HURRICANE READINESS
L-311

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

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

HURRICANE READINESS
Evaluations

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.”
<table>
<thead>
<tr>
<th>HURRICANE READINESS Evaluations</th>
</tr>
</thead>
<tbody>
<tr>
<td>STATE CODES</td>
</tr>
<tr>
<td>• Texas                         49</td>
</tr>
<tr>
<td>• Louisiana                     22</td>
</tr>
<tr>
<td>• Mississippi                   29</td>
</tr>
<tr>
<td>• Alabama                       02</td>
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<tr>
<td>• Florida                       12</td>
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<tr>
<td>• Georgia                       13</td>
</tr>
<tr>
<td>• South Carolina                45</td>
</tr>
<tr>
<td>• North Carolina                31</td>
</tr>
<tr>
<td>• Virginia                      51</td>
</tr>
<tr>
<td>• Maryland                      24</td>
</tr>
<tr>
<td>• DC                            10</td>
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<td>• Connecticut                   08</td>
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<td>• Delaware                      11</td>
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<td>• Maine                         25</td>
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<td>• New York                      38</td>
</tr>
<tr>
<td>• Pennsylvania                  42</td>
</tr>
<tr>
<td>• Puerto Rico                   43</td>
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<tr>
<td>• Virgin Islands                52</td>
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<tr>
<td>• Vermont                       53</td>
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</tbody>
</table>
HURRICANE READINESS

L-311

HURRICANE READINESS

Hurricane Basics
HURRICANE READINESS
There is a Storm. What’s the Info?

1. National Hurricane Center
2. Forecast Uncertainty. What, Me Worry?

- Forecast Period (Days)
- Intensity Errors
- Track Errors
- Increasing Error
- Forecast Period (Days)
HURRICANE READINESS
Making Better Decisions

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
UNIT ONE
Hurricane Basics

HURRICANE BASICS
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

TROPICAL CYCLONES

Classified by Maximum Wind Speed

– 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?

Advisory #1 issued based on aircraft data

TROPICAL CYCLONES
Ernesto 2006
CYCLONES
Tropical, Subtropical and Extratropical

Hurricane Katrina 2005

March Superstorm 1993

Subtropical Storm Ana 2015

TROPICAL CYCLONES
Atlantic since 1851. Pacific since 1949.
MAJOR HURRICANES
Atlantic since 1851. Pacific since 1949.

CLIMATOLOGY
What do you know?

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

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

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

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**CLIMATOLOGY**

*August Formation Areas*

- On average about 2-3 storms form each year.
- The Cape Verde season usually begins in August.
September is the climatological peak of the season.
Storms can form nearly anywhere in the basin; Long track Cape Verde storms.

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

- Tropical disturbance
- Tropical depression
- Tropical disturbance
HURRICANE LIFECYCLE
Cape Verde Hurricanes

HURRICANE LIFECYCLE
Cape Verde Hurricanes
HURRICANE LIFECYCLE
Cape Verde Hurricanes

- Tropical disturbance
- Tropical depression
- Hurricane
- Tropical storm
- Extratropical transition

HURRICANE LIFECYCLE
Cape Verde Hurricanes

- Tropical disturbance
- Tropical depression
- Hurricane
- Tropical storm
- Extratropical transition
HURRICANE LIFECYCLE
Hurricane Bill (2009)

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

HURRICANE FORECASTING
What do you know?

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
**HURRICANE LIFECYCLE**
*Ingredients for Formation*

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

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

**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
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

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.

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
What do you know?
HURRICANE HAZARDS

Water is responsible for vast majority

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

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

HURRICANE HAZARDS


- Wind
- Waves / Rip Currents
- Tornadoes
- Storm Surge
- Inland Flooding
**SAFFIR-SIMPSON SCALE**

- Estimates wind damage

<table>
<thead>
<tr>
<th>Category</th>
<th>Speeds</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>74 – 95 mph (34 – 63 kt)</td>
<td>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.</td>
</tr>
<tr>
<td>2</td>
<td>96 – 110 mph (55 – 61 kt)</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>111 – 129 mph (54 – 69 kt)</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>130 – 156 mph (66 – 87 kt)</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>&gt; 156 mph (&gt; 87 kt)</td>
<td></td>
</tr>
</tbody>
</table>

**MAJOR HURRICANES**

- Humberto (2007) Southeast TX
- Claudette (2003) Palacios, TX
- Lili (2002) Louisiana
- Debby (2012)
- Allison (2001)
- Isaac (2008)
- Ike (2006)
- Katrina (2005)
- Wilma (2005)
- Charley (2004)
- Hugo (1989)
- Andrew (1992)
- Camilla (1969)
**HURRICANE WINDS**

*Category 2 (96 – 110 mph)*

**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.

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**HURRICANE WINDS**

*Category 3 (111– 129 mph)*

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

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.

Hugo (1989) Sullivans Island, SC
Ike (2008) Holguin, Cuba

HURRICANE WINDS
Category 5 (>156 mph)

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.*

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

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

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**STORM SURGE**
*Storm Surge vs Storm Tide*

**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.
STORM SURGE HISTORY
New England

• Hurricane Carol (1954)
• Hurricane Irene (2011)
• 1938 Hurricane
• Hurricane Sandy (2012)

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?

15 mph stronger

STORM SURGE
What’s the effect of size?
STORM SURGE
What’s the effect of forward speed?

Slow Speed (5 mph)
• More inland penetration

Fast Speed (25 mph)
• Higher maximum

STORM SURGE
Location. Location. Location.

Category 4 Hurricane

Legend
- 0 - 2
- 2 - 4
- 4 - 6
- 6 - 8
- 8 - 10
- 10 - 12
- 12 - 14
- 14 - 16
- 16 - 18
- 18 - 20
- 20 - 22
- 22 - 24
- 24 - 26
- 26 - 28
- 28 - 30

- >30
STORM SURGE
What’s the effect of width/slope of shelf?

Wide shelf – Gentle slope  Narrow shelf – Sharp slope

STORM SURGE
Wave Setup

Wave Setup

Mean Water Level
**Storm Surge**

Components of ‘Total Water Level’

**Total Water Level**

- Storm surge
- Tides
- Wave Setup
- Freshwater

**FRESHWATER FLOODING**

*U.S. Atlantic Tropical Cyclone Deaths*

**FATALITIES**

U.S. tropical cyclone fatalities – from 1963 - 2012

- Storm Surge 50%
- Rainfall-induced Flood 25%
- Surf 5%
- Offshore 5%
- Wind 5%
- Tornado 5%
- Unknown 5%
- Other 5%
FRESHWATER FLOODING
Flash Floods. Riverine Flooding.

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

INTERSTATE 10, HOUSTON

GOOGLE MAPS, 2017  AUG. 27, 2017

FRESHWATER FLOODING
Interstate 10 – Houston, TX

Interstate 10 – West View
**FRESHWATER FLOODING**  
*TS Allison (2001) – Houston, TX*  

Interstate 10 – West View  

*Photo courtesy of L. Gange, Mansfield Helifight*  

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

Prattsville, NY Damage (Jimmy Vielkind/Times Union)
FRESHWATER FLOODING
Hurricane Irene (2007) – New York and Vermont

Factors Affecting Tropical Cyclone Rainfall

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)

FRESHWATER FLOODING
Hurricane Harvey (2017)
TORNADOES
Landfalling hurricanes spawn tornadoes.

TORNADOES
• 70% produce at least 1 tornado
• 40% produce more than 3 tornadoes

Tornado “outbreak”
Hurricane Ivan (2004)
– 117 Tornadoes

Sept 17, 2004

TORNADOES
Landfalling hurricanes spawn tornadoes.

Friction over land creates low-level wind conditions favorable for the development of tornadoes.

Right Front Quadrant
Storm Motion
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