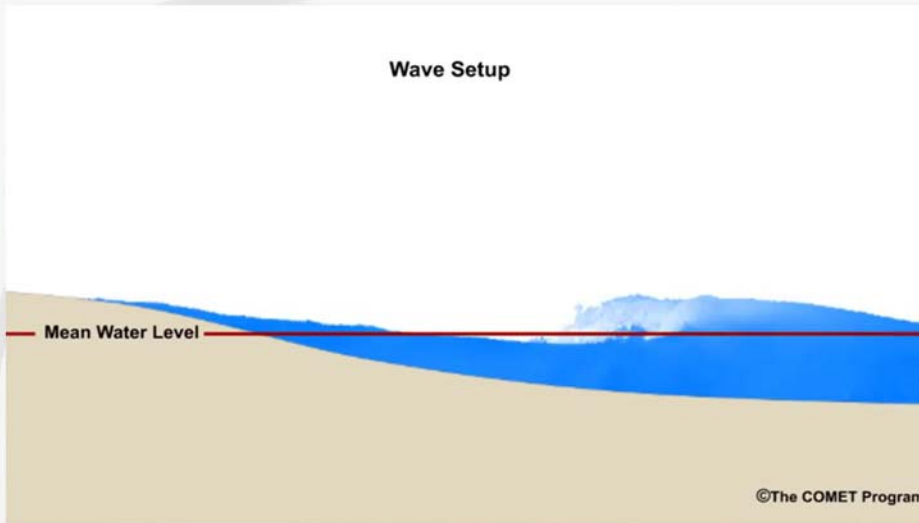*What's the effect of width/slope of shelf?*



Wide shelf – Gentle slope            Narrow shelf – Sharp slope

# STORM SURGE
*Wave Setup*

## STORM SURGE
*Components of 'Total Water Level'*

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### Total Water Level

**Storm surge + Tides + Wave Setup + Freshwater**

wave runup

wave crest (total water level)

wave setup

wind setup
pressure setup

Shoreline

mean sea level
(astronomical tide)

Kinetic Analysis Corporation © 2007

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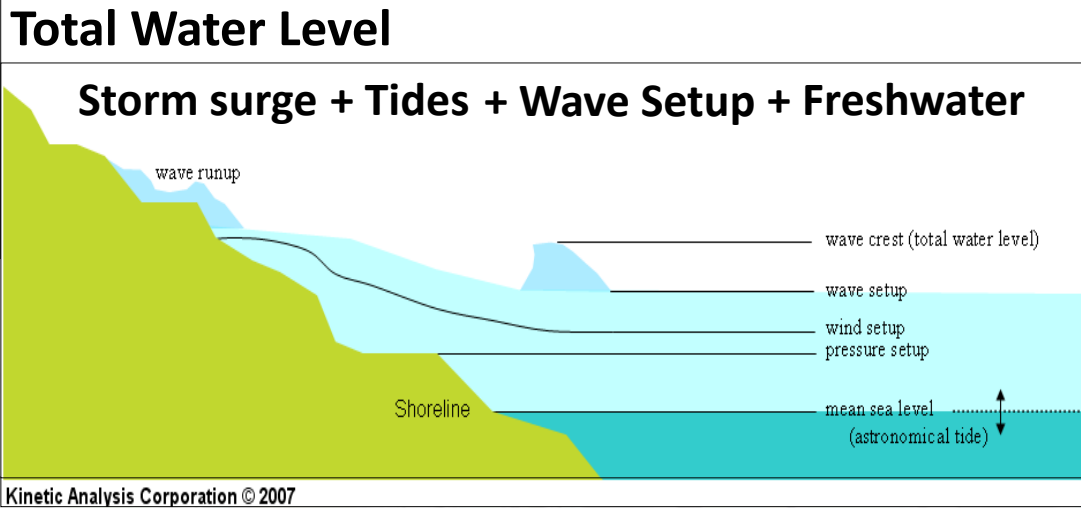
## FRESHWATER FLOODING
*U.S. Atlantic Tropical Cyclone Deaths*

FEMA

### FATALITIES
**U.S. tropical cyclone fatalities**
*– from 1963 - 2012*

Rainfall-induced
Flood
25%

Storm Surge
50%

Surf 5%

Offshore 5%

Wind 5%

Tornado 5%

Unknown 5%   Other

## FRESHWATER FLOODING
### *Flash Floods. Riverine Flooding.*

FEMA



Times Herald

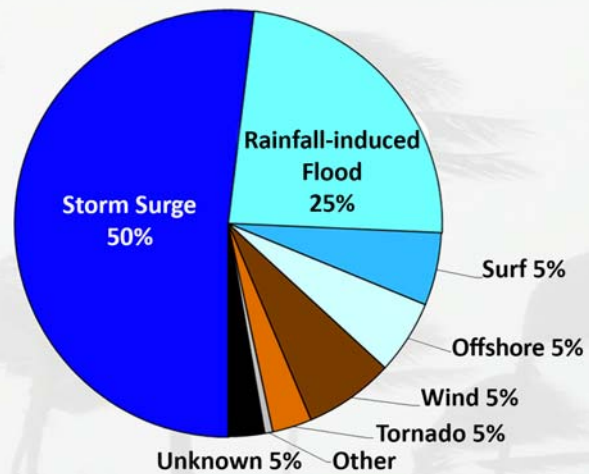Mansfield Heliflight

Reuters

US Army Corps of Engineers

## FRESHWATER FLOODING
### *Hurricane Harvey (2017) – Houston, TX*

FEMA



MARKET STREET, HOUSTON

GOOGLE MAPS, 2016

AUG. 27, 2017

## FRESHWATER FLOODING
*Hurricane Harvey (2017) – Houston, TX*



## FRESHWATER FLOODING
*Interstate 10 – Houston, TX*

## FRESHWATER FLOODING
### TS Allison (2001) – Houston, TX



Interstate 10 – West View

Houston Chronicle

## FRESHWATER FLOODING
### Hurricane Irene (2007) – New York and Vermont



Photo courtesy of L. Gange, Mansfield Helifight

Prattsville, NY Damage (Jimmy Vielkind/Times Union)

## FRESHWATER FLOODING
### *Hurricane Irene (2007) – New York and Vermont*

FEMA



Rochester, VT Flash Flooding



Gilboa Dam – Significant scouring & erosion

## FRESHWATER FLOODING
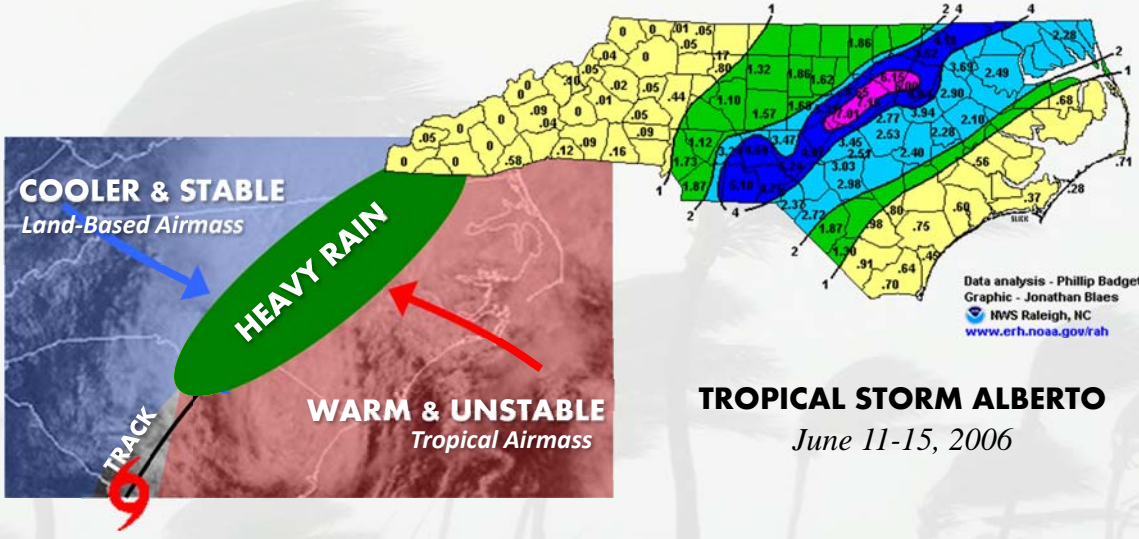### *Factors Affecting Tropical Cyclone Rainfall*

FEMA

### RAINFALL FACTORS

- **Forward Speed**
  *Slower storm = More rain*

- **Size**
  *Larger storm = More rain*

- **Topography / Mountains**
  *More rain on windward side*

- **Fronts / Upper-level troughs**
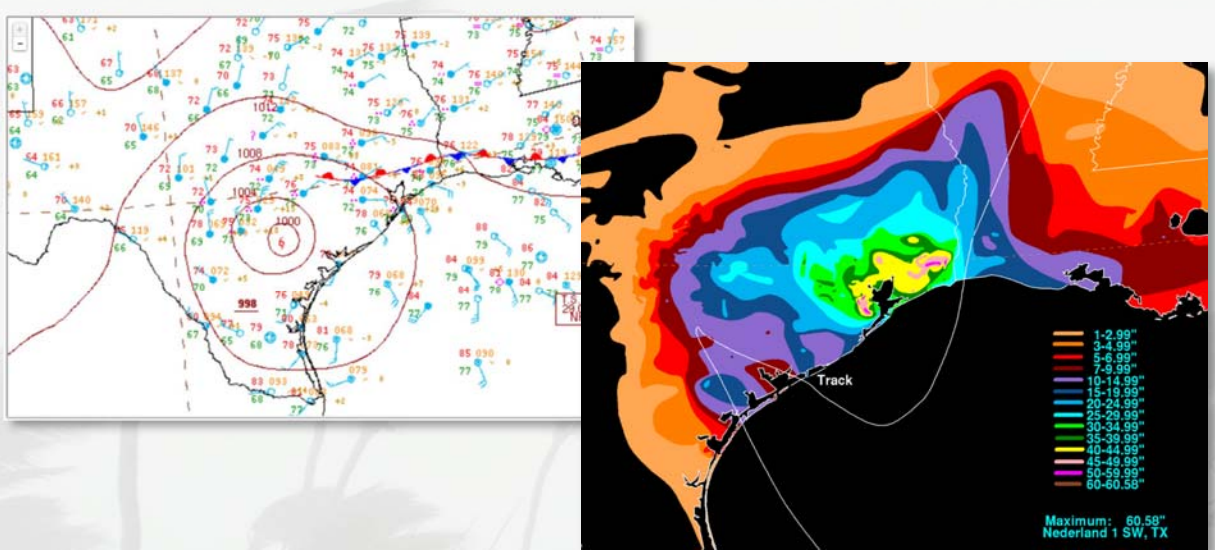  *Enhance rainfall*

# FRESHWATER FLOODING
## *TS Alberto (2016)*

FEMA



**TROPICAL STORM ALBERTO**
*June 11-15, 2006*

# FRESHWATER FLOODING
## *Hurricane Harvey (2017)*
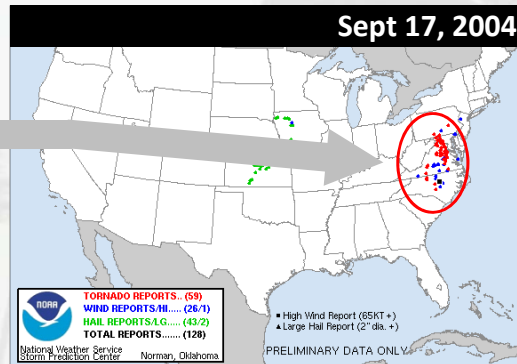
FEMA

## TORNADOES
*Landfalling hurricanes spawn tornadoes.*

FEMA

### TORNADOES
- **70% produce at least 1 tornado**
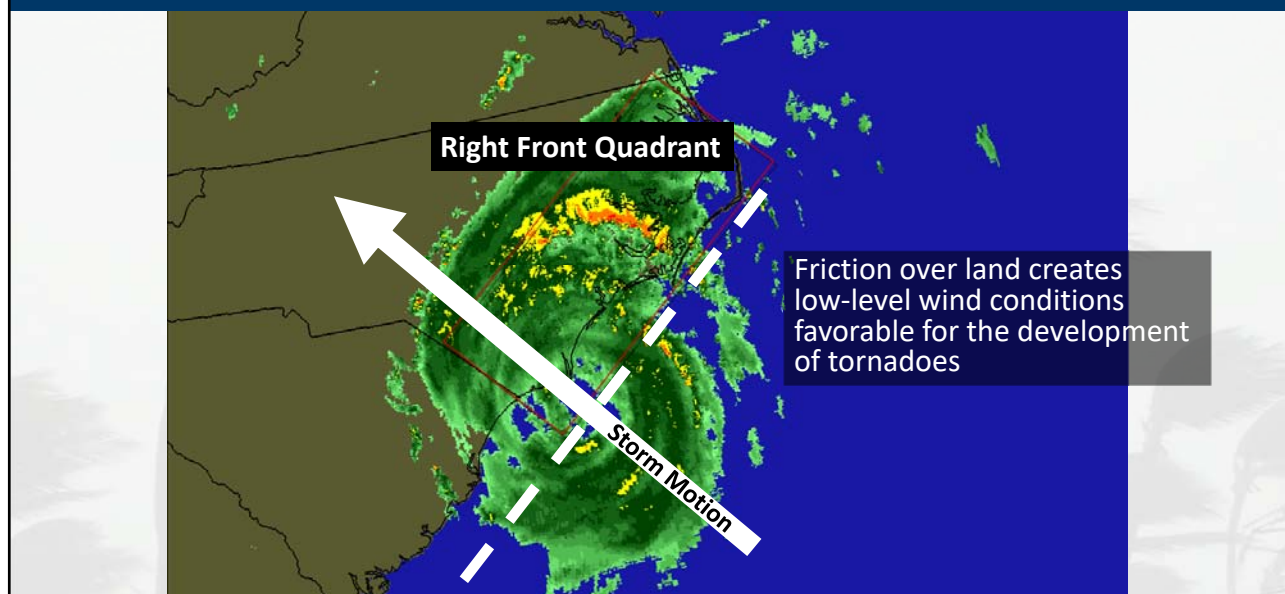- **40% produce more than 3 tornadoes**

**Sept 17, 2004**

**Tornado "outbreak"**

**Hurricane Ivan (2004)**
- **117 Tornadoes**

TORNADO REPORTS.. (59)
WIND REPORTS/HI..... (26/1)
HAIL REPORTS/LG..... (43/2)
TOTAL REPORTS....... (128)

National Weather Service
Storm Prediction Center    Norman, Oklahoma

■ High Wind Report (65KT +)
▲ Large Hail Report (2" dia. +)

PRELIMINARY DATA ONLY

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## TORNADOES
*Landfalling hurricanes spawn tornadoes.*

FEMA

**Right Front Quadrant**

Friction over land creates low-level wind conditions favorable for the development of tornadoes
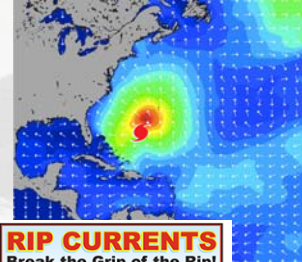
*Storm Motion*

## WAVES AND RIP CURRENTS
*Can occur when a storm is well offshore*



**Swells from a large hurricane can affect the beach of the entire western Atlantic**

**Hurricane Bertha (2008)**
- Over 1500 rescues in Ocean City, Maryland
- 3 people drowned along the coast of New Jersey

**Hurricane Bill (2009)**
- 1 person died in Maine
- 1 person died in Florida

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## HURRICANE BASICS
*Questions?*