

New Metrics for Hurricane Impacts

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● Risk Perception



Despite excellent forecasts and warnings, people act on perceived vulnerability

- Past experience influences perception (Baker 2006, Wilkinson and Ross 1970)
- Those who experienced significant loss are more likely to act in the future (Shulz et al 2005, Miletti 1992)
- Experiences from Hurricane Camille of 1969 influenced actions taken in Katrina
- Camille and Katrina were very different storms

Biloxi Sun Herald Sun, Sep. 21, 2008

Americans need a better way to assess the risk of hurricanes Saffir-Simpson categories contribute to casualties

The Saffir-Simpson Hurricane Scale is lulling coastal residents into a fatally false sense of security. That's because the scale's five single-digit categories distort the danger of an approaching tropical weather system.

It happened during Hurricane Katrina, when some South Mississippians made the mistake of underestimating the hurricane's threat by comparing it to Hurricane Camille. Because Camille was a 5 on the Saffir-Simpson scale and Katrina was weakening into a 3, some people assumed Katrina was less of a threat to their lives and property.

That assumption cost some people their lives. Biloxi Mayor A.J. Holloway said the day after Katrina: "It looks like Hurricane Camille killed more people yesterday than it did in 1969." While Katrina's winds were slower than Camille's, its unprecedented storm surge was far deeper and deadlier.

The same thing just took place in Texas, where coastal residents understandably but regrettably compared Hurricane Ike, a deceptively low-level Category 2, to previous higher-level storms and decided not to evacuate. We appreciate that perfection is not possible.

- **Motivation for a new hurricane metric:**
 - Intensity is important but independent of size
 - Wind radii are important but independent of intensity
 - Destructive potential depends on both
 - We need a metric to convey this to the public

- ***Wind stress on the ocean scales with the square of the wind speed***
- ***Forces waves and storm surge***



Wind Damage increases dramatically at ~ 55 m/s

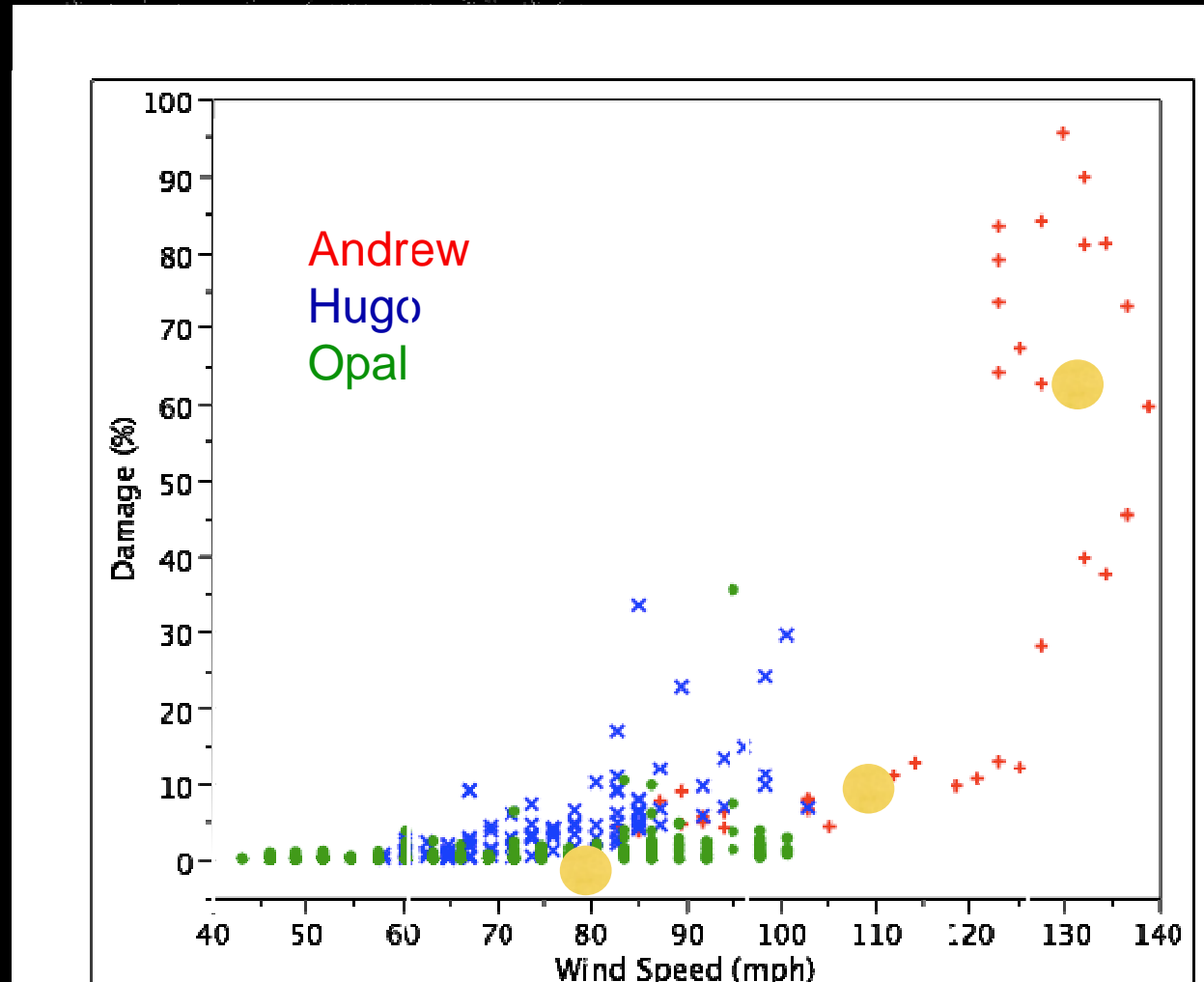
Figure 1

Figure 1

% Damage
claim/insured value

Threshold damages

- at 2%
- 12%
- 60%



Wind Speed

- **Integrated Kinetic Energy (IKE)**

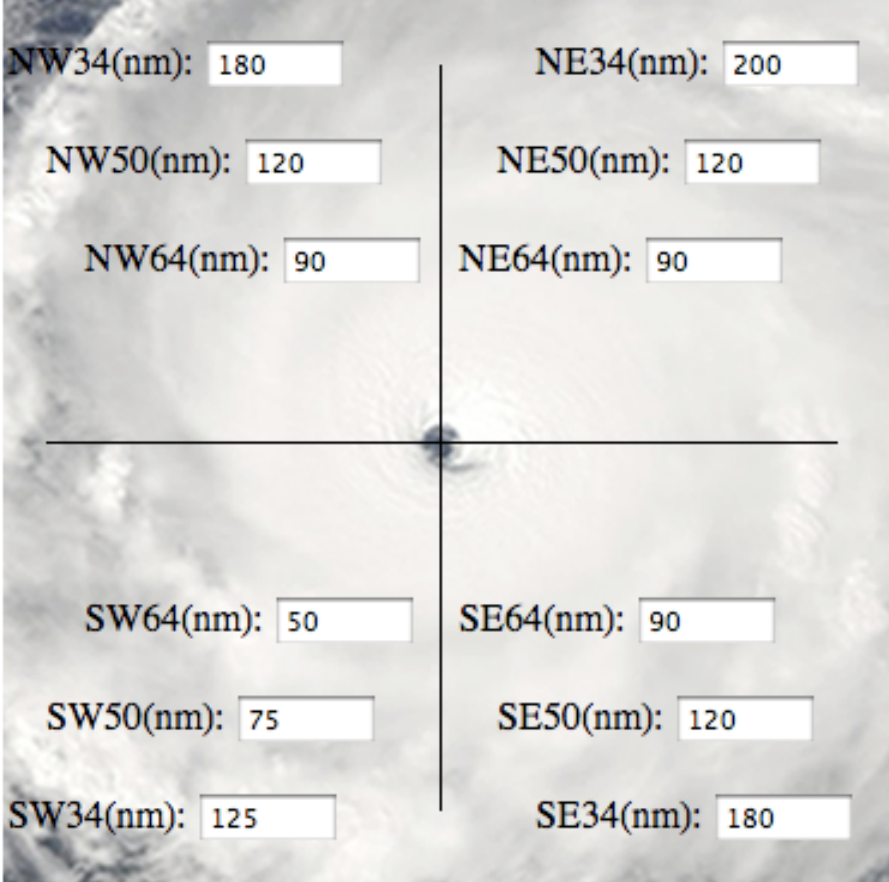
$$IKE = \int \frac{1}{2} \rho w s^2 dV$$

- **Kinetic energy/ volume**
- **Scales with the square of the wind speed and the areal coverage of damaging winds**
- **Contributions of IKE over various wind thresholds**
- **Sum grid cell KE ~ 5 x 5 km, 1 m deep at 10 m**
- **IKE range from H*Wind archive**

- **Surge / Wave Destructive Potential (SDP):**
 - Depends on IKE from winds $>$ tropical storm force
 - A large TS can be more destructive than small hurricane
 - Actual destruction depends on local effects

Kinetic Energy and SDP Calculator at:

www.aoml.noaa.gov/hrd/ike

Rmax(nm): <input type="text" value="20"/>	Vmax(kt): <input type="text" value="150.01848"/>	Results	
		Entire Storm	
		Storm Total IKE _{TS-50} (TJ)	<input type="text" value="38.576"/>
		Storm Total IKE _{50-H} (TJ)	<input type="text" value="22.843"/>
		Storm Total IKE _H (TJ)	<input type="text" value="105.853"/>
		IKE _{TS} (TJ)	<input type="text" value="167.272"/>
		SDP	<input type="text" value="5.452"/>
		<input type="text" value="H. Katrina 2005-08-28 1800z"/> ▾	
<input type="button" value="Calculate"/> <input type="button" value="reset"/>			

Integrated Kinetic Energy for winds > TS force in Terra Joules

Camille Landfall 63 TJ

Katrina 28th 117 TJ

Katrina Landfall 112 TJ

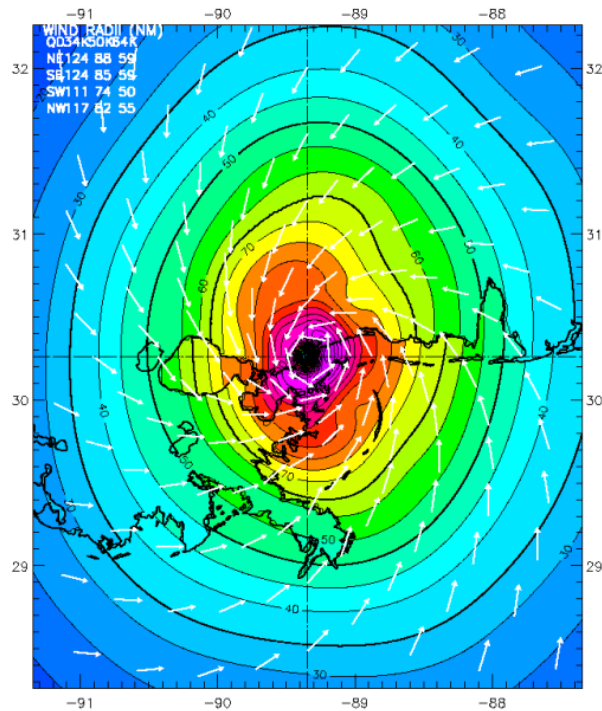
Hurricane Camille 0430 UTC 18 AUG 1969

Max 1-min sustained surface winds (kt)

Valid for marine exposure over water, open terrain exposure over land

Analysis based on 1 from 0430 - 0430 z; 4 from 0000 - 0600 z; 3 from 2115 - 2330 z;
2 from 1954 - 0658 z

0430 z User fix; mslp = 909.0 mb



Observed Max. Surface Wind: 129 kts, 8 nm NE of center based on 0430 z 1 sfc measurement
Analyzed Max. Wind: 127 kts, 7 nm NE of center

Experimental research product of [NOAA / AOML / Hurricane Research Division](#)

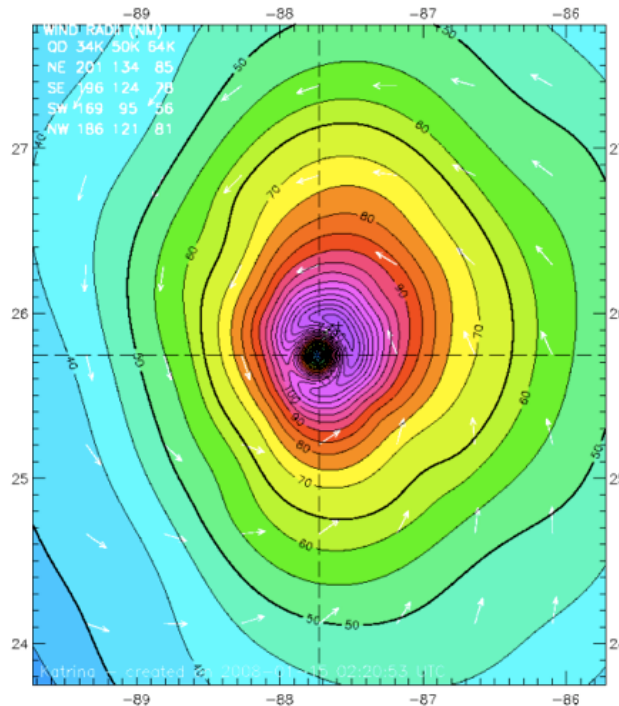
Hurricane Katrina 1201 UTC 28 AUG 2005

Max 1-min sustained surface winds (kt)

Valid for marine exposure over water, open terrain exposure over land

Analysis based on: QCCAT from 1125 - 1128 z; SHIP from 1208 - 1312 z; AFRC (SFHR-Katrina adjusted) from 0907 - 1459 z;
CMAN from 0900 - 1000 z; GPSSONDE_WL150 from 0900 - 1458 z; MOORED_BUOY from 0909 - 1459 z;

1201 z position interpolated from 1200 Interpolation; mslp = 908.0 mb



Integrated Kinetic Energy: for Winds > TS force: 117 TJ, for Winds > Hurricane Force: 42 TJ
Destructive Potential Rating(0-6) Wind: 5.8, Surge/Waves: 5.0

Observed Max. Surface Wind: 139 kts, 14 nm NE of center based on 1422 z AFRC
Analyzed Max. Wind: 139 kts, 14 nm NE of center

Uncertainty -> mean wind speed error: 3.01 kt, mean direction error: -0.04 deg
rms wind speed error: 7.35 kt, rms direction error: 8.39 deg

Experimental research product of [NOAA / AOML / Hurricane Research Division](#)

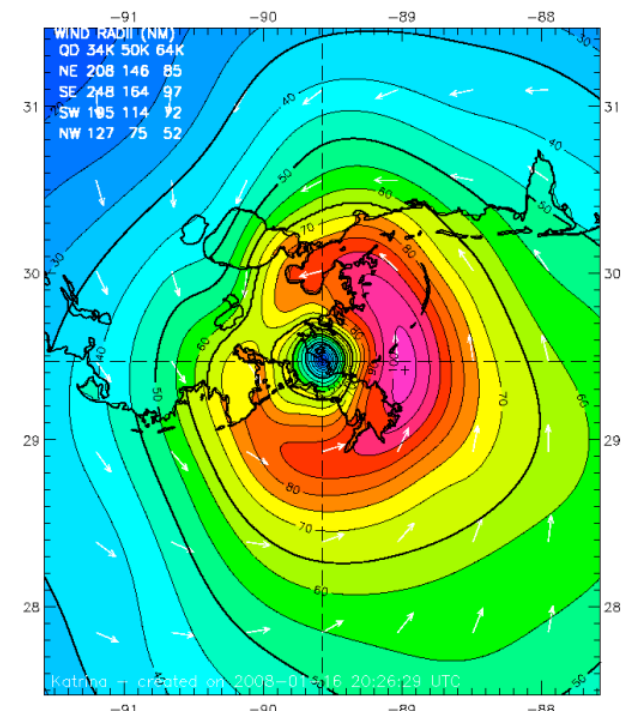
Hurricane Katrina 1158 UTC 29 AUG 2005

Max 1-min sustained surface winds (kt)

Valid for marine exposure over water, open terrain exposure over land

Analysis based on: FCMP_TOWER from 0942 - 1359 z; MESONET from 0937 - 1400 z; SHIP from 1010 - 1212 z;
MADIS from 0936 - 1359 z; GOES_SWIR from 1002 - 1002 z;
GPSSONDE_WL150 from 0959 - 1357 z; ASOS from 0936 - 1359 z;
DUAL_DOPPLER (User-defined adjusted) from 1010 - 1302 z; VAD_88D from 0959 - 1354 z;
QSCAT from 1100 - 1102 z; CMAN from 0936 - 1400 z;
TAIL_DOPPLER (User-defined adjusted) from 1020 - 1346 z; MOORED_BUOY from 0939 - 1400 z;
SFMRA3 from 0936 - 1359 z; METAR from 0950 - 1355 z;

1158 z position interpolated from 1132 Army Corps; mslp = 923.0 mb



Integrated Kinetic Energy: for Winds > TS force: 112 TJ, for Winds > Hurricane Force: 41 TJ
Destructive Potential Rating(0-6) Wind: 3.4, Surge/Waves: 4.9

Observed Max. Surface Wind: 102 kts, 35 nm SE of center based on 1020 z TAIL_DOPPLER
Analyzed Max. Wind: 102 kts, 36 nm SE of center

Uncertainty -> mean wind speed error: 6.16 kt, mean direction error: 10.70 deg
rms wind speed error: 10.97 kt, rms direction error: 18.61 deg

Experimental research product of [NOAA / AOML / Hurricane Research Division](#)

Integrated Kinetic Energy for winds > TS force in Terra Joules, SDP, SS

Camille Landfall
63 TJ SDP 4.1 SS

5

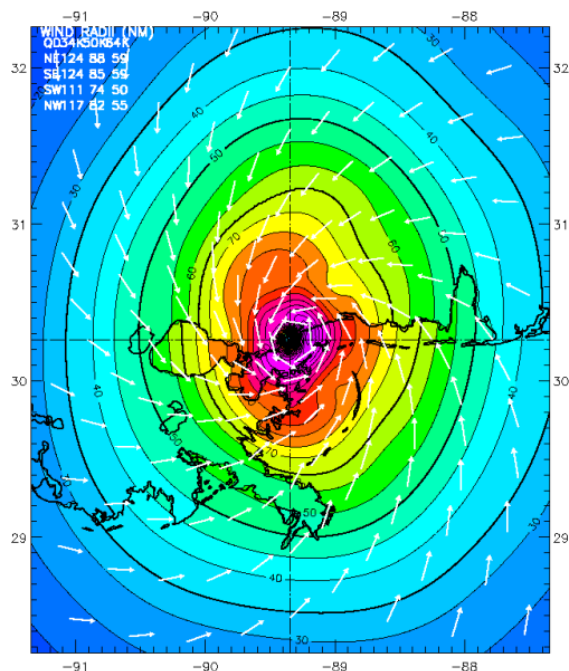
Hurricane Camille 0430 UTC 18 AUG 1969

Max 1-min sustained surface winds (kt)

Valid for marine exposure over water, open terrain exposure over land

Analysis based on 1 from 0430 - 0430 z; 4 from 0000 - 0600 z; 3 from 2115 - 2330 z; 2 from 1954 - 0658 z

0430 z User fix; mslp = 909.0 mb



Observed Max. Surface Wind: 129 kts, 8 nm NE of center based on 0430 z 1 sfc measurement
Analyzed Max. Wind: 127 kts, 7 nm NE of center

Experimental research product of NOAA / AOML / Hurricane Research Division

Katrina Landfall
112 TJ SDP 4.9 SS3

Hurricane Katrina 1158 UTC 29 AUG 2005

Max 1-min sustained surface winds (kt)

Valid for marine exposure over water, open terrain exposure over land

Analysis based on FCMP_TOWER from 0942 - 1359 z; MESONET from 0937 - 1400 z; SHIP from 1010 - 1212 z; MADIS from 0936 - 1359 z; GOES_SWIR from 1002 - 1002 z;

GPSSONDE_WLL150 from 0959 - 1357 z; ASOS from 0936 - 1359 z;

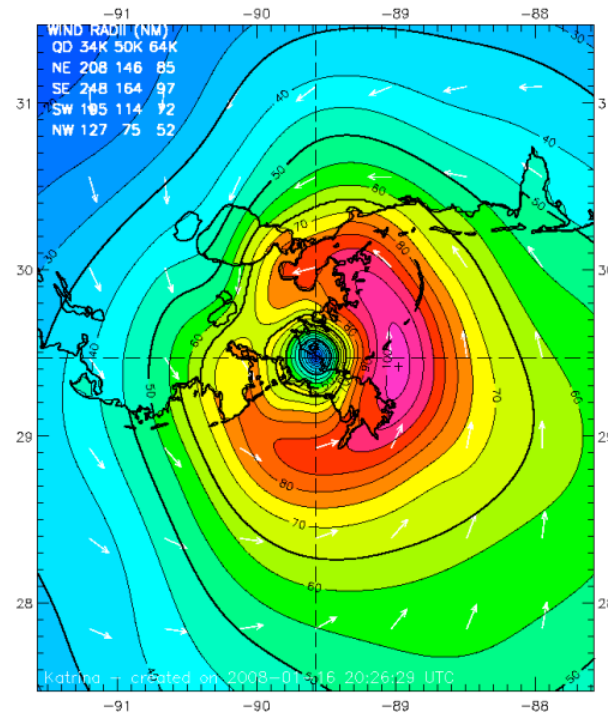
DUAL_DOPPLER (User-defined adjusted) from 1010 - 1302 z; VAD_88D from 0959 - 1354 z;

OSCAT from 1100 - 1102 z; CMAN from 0936 - 1400 z;

TAIL_DOPPLER (User-defined adjusted) from 1020 - 1346 z; MOORED_BUOY from 0939 - 1400 z;

SFMR43 from 0936 - 1359 z; METAR from 0950 - 1355 z;

1158 z position interpolated from 1132 Army Corps; mslp = 923.0 mb



Integrated Kinetic Energy: for Winds > TS force: 112 TJ, for Winds > Hurricane Force: 41 TJ
Destructive Potential Rating(0-6) Wind: 3.4, Surge/Waves: 4.9

Observed Max. Surface Wind: 102 kts, 35 nm SE of center based on 1020 z TAIL_DOPPLER
Analyzed Max. Wind: 102 kts, 36 nm SE of center

Uncertainty -> mean wind speed error: 6.16 kt, mean direction error: 10.70 deg
rms wind speed error: 10.97 kt, rms direction error: 18.61 deg

Experimental research product of NOAA / AOML / Hurricane Research Division

Ike day before Landfall
149 TJ SDP 5.4 SS 2

Hurricane Ike 1330 UTC 12 SEP 2008

Max 1-min sustained surface winds (kt)

Valid for marine exposure over water, open terrain exposure over land

Analysis based on GOES_SWIR from 1002 - 1002 z; CMAN from 0739 - 1259 z; MOORED_BUOY from 0730 - 1315 z; ASOS from 0730 - 1322 z; GPSSONDE_SFC from 0740 - 1250 z;

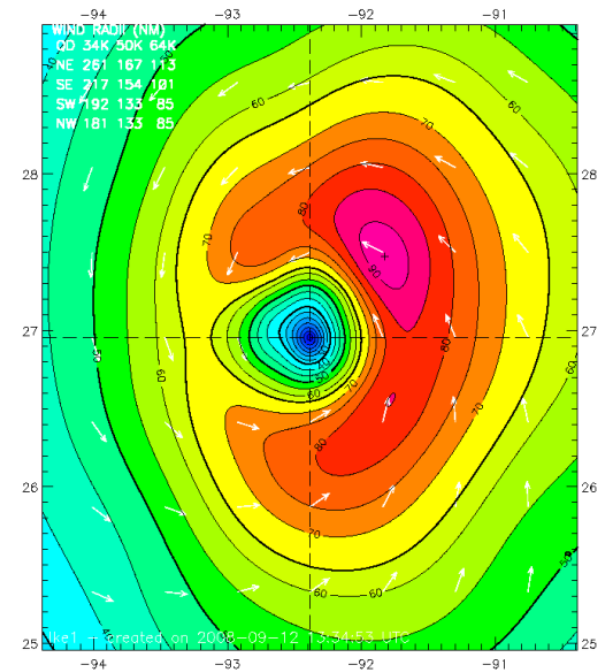
GPSSONDE_MBL from 0815 - 1250 z; DRIFTING_BUOY from 0730 - 1150 z;

SHIP from 0800 - 1300 z; GPSSONDE_WLL150 from 0740 - 1250 z;

BACKGROUND_FIELD from 1330 - 1330 z; SFMR43 from 1124 - 1321 z;

SFMR_AFRC from 0413 - 1322 z; OSCAT_HIRES from 1109 - 1111 z;

1330 z position extrapolated from 1308 z Estimator tool wind center using 290 deg @ 12 kts; mslp = 955.0 mb



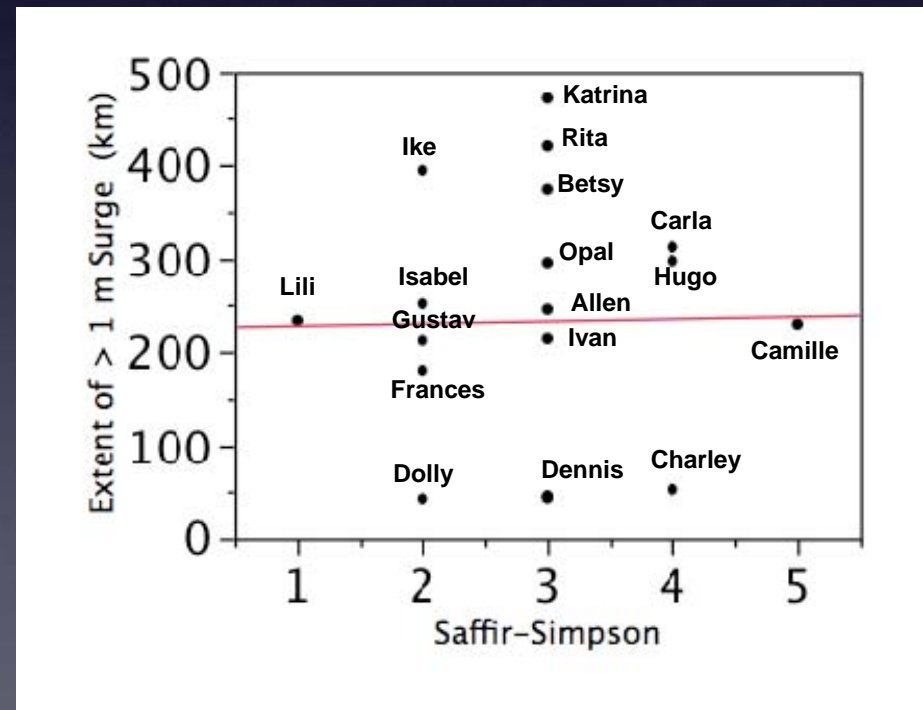
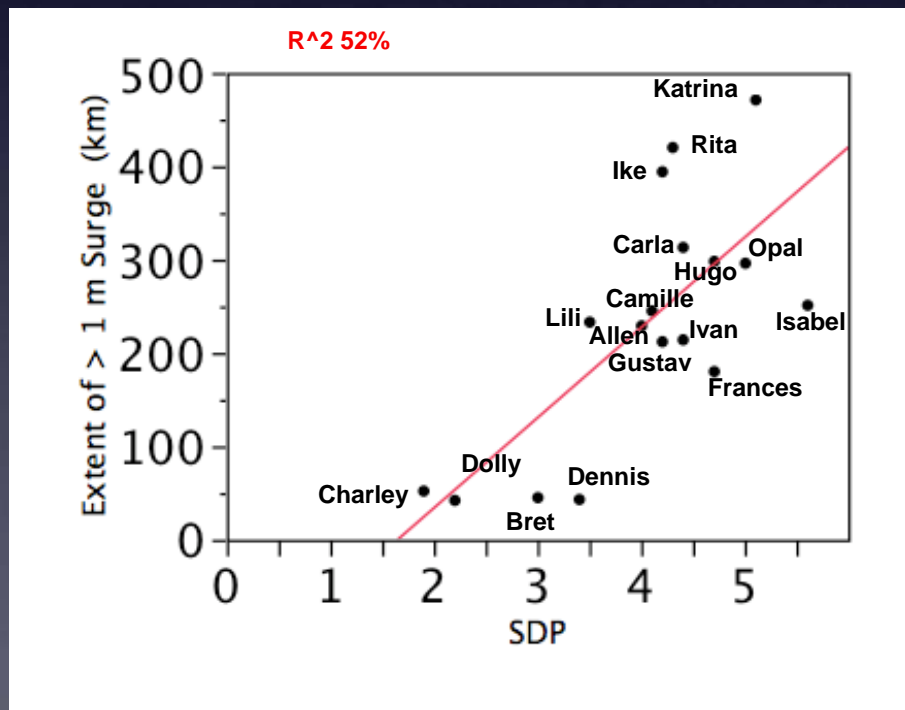
Integrated Kinetic Energy: for Winds > TS force: 149 TJ, for Winds > Hurricane Force: 54 TJ
Destructive Potential Rating(0-6) Wind: 3.4, Surge/Waves: 5.4

Observed Max. Surface Wind: 93 kts, 46 nm NW of center based on 1145 z MOORED_BUOY
Analyzed Max. Wind: 93 kts, 46 nm NE of center

Uncertainty -> mean wind speed error: 1.99 kt, mean direction error: -0.67 deg
rms wind speed error: 5.84 kt, rms direction error: 6.98 deg

Experimental research product of NOAA / AOML / Hurricane Research Division

- SDP and SS comparison to Alongshore extent of >1 m surge inundation
- *Irish and Resio 2009, in review, Ocean Engineering, using approach described in Irish and Resio, JPO 2008.*



- SDP is a means to compare storms based on oceanic wind field forcing alone
- Correlates best with alongshore inundation relevant to evacuation and damage from surge and waves (r^2 of 52% for extent of surge >1 m (n=17 storms), 34% for > 2 m (n=14 storms))
- Independent of bottom slope or coastline shape so correlation with peak surge height is smaller (r^2 of 10% compared to 8% for SS, 19 storms)
- SDP can enhance the Saffir-Simpson scale for cases in which large wind fields supply ample forcing for surge and wave damage
- SDP is relatively simple to compute, insensitive to the max wind value, with the same range as the SS scale

For more
informaton see:
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American
Meteorological
Society
April 2007

TROPICAL CYCLONE DESTRUCTIVE POTENTIAL BY INTEGRATED KINETIC ENERGY

BY MARK D. POWELL AND TIMOTHY A. REINHOLD

The maximum sustained surface wind speed and the Saffir-Simpson scale are poor indicators of a hurricane's destructive potential; integrated kinetic energy is more relevant to damage by wind, storm surge, and waves.

The Hurricane Katrina disaster and recent studies examining hurricanes and global climate change have generated discussion on tropical cyclone intensity and its relevance to destructive potential. Climate scientists are trying to determine whether hurricanes are becoming more frequent or destructive (e.g. Webster et al. 2005; Emanuel 2005), with resulting impacts on increasingly vulnerable coastal populations. People who lived in areas affected by Hurricane Katrina are wondering how a storm weaker than Hurricane Camille at landfall, could have contributed to so much more destruction. While intensity provides a measure to compare the maximum sustained surface winds (V_{MS}) of different storms, it is a poor measure ▶

H*Wind analysis of Hurricane Camille at landfall. See figure 1 on page 4 for more information.