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

Presenter: Mrs. Kathy Rice
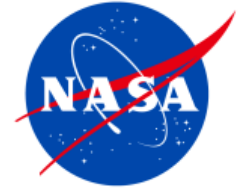
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Hurricanes Impacting KSC

- 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

Reference: Powell, M. and Reinhold, T., 2007: Tropical Cyclone Destructive Potential by Integrated Kinetic Energy. *Bulletin of the American Meteorological Society*, April, 513-526.

Integrated Kinetic Energy (IKE)

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

$$IKE = \int_V \tfrac{1}{2} \rho \, U^2 \, dV$$

ρ = air density , V = storm domain volume, U = sustained wind speeds at 10-m level

KSC Storms: Calculation from a particular tower

Kinetic Energy $\qquad KE = \tfrac{1}{2} \sum \rho \; V_{WS}{}^2 dV_{VOL}$

ρ = 1 kg m^{-3} (assumed)
V_{WS} = average of the 5-min averages between two measurement levels in m/s
V_{VOL} = 1km^2 area at the surface with a vertical extent between the altitudes of each consecutive wind level.
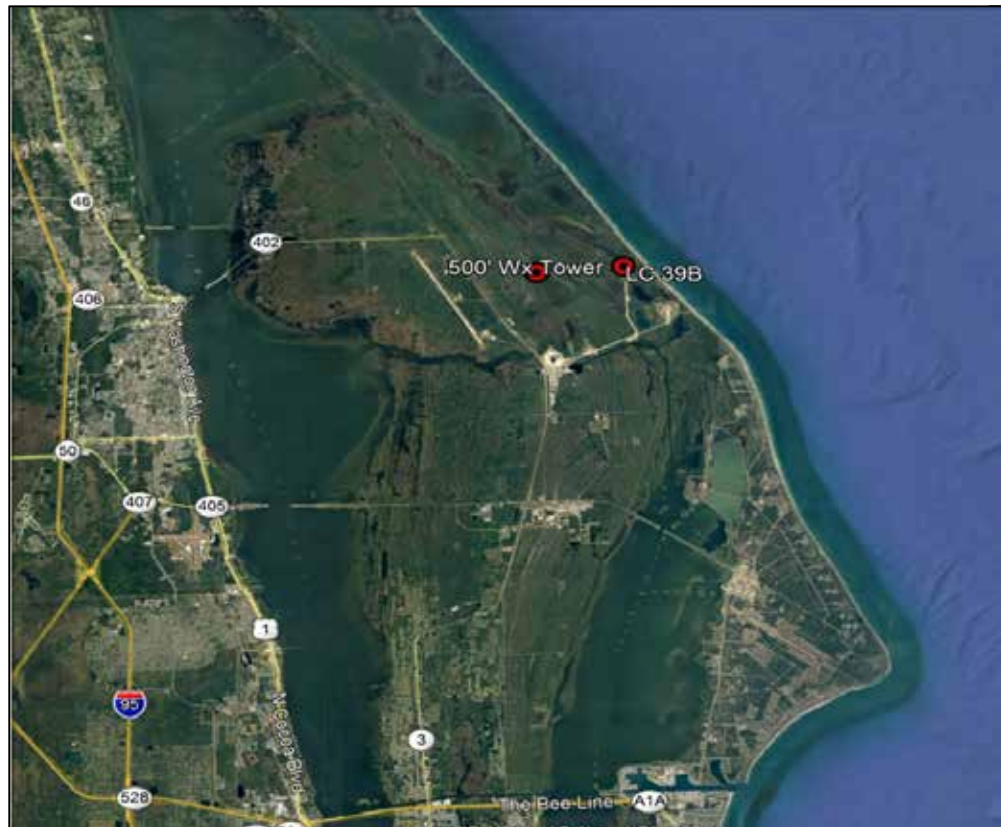
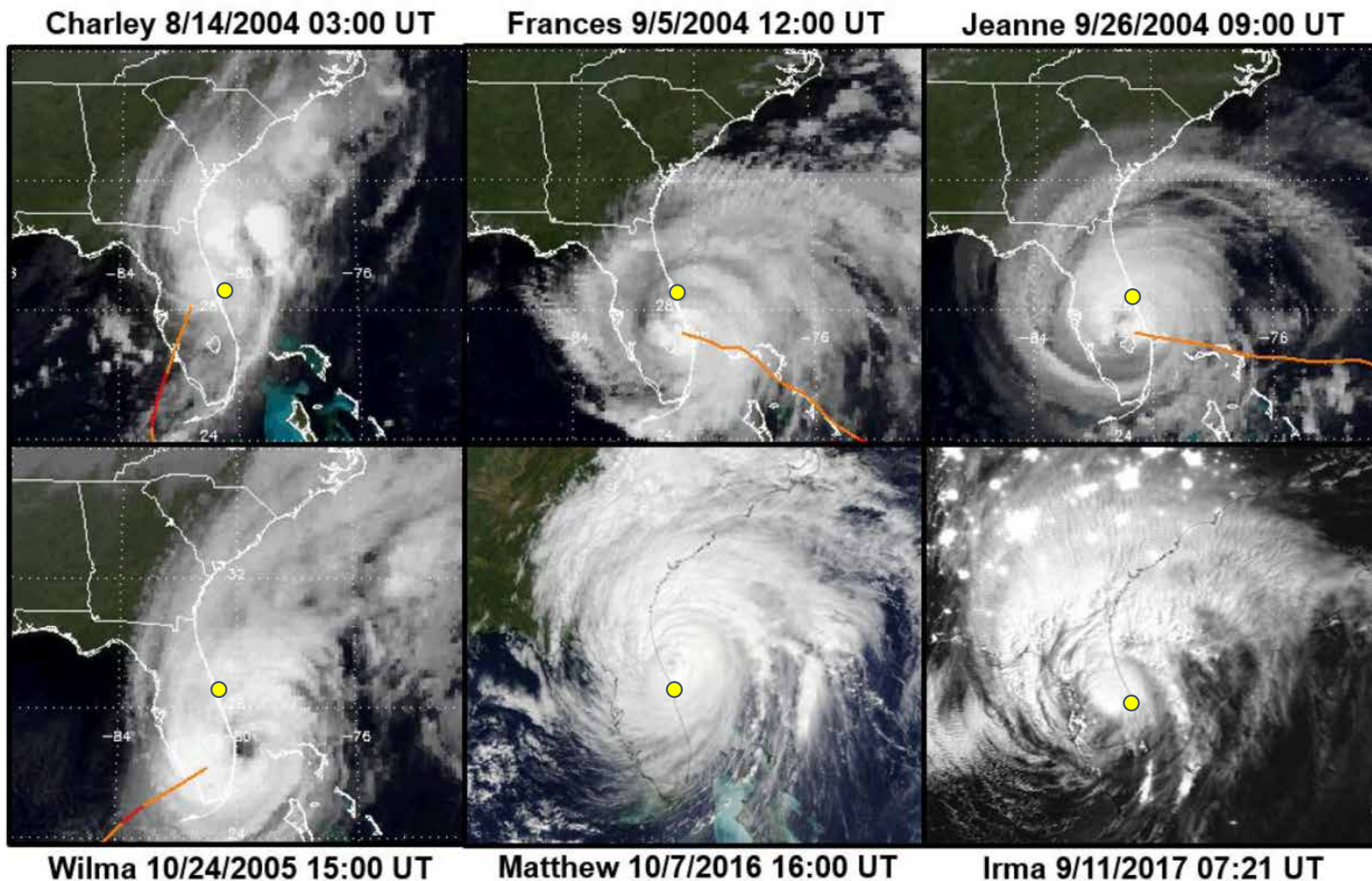Destructive Force $\qquad F = \sum KE \; x \; dt$

Measurements

- KSC 500-ft and Launch Complex 39B weather towers

Satellite Comparison of Hurricanes

Charley 8/14/2004 03:00 UT

Frances 9/5/2004 12:00 UT

Jeanne 9/26/2004 09:00 UT

Wilma 10/24/2005 15:00 UT

Matthew 10/7/2016 16:00 UT

Irma 9/11/2017 07:21 UT

- IR satellite images near the time of maximum 5-minute average wind

- Yellow dot represents the location of KSC

Radar Comparison of Hurricanes

Charley 8/14/2004 02:40 UT

Frances 9/5/2004 11:30 UT

Jeanne 9/26/2004 09:20 UT
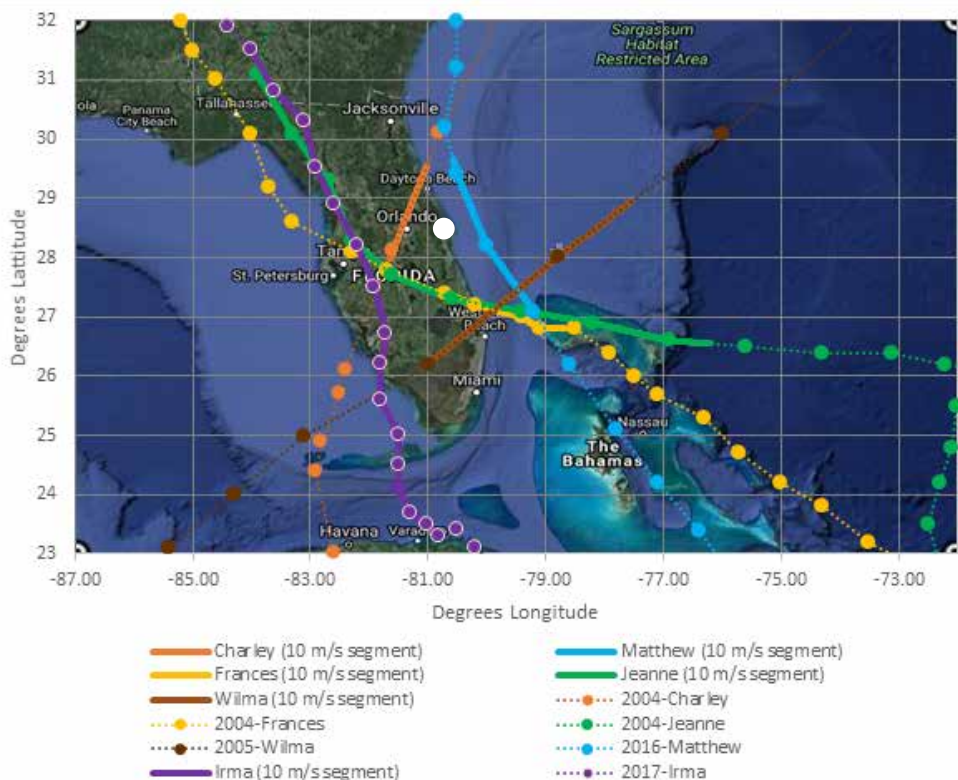
Wilma 10/24/2005 15:30 UT

Matthew 10/7/2016 11:35 UT

Irma 9/11/2017 02:15 UT

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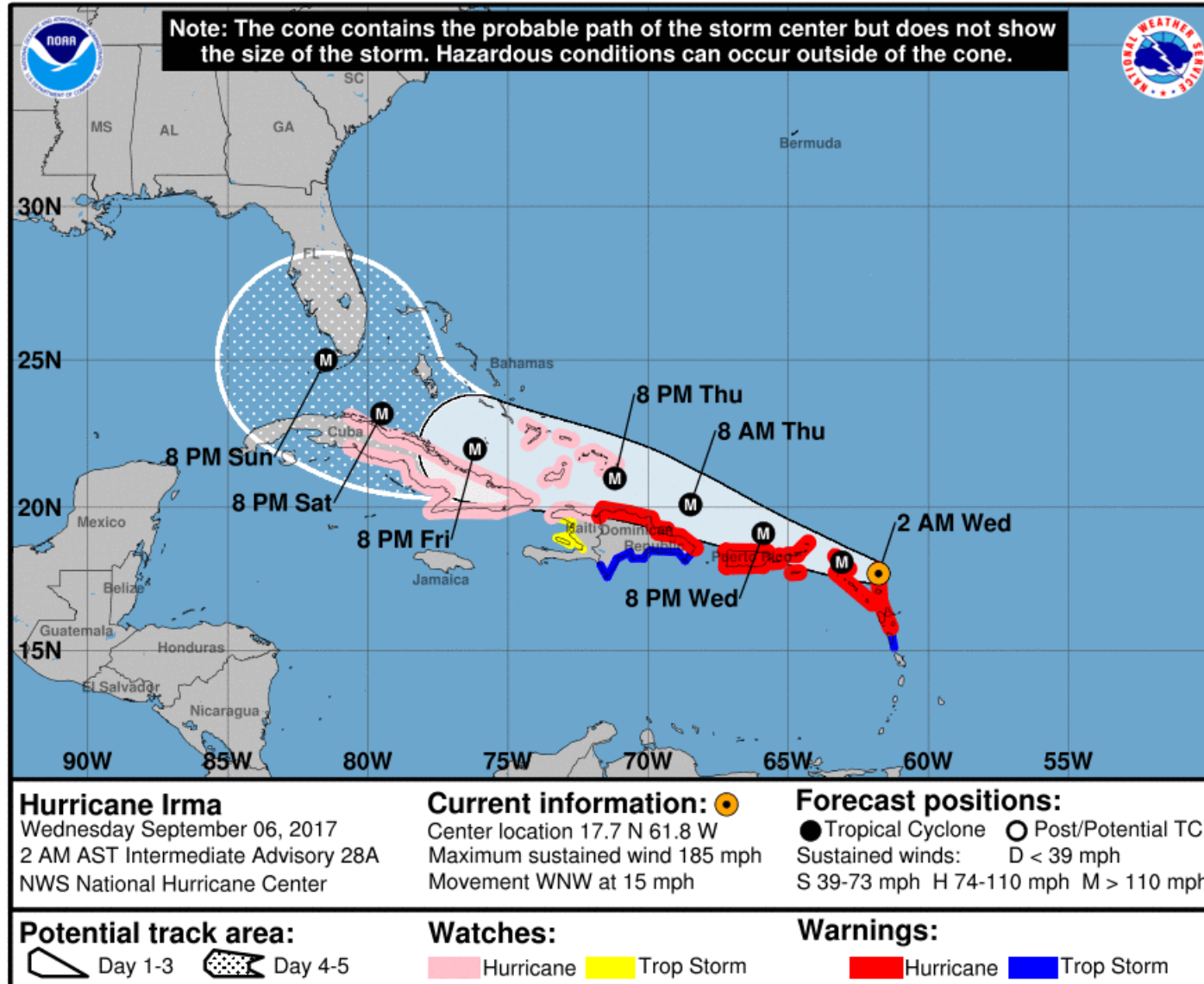- Red arrow represents direction storm was traveling

Hurricanes Compared

Hurricane	Year	Duration of 10 m s⁻¹ at 10 m (Hours:Minutes)	Maximum Wind Speed (m s⁻¹)	Measured at Time of Max Wind Speed		
				Central Storm Press (mb)	Distance From KSC (km/nm)	Storm Speed (m s⁻¹/kts)
Jeanne	2004	51:05	20.0	960	132/71	5.0/9.7
Irma	2017	46:00	27.3	949	192/104	7.6/14.7
Frances*	2004	22:30	20.0	969	138/75	2.5/4.9
Matthew	2016	14:30	22.8	942	44/24	6.7/13.0
Wilma	2005	8:50	18.7	953	179/97	13.7/26.6
Charley	2004	4:40	15.5	981	71/38	10.9/21.2

Hurricane	Year	Distance (nm) from KSC (approximate)	Sustained Wind Radii (nm)		
			34 Kt	50 Kt	64 Kt
Charley	2004	30	75	40	20
Frances	2004	78	125	75	60
Jeanne	2004	50	180	100	60
Wilma	2005	100	150	90	50
Matthew	2016	21	120	70	50
Irma	2017	80	360	140	70

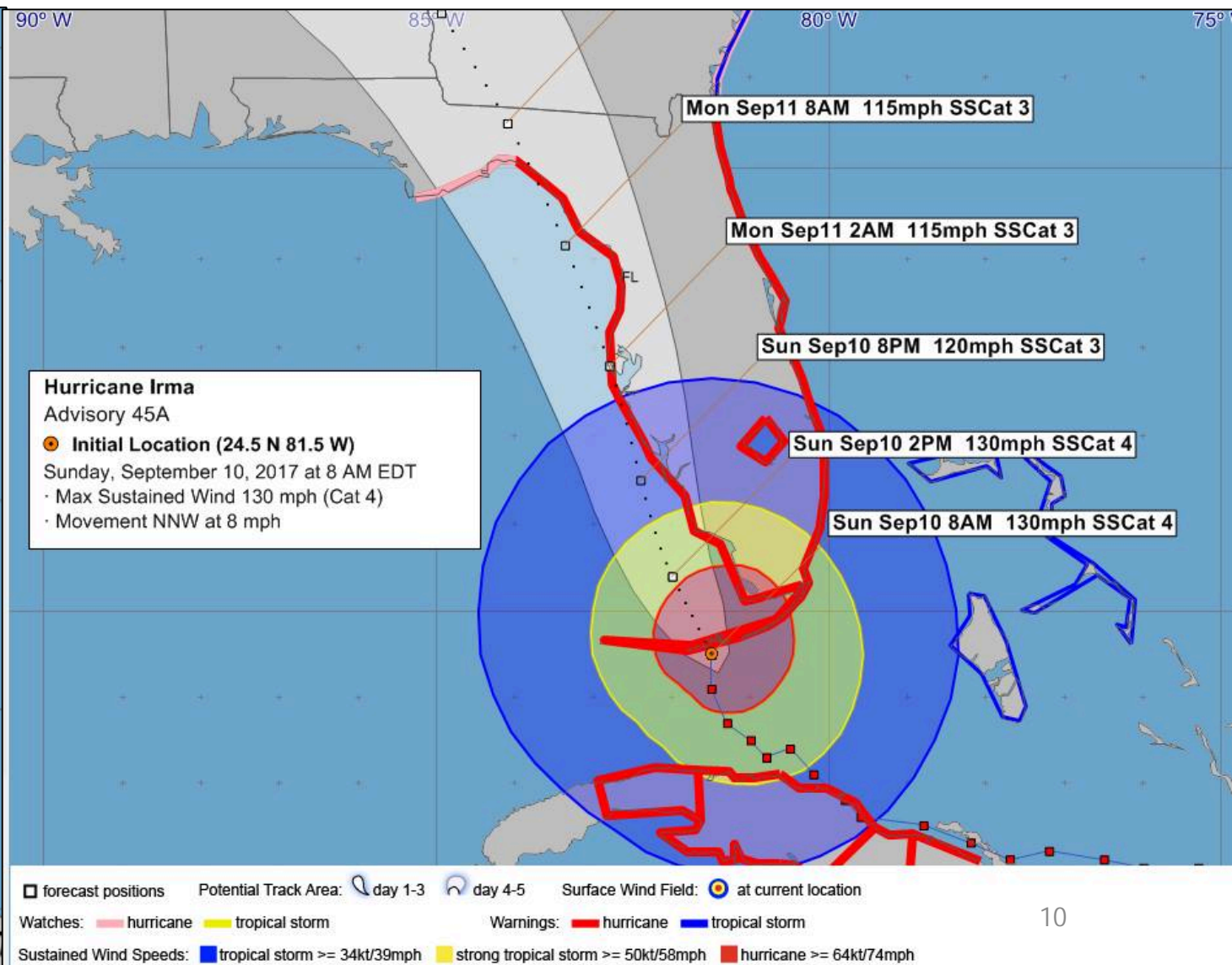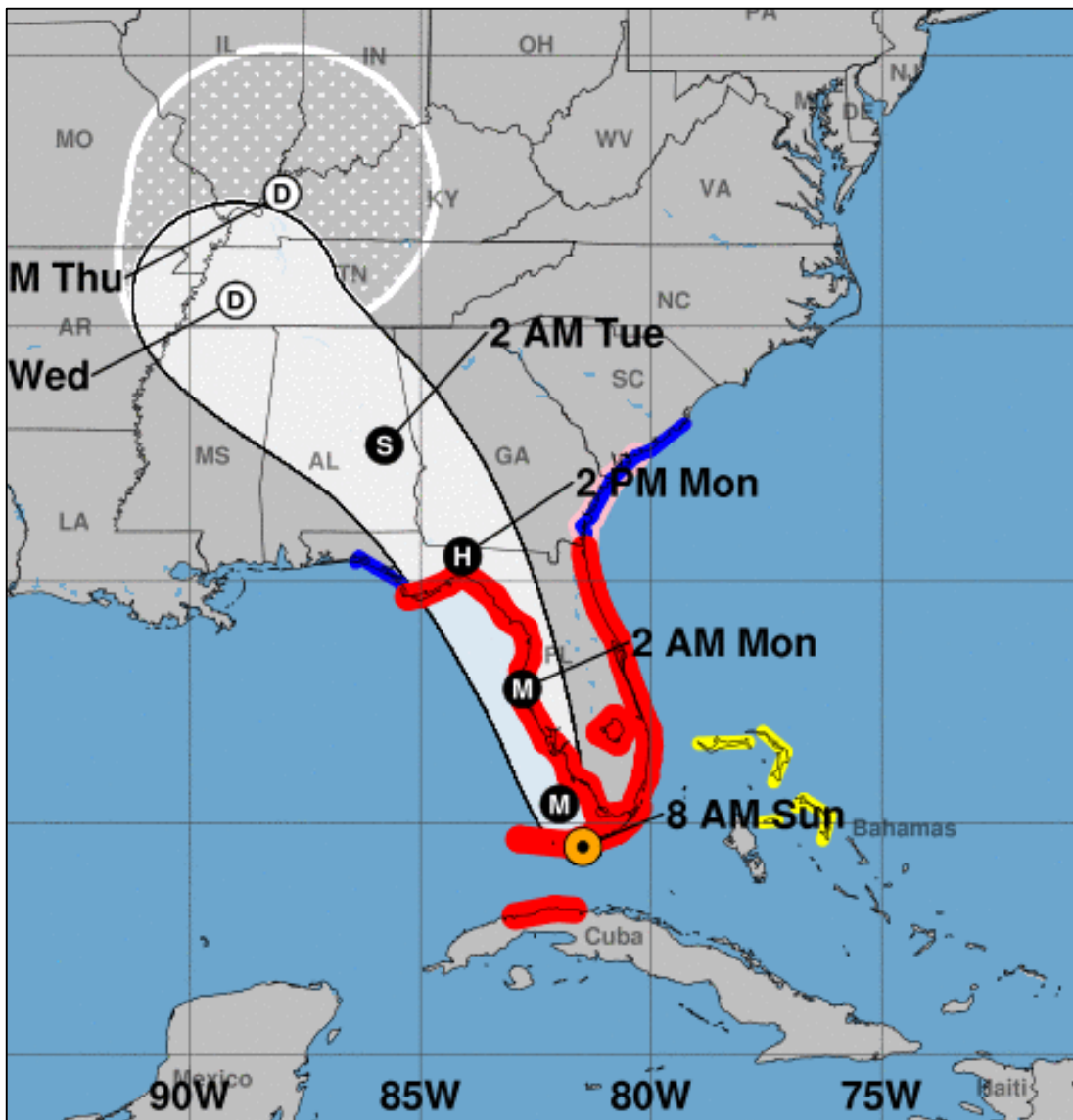* Hurricane Frances – Potential underestimation from loss of most of the wind measurements
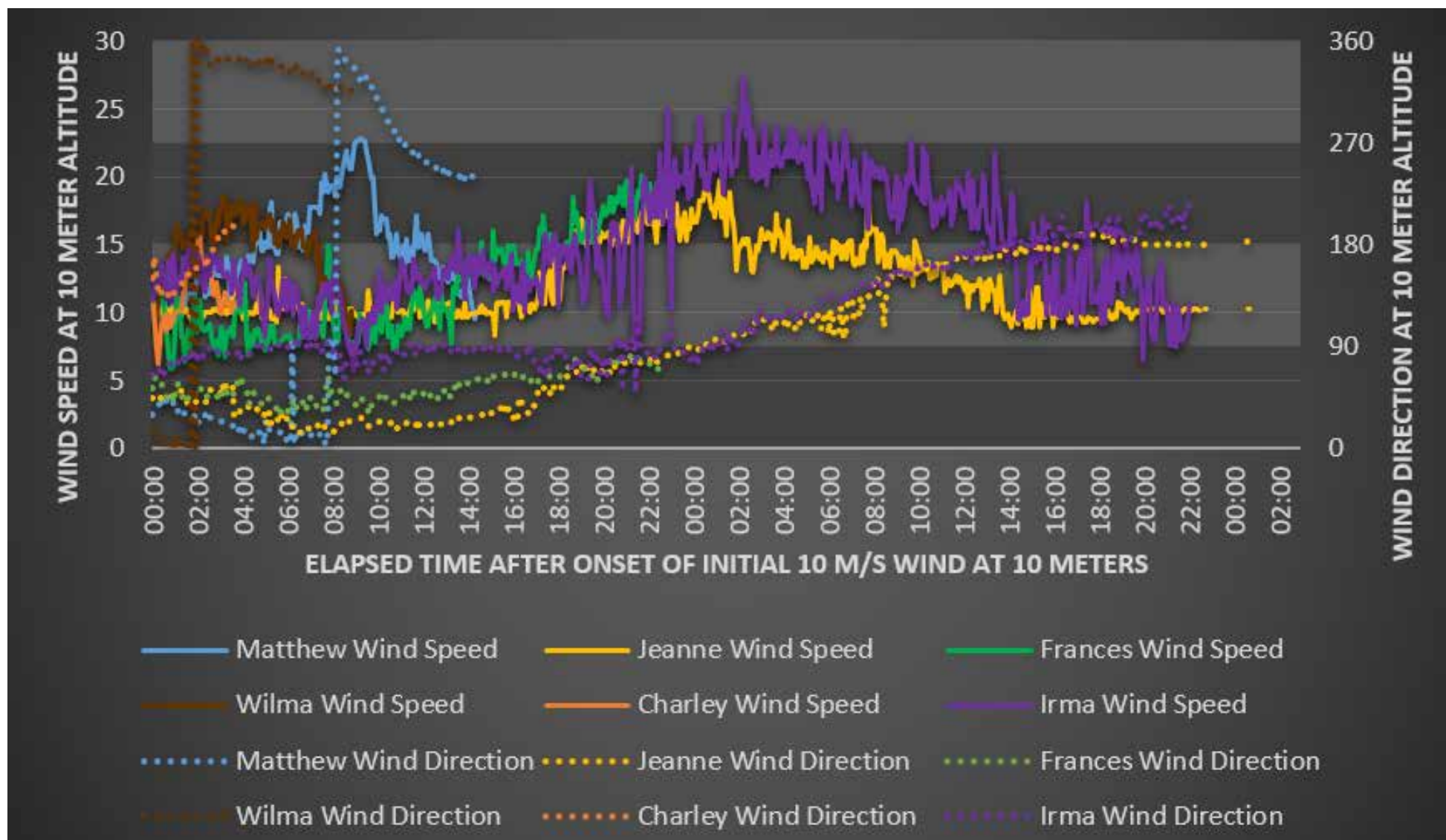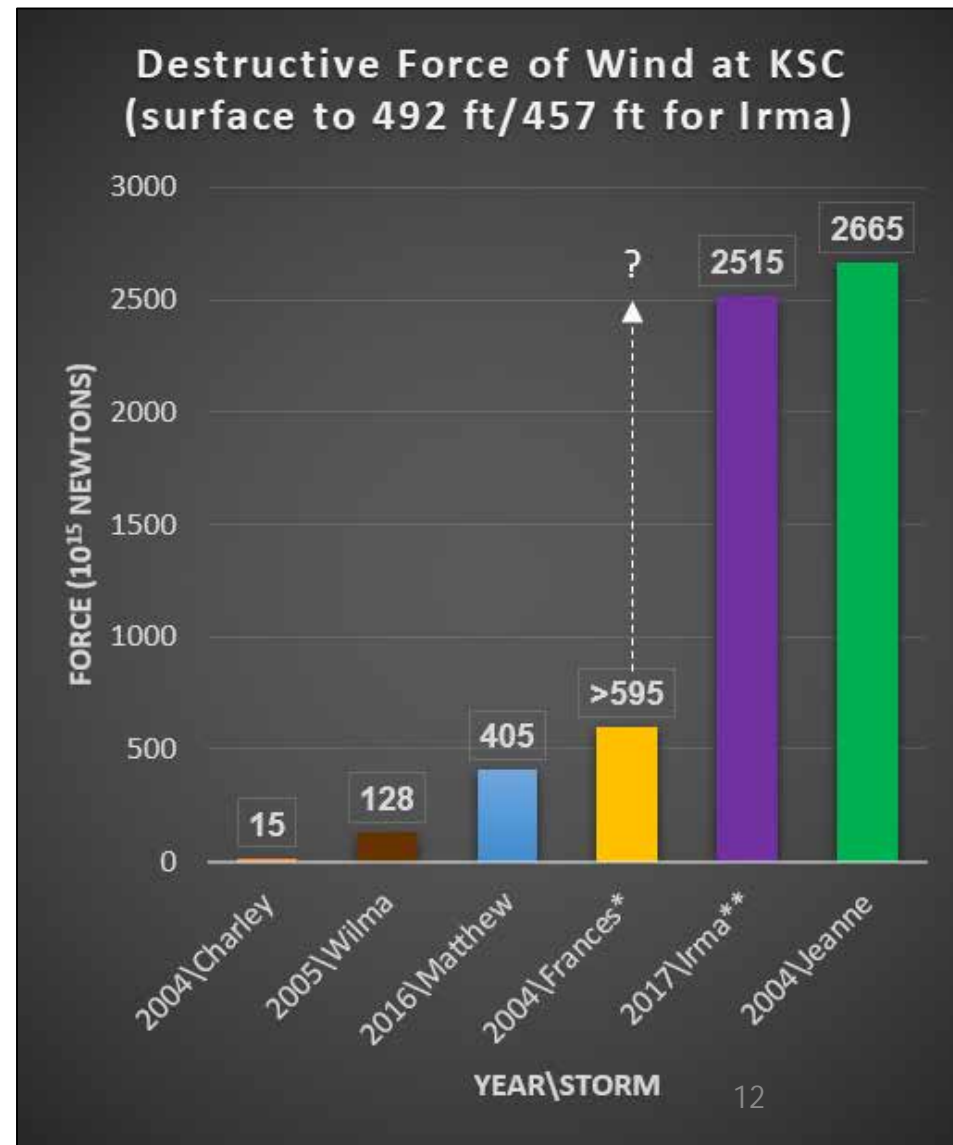
Irma's Wind Field

Irma's Wind Field

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)
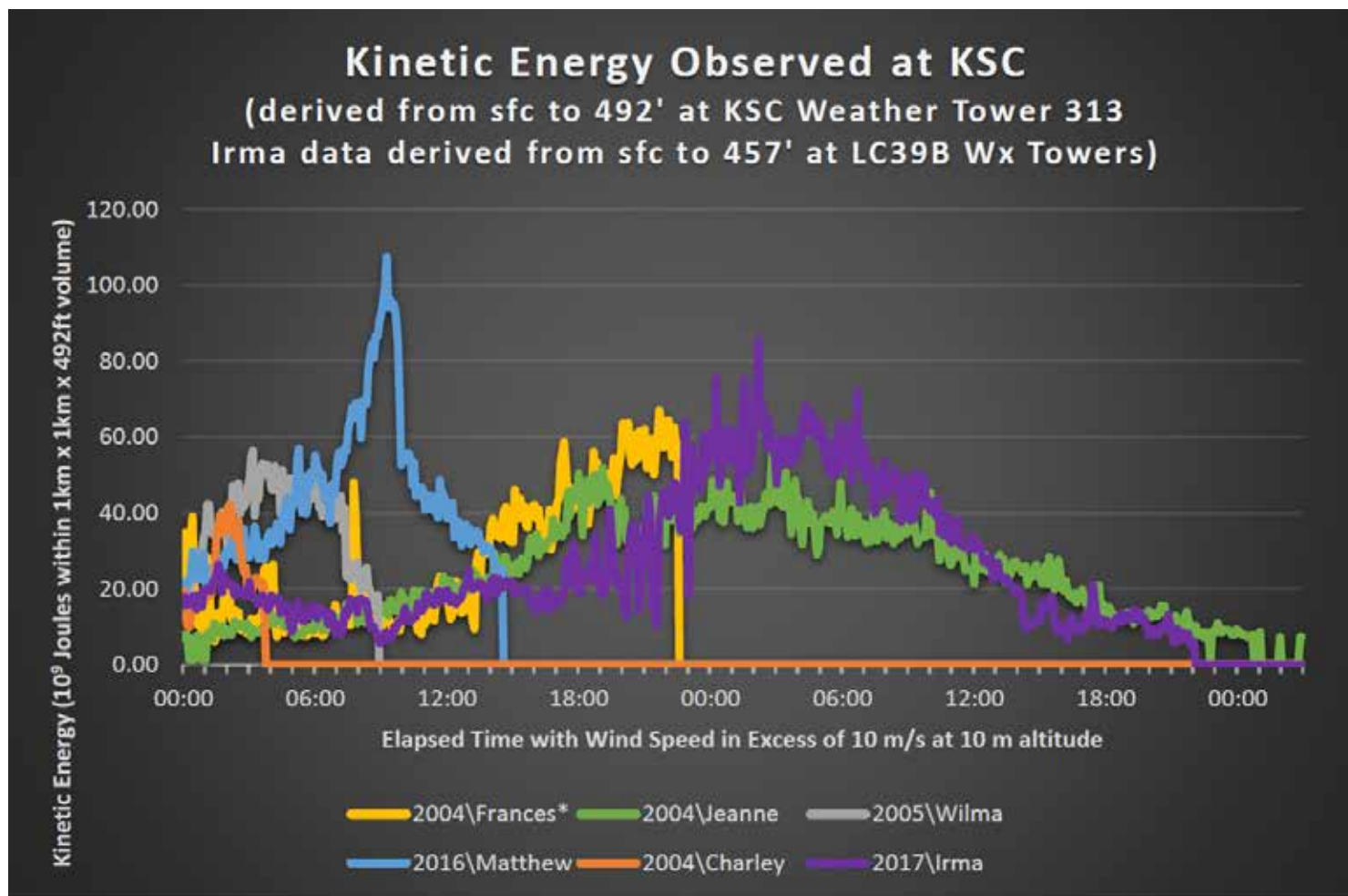
Comparing Peak Wind to Destructive Force

Storm in Rank Order Peak Wind	Peak Wind (Kts) (<=60ft)	Storm in Rank Order Destructive Force	Destructive Energies (10^{15} Newtons)
Matthew	93	Jeanne	2665
Frances	82	Irma	2515
Wilma	82	Frances	?
Irma	76	Matthew	405
Jeanne	76	Wilma	128
Charley	75	Charley	15

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?**