Comparison of Destructive Wind Forces of Hurricane Irma with Other Hurricanes Impacting NASA Kennedy Space Center, 2004 - 2017

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Reference EDR Log #: 4657, NASA KSC Export Control Office, (321) 867-9209
In September 2017, Hurricane Irma produced sustained hurricane force winds resulting in facility damage at Kennedy Space Center (KSC).

In 2004, 2005, and 2016, hurricanes Charley, Frances, Jeanne, Wilma, and Matthew also caused damage at KSC.

Destructive energies from sustained wind speed were calculated to compare these hurricanes.

Emphasis is placed on persistent horizontal wind force rather than convective pulses.

Result: Although Hurricane Matthew (2016) provided the highest observed wind speed and greatest kinetic energy, the destructive force was greater from Hurricane Irma.
Powell & Reinhold’s Article 2007

- Purpose: “Broaden the scientific debate on how best to describe a hurricane’s destructive potential”
- Names the following as poor indicators of a hurricane's destructive potential
  - Intensity (Max Sustained Surface Winds): Provides a measure to compare storms, but does not measure destructive potential since it does not account for storm size.
  - The Saffir-Simpson scale: Useful for communicating risk to individuals and communities, but is only a measure of max sustained winds, again, not accounting for storm size.
  - Mortality and insured losses: Dependent upon population density and coastal vulnerability
- Suggestions:
  - A metric relevant to the physical forces that contribute to damage, based on the size of the wind field and magnitude of the winds.
  - An objective starting point to estimate the impact of the wind field before coastal vulnerability, infrastructure, and affected populations are taken into account.
  - A better risk perception as an important goal for any new metric of hurricane destructive potential
- Proposal: Integrated Kinetic Energy

Integrated Kinetic Energy (IKE)

Powell & Reinhold, 2007: Calculation from the surface wind field

\[ \text{IKE} = \int_V \frac{1}{2} \rho U^2 dV \]

\( \rho = \text{air density} , \ V = \text{storm domain volume} , \ U = \text{sustained wind speeds at 10-m level} \)

KSC Storms: Calculation from a particular tower

Kinetic Energy

\[ KE = \frac{1}{2} \sum \rho \ V_{WS}^2 dV_{VOL} \]

\( \rho = 1 \, \text{kg m}^{-3} \) (assumed)

\( V_{WS} = \text{average of the 5-min averages between two measurement levels in m/s} \)

\( V_{VOL} = 1 \, \text{km}^2 \) area at the surface with a vertical extent between the altitudes of each consecutive wind level.

Destructive Force

\[ F = \sum KE \times dt \]
Measurements

• KSC 500-ft and Launch Complex 39B weather towers
Satellite Comparison of Hurricanes

- IR satellite images near the time of maximum 5-minute average wind
- Yellow dot represents the location of KSC
Radar Comparison of Hurricanes

- Radar images near time of maximum 5-minute average wind
- Black dot represents the location of KSC
- Red arrow represents direction storm was traveling
Hurricanes Compared

* Hurricane Frances – Potential underestimation from loss of most of the wind measurements
Irma’s Wind Field

Note: The cone contains the probable path of the storm center but does not show the size of the storm. Hazardous conditions can occur outside of the cone.

Hurricane Irma
Wednesday September 06, 2017
2 AM AST Intermediate Advisory 28A
NWS National Hurricane Center

Current information:
Center location 17.7 N 61.8 W
Maximum sustained wind 185 mph
Movement WNW at 15 mph

Forecast positions:
● Tropical Cyclone
○ Post/Potential TC
Sustained winds:
D < 39 mph
S 39-73 mph
H 74-110 mph
M > 110 mph

Potential track area:
Day 1-3
Day 4-5

Watches:

Warnings:
Irma’s Wind Field

- Initial Location (24.5 N 81.5 W)
- Sunday, September 10, 2017 at 8 AM EDT
- Max Sustained Wind 130 mph (Cat 4)
- Movement NNW at 8 mph
Time of Max Sustained Wind
Kinetic Energy & Destructive Force

Kinetic Energy Observed at KSC
(derived from sfc to 492' at KSC Weather Tower 313
Irma data derived from sfc to 457' at LC39B Wx Towers)

Destructive Force of Wind at KSC
(surface to 492 ft/457 ft for Irma)
### Comparing Peak Wind to Destructive Force

<table>
<thead>
<tr>
<th>Storm in Rank Order Peak Wind</th>
<th>Peak Wind (Kts) (&lt;=60ft)</th>
<th>Storm in Rank Order Destructive Force</th>
<th>Destructive Energies (10^{15} Newtons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Matthew</td>
<td>93</td>
<td>Jeanne</td>
<td>2665</td>
</tr>
<tr>
<td>Frances</td>
<td>82</td>
<td>Irma</td>
<td>2515</td>
</tr>
<tr>
<td>Wilma</td>
<td>82</td>
<td>Frances</td>
<td>?</td>
</tr>
<tr>
<td>Irma</td>
<td>76</td>
<td>Matthew</td>
<td>405</td>
</tr>
<tr>
<td>Jeanne</td>
<td>76</td>
<td>Wilma</td>
<td>128</td>
</tr>
<tr>
<td>Charley</td>
<td>75</td>
<td>Charley</td>
<td>15</td>
</tr>
</tbody>
</table>
Summary

• Destructive forces were compared for six hurricanes impacting KSC over the past 15 years
• The destructive force can be calculated by integrating the kinetic energy over the duration of the high speed winds (Powell and Reinhold, 2007)
• Irma was the latest in the comparison of 6 storms in this study
  • Although highest sustained wind speed, ranked 2nd / 3rd for Integrated Kinetic Energy (Destructive Wind Force)
  • Large wind field resulted in second longest duration of destructive winds (46 hours) even though the storm was farthest distance from KSC
  • Comparable to Hurricane Jeanne and (likely) Frances
• QUESTIONS?