Understanding Hurricanes

Kieran Bhatia
What do you know about hurricanes?

What do you want to know?
• Why do we care?

• What are they?

• When should we be ready?

• Why aren’t forecasts perfect?

• If a hurricane makes landfall, what should we expect?
Why Do We Care?
The Name Game

• Tropical cyclones have different names, depending on their location.

  – In the Atlantic Ocean and Eastern Pacific Ocean, weaker systems are called tropical storms and the stronger ones are called hurricanes.

  – In the Northwest Pacific Ocean, weaker systems are also called tropical storms, but the stronger ones are called typhoons.

  – In the Southwest Pacific and Indian Oceans, they are simply called cyclones.
Tropical Cyclone Tracks

Typhoons

Hurricanes

Cyclones
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2015 Hurricane Season

U.S. DEPARTMENT OF COMMERCE, NATIONAL WEATHER SERVICE
NORTH ATLANTIC HURRICANE TRACKING CHART

Preliminary
What Are They?

Hurricane Rita
Visible
VDT 09/22/2005 at 17:32 UTC
A ‘Cane?

- Counter-clockwise rotating thunderstorms spinning around a massive low pressure system

- Energy comes from sea water evaporating, rising, and releasing heat

- An area of strong winds and heavy rain

- Only classified by surface wind speed... Saffir-Simpson Scale:
  - Tropical Depression (numbered but not named)
  - Tropical Storm (named... 40mph+, better organized)
  - Hurricane (named... 74mph+, assigned a category 1-5)
# The Saffir-Simpson Intensity Scale

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<th>Category</th>
<th>Maximum Sustained Winds</th>
<th>Description</th>
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<tr>
<td>Tropical Storm</td>
<td>40-73 mph</td>
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<tr>
<td>Category 1 Hurricane</td>
<td>74-95 mph</td>
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<tr>
<td>Category 2 Hurricane</td>
<td>96-110 mph</td>
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<tr>
<td>Category 3 Hurricane</td>
<td>111-130 mph</td>
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<tr>
<td>Category 4 Hurricane</td>
<td>131-155 mph</td>
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<tr>
<td>Category 5 Hurricane</td>
<td>&gt; 155 mph</td>
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Side-View of a Hurricane

Typical eye width ~20 miles

Typical hurricane width ~300-400 miles
Life Expectancy

Day 0, Disturbance

Day 1, 35mph Depression

Day 2, 46mph Tropical Storm

Day 3, 63mph Tropical Storm

Day 4, 92mph Hurricane

Day 5, 127mph Hurricane

Day 6, 150mph Hurricane

Day 7, 144mph Hurricane

Day 8, 155mph Hurricane
• Yes, the bigger a storm is, the more area it will affect with rain, wind, and storm surge, but...
• A larger storm is not necessarily a stronger storm and vice versa.
When Should We Be Ready?
When is it Time to Tune in?

Atlantic Tropical Cyclone Climatology (1851-2013)

- Tropical Storms
- Hurricanes
- Major Hurricanes

Daily Average Number of Active Storms

Graph showing peaks in activity in September (Sep8, Sep9, Sep10) for Tropical Storms and Hurricanes.
With Great Weather Comes Great Responsibility?

Hurricanes affecting South Florida since 1851
58 (31 major) Hurricanes Passed Through South Florida from 1851-Present
What Month Has Had Most Hurricane Strikes in South FL?

• A) August
• B) October
• C) September
• D) June

Since 1851, 23 hurricanes have struck South Florida in October, compared to 17 in September, 13 in August, 2 in July, and 2 in June.
It’s not “IF”, It’s “When”

- South Florida is one of the most frequently hit sections of the entire US coastline
- Average of one hurricane per 3 years and one major hurricane every 5.2 years
Why Aren’t Hurricane Forecasts Perfect?

...Thanks, Dave. And now, the weather report. Look out your window. See that? That’s the weather. Duh. Back to you, Dave.
1) Taking Measurements
Variety of instruments define initial conditions (starting point for forecasts)

2) Model Predictions
Weather models on the world’s fastest super computers predict the future state of the weather based on current information and approximate equations

\[ \frac{\partial u}{\partial t} + \nu \left( \frac{\partial u}{\partial r} + \frac{u}{r} \frac{\partial u}{\partial \theta} \right) + \omega \frac{\partial u}{\partial \phi} \]

\[ = \frac{\partial}{\partial r} \left[ r \left( \frac{\partial u}{\partial r} + \frac{u}{r} \frac{\partial u}{\partial \theta} \right) \right] + \frac{\partial}{\partial \theta} \left[ \nu \frac{\partial u}{\partial \theta} \right] \]

\[ + \frac{\partial}{\partial \phi} \left[ \frac{\partial u}{\partial \phi} \right], \]

\[ \frac{\partial v}{\partial t} + \nu \left( \frac{\partial v}{\partial r} + \frac{u}{r} \frac{\partial v}{\partial \theta} \right) + \omega \frac{\partial v}{\partial \phi} \]

\[ = -\frac{\partial}{\partial r} \left[ r \left( \frac{\partial v}{\partial r} + \frac{v}{r} \frac{\partial v}{\partial \theta} \right) \right] + \frac{\partial}{\partial \theta} \left[ \nu \frac{\partial v}{\partial \theta} \right] \]

\[ + \frac{\partial}{\partial \phi} \left[ \frac{\partial v}{\partial \phi} \right] - \frac{2}{r} \frac{\partial (uv)}{\partial \theta}, \]
3) “Ensemble” of Forecasts
Different equations, initial conditions, and modelling techniques lead to a variety of predictions.

4) The Official Forecast
Forecasters at the National Hurricane Center examine computer model forecasts and issue the official forecast based on what they deem as the most likely scenario.
What is the Cone?

• The “forecast cone” or “cone of uncertainty” predicts the path of the storm center (track forecast).

• It is not an impacts cone!
Making the Cone

• For 2 out of 3 forecasts:
  – The 24-hour true storm location will differ from its predicted track by less than 70 miles
  – At 48 hours ... by less than 95 miles

• Draw a circle for the possible location of the center of the hurricane at each forecast hour

• Outline the circles to complete the cone
Smaller Errors = Smaller Cone

Hurricane Delta
Moving WNW at 13.8 mph

2009 CONE
2015 CONE

+5day  +4day  +3day  +2day  +1day

B. McNoldy, UM/RSMAS
Background image courtesy of NOAA
• Forecasts further out in time have **more** uncertainty.

• As track forecasts improve, the size of the cone **decreases**.

• Storms should leave the cone _1/3_ of the time.

• The forecast cone **is not** an impacts cone!
What to Expect During a Hurricane Landfall

- Storm Surge
- Wind
- Rain
- Tornadoes
- Waves/Rip Currents
Wind, Rain, and Waves
• Nearly 70% of landfalling hurricanes cause at least 1 tornado.
• These tornadoes most often occur in thunderstorms in rainbands away from the center of the hurricane.
• The #1 cause of deaths in hurricanes

• Storm surge is produced by water being pushed toward the shore by the storm winds
A Long-Distance Relationship

Hurricane Ike (2008) Wind, Position and Storm Surge/Storm Tide Data

Hourly storm position and intensity
+ Tropical Storm
+ Category-1 Hurricane
+ Category-2 Hurricane
+ Category-3 Hurricane
+ Category-4 Hurricane
+ Category-5 Hurricane

Observed High Water Marks
Surge
- < 4 feet
- 4-8 feet
- 8-12 feet
- 12-16 feet
- > 16 feet

Storm Tide
- < 4 feet
- 4-8 feet
- 8-12 feet
- 12-16 feet
- > 16 feet

Storm position and intensity data provided by Elsner and Jagger at Florida State Univ
Storm surge data provided by SCIPP/SURGEDAT
Could we see this type of flooding in South Florida?

Hurricane Katrina (2005): New Orleans
Hurricane Wilma (2005): Miami
So... Know Your Zone

[Map showing storm surge planning zones]

Storm Surge Planning Zones

Zone

A
B
C
D
E

Emergency Management
http://miami-dade.gov/em
Lessons Learned

• Hurricanes and tropical storms (tropical cyclones) are named differently in different oceans and based on their wind speeds.

• August through October is the peak of hurricane season for the U.S. but October is the busiest month for Florida.

• The “cone of uncertainty” shows where the center of the storm will go 2/3 of time but the storm’s destruction can extend far beyond the cone (even if the track forecast is correct).

• Tropical cyclones have a variety of hazards but storm surge is responsible for the most damage and deaths.