



SLOSH New Orleans Basin 2012 Update

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• What is storm surge?

• What is SLOSH?

– Details

– Assumptions



Storm Surge = amount of water pushed on shore by hurricane winds. Storm Tide = sum of astronomical tide + storm surge. Inundation = Storm Tide – Terrain Height or Depth (New Orleans case)



Landfall

a. Top View of Sea Surface and Land



b. Side View of Cross Section "ABC"



Meteorological

What is SLOSH? Sea, Lake and Overland Surge from Hurricanes



A computer model developed by the National Weather Service (NWS) to estimate storm surge heights and winds resulting from *historical*, hypothetical, or predicted hurricanes.



SLOSH Grid Types of Information for each SLOSH Grid Cell



- Polar coordinate grid
- Each grid cell has
 - Average surge height
 - Terrain elevation
 - Barriers such a levees, roads and railroads
 - Cuts to allow flow through deep water passes.
 - Bathymetry

Accuracy +/- 20% of peak surge values





New Orleans Hurricane Protection Levee System



 Updated and improved annually by Corps of Engineers (COE).

Annual updates made to SLOSH using COE data.









- Levees and barriers are assumed to maintain structural integrity even if over topped by storm surge. SLOSH is not an engineering model.
- No storm frequency can be attributed to any MEOW.

Run off from rainfall not included in SLOSH. It is considered to be minor compared to storm surge.

Wind Waves are not included in SLOSH. Use 1/3 surge height to get estimate.





Storm Surge Products

- MOMS
- MEOWS
- Ensembles or P-surge
- When do I use them?

Which Storm Surge Product Do I Use and When Do I Use It?

- MEOWs
- MOMS
- Ensemble or Storm Surge Probability



MOM – Maximum of MEOW



- MEOW Maximum Envelope of Water from a family of land falling hurricanes which share the same
 - Direction
 - Forward Speed
 - Category
- Maximum amount of surge is saved from each individual SLOSH model run and displayed here
 - MOMS take this a step further by combining all MEOW possibilities (considering all directions and forward speeds) within each Category.





New Orleans Basin 2012 How many individual SLOSH Model Runs are Used to Make MEOWS? Answer: 23,760



Category	Direction (moving toward)	Speed (mph)	Tide - ft (2.0 / 0.0)	RMW (st mi)	Tracks	Runs
0,1,2,3,4,5	W	5,10,15,25	High,Mean	15,25,40	20	2880
0,1,2,3,4,5	WNW	5,10,15,25	High,Mean	15,25,40	19	2736
0,1,2,3,4,5	NW	5,10,15,25	High,Mean	15,25,40	19	2736
0,1,2,3,4,5	NNW	5,10,15,25	High,Mean	15,25,40	19	2736
0,1.2.3.4.5	Ν	5,10,15,25	High,Mean	15,25.40	20	2880
0,1,2,3.4,5	NNE	5,10,15,25	High,Mean	15,25,40	19	2736
0,1,2,3,4,5	NE	5,10,15,25	High,Mean	15,25,40	17	2448
0,1,2,3.4,5	ENE	5,10,15,25	High,Mean	15,25,40	17	2448
0.1.2.3.4.5	NE	5.10.15.25	High.Mean	15.25.40	15	2160



What is a MEOW?



MEOW – Maximum Envelope of Water from each member of a family or ensemble of land falling model hurricanes.

The Slosh Display Program has 216 MEOWS available for viewing.





What is a MEOW?



 MEOW – Maximum Envelope of Water from each member of a family or ensemble of land falling model hurricanes.





Why Do Use MEOWs or Ensembles?



 Because we must take into account Forecast Error and Size of Tropical Storm or Hurricane!

- Types of Forecast Error
 - Along track or speed faster or slower?
 - Cross track right or left?
 - Intensity stronger or weaker?



National <u>Hurricane</u> <u>Center</u> Track Error Trends







NHC Intensity Error Trends













SLOSH Ensemble developed to account for uncertainty in track and intensity forecasts



Storm: Dir nnw: Cat 3: 05 mph Basin: New Orleans v4 <ms3> и спрах Smith Jasper Clarke Winn Simpson Wilcox Copiah Butler Clarke Stm Tide ft Jefferson NAVD 1988 Wayne Jones CcConecuh -12 -10 -8 -6 -4 Greene Pike Escambia, Vernbn George Mobile Stone Tide level: Walto 2.0 ft Jackson Baldwin 100 Acadia asieu

More intense storms cause higher surges

Generalizations from SLOS

Escambia

Genéva

Amite Pike

Rapidé

Allen

ernon

- Highest surges usually occur to the right of the storm track
 - Fast moving storms = high surges along the open coast
 - Slow moving storms = greater flooding inside bays and estuaries

Larger storms affect longer stretches of coastline

Escambia

Genéva

• Direction of storm approach often impacts the extent of flooding

Generalizations from SLO

Amite Pike

Rapidé

Allen

ernon

- Shallow slopes in the continental shelf allow greater storm surge with small waves
- Storm surge is less in areas with steeper coastal slopes, but large breaking waves can occur







- <u>Maximum of MEOWS = MOM</u>
- Terrebonne and Lafourche Parishes including LA Highway 1
- MOMS display height in feet NAVD88 for
 - Tropical Storm
 - Saffir Simpson Categories 1, 2, 3, 4, 5



Tropical Storm (39 to 73 mph) MOM Surge Height – ft NAVD88







NOAA









Category 3 (111 to 129 mph) MOM Surge Height – ft NAVD88





Category 4 (130-156 mph) MOM • Surge Height – ft NAVD88

NOAA





Category 5 (> 157 mph) MOM Surge Height – ft NAVD88

NOAA





Just a Few MEOWS LA Highway 1 Focus



- Category impact
 - Increasing category from
 - Tropical Storm to 1
 - 1 to 2
 - 2 to 3
- Directional impact
 - Northwest
 - Speed impact
 - 15 mph
 Inquire Height Option

Northwest 15 mph Cat 0 MEOW Minor flooding mpti Bernard along LA **Highway 1** south of Stm Tide ft Thibodaux.

Tide level: 2.0 ft

Larose to Golden Meadow dry due to hurricane protection levee.



- Not much difference compared to tropical storm flood in this particular case.
- Minor flooding along LA Highway 1 south of Thibodaux.
- Larose to Golden Meadow dry due to hurricane protection levee.



Northwest 15 mph Cat 2 MEO

Degree of flooding has increased from Cat 1 to Cat 2.

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- Severe flooding below Golden Meadow and south of Intracoastal Waterway.
- Houma and Thibodaux threatened.



Northeast 15 mph Cat 3 MEOW

- Increasing category from 2 to 3 causes severe storm surge flooding in most places.
- Houma is overwhelmed.
- Deep flood waters threatening Thibodaux.
- Inquire all heights done for



LA 1 Highway Approach to Grand Isle

- Available for all 219 MEOWS for a specified area.
- Only have shown deeper storm surge for some Cat 1, 2 and 3 MEOWS here
 - There are many Cat 2 possibilities that could over top this road trapping people on Grand Isle.

Category 1 Feet Aby Datum		Â	Category 2 Feet Aby Datum		Â	Category 3 Feet Aby Datum	
nw 05 I2	4.4		nw 25 I2	7.2		nw 25 I2	10.1
wnw 05 I2	4.3		nnw 25 I2	7.1		nnw 25 I2	9.8
nnw 05 I2	4.2	Ξ	nw 05 I2	7.0	Ξ.	wnw 25 I2	9.8
nw 25 I2	4.0		wnw 25 I2	7.0		nw 05 I2	9.7
wnw 25 I2	4.0		n 25 I2	6.9		wnw 05 I2	9.5
e 05 I2	3.9		nw 15 I2	6.9		n 25 I2	9.4
ene 05 I2	3.9		wnw 05 I2	6.9		nw 15 I2	9.3
n 05 I2	3.8		nnw 15 I2	6.8		nne 25 I2	9.1
ne 05 I2	3.8		nnw 05 I2	6.7		nw 10 I2	9.1
nne 05 I2	3.8		nnw 10 I2	6.7		nnw 15 I2	9.0
nw 15 I2	3.7		nw 10 I2	6.7		wnw 15 I2	9.0
w 05 I2	3.7		wnw 15 I2	6.7		nnw 05 I2	8.9
nnw 25 I2	3.6		n 15 I2	6.6		nnw 10 I2	8.9
nw 10 I2	3.6		wnw 10 I2	6.5		n 15 I2	8.7
wnw 15 I2	3.6		n 10 I2	6.4		ne 25 I2	8.7
ne 10 I2	3.5		nne 25 I2	6.4		w 05 I2	8.6
nne 10 I2	3.5		w 05 I2	6.4		ene 25 I2	8.5
nnw 10 I2	3.5		w 25 I2	6.4		wnw 10 I2	8.5
wnw 10 I2	3.5		n 05 I2	6.3		n 10 I2	8.4
ene 10 I2	3.4		nne 15 I2	6.1		w 25 I2	8.4
n 10 I2	3.4		nne 05 I2	6.0		n 05 I2	8.3
nnw 15 I2	3.4	Ŧ	nne 10 I2	6.0	Ŧ	nne 15 I2	8.2

What Would Hurricane Betsy Storm Surge Look Like Today?









- MOMs show that minor flooding can occur along LA Highway 1 even for tropical storms.
- As the strength of the tropical storm or hurricane increases, the degree of flooding increases.
- There is a great sensitivity of storm surge flooding for slight changes in direction, forward speed and hurricane strength.
- The difference between not getting any storm surge flooding and catastrophic storm surge incident is a very fine line that can be easily crossed by nature.
 - In the real world, all possibilities come into play including track/intensity forecast error, size of the hurricane and initial water levels left over from prior hurricanes or tropical storms.







- Takes in many possibilities including
 - Track
 - Strength
 - Size



Probabilistic Storm Surge Methodology



- Use an ensemble of SLOSH runs to create probabilistic storm surge (P-surge)
 - Intended to be used operationally so it is based on NHC's official advisory.
 - P-surge's ensemble perturbations are determined by statistics of past performance of NHC's advisories
- P-surge technique accounts for Hurricane forecast errors which impact storm surge:
 - **Cross track errors (impacts Location)**
 - Along track errors (impacts Forward Speed)
 - Intensity errors (impacts Pressure)
 - Size of the storm errors.



Example: Katrina Advisory 23







Varying Katrina's Tracks



Include 90% of possible cross track error (roughly 3 times the size of the cone of error).

Spacing based on size of the storm





Size: Small, Medium, Large Forward Speed: Fast, Medium, Slow Intensity: Strong, Medium, Weak

Exceedance Probability of Surge (P-Surge) Hurricane Katrina Example

Ensembles
 based on
 current NHC
 advisory and
 forecast error.

- A 90 % chance of surge heights that could occur.
- Or only a 10 % chance of greater surge heights possible.



Probability of Surge (P-Surge) NOAA



- **Probability of** Surge **Exceeding 10** feet.
- Available in one foot increments from 2 to 25 feet.
 - **Upper bound** increased from 10 to 25 feet in 2009.



Where can you access P-Surge product? http://www.weather.gov/mdl/psurge

When is it available?

NNAA

– Beginning when the NHC issues a hurricane watch or warning for the continental US

NHC

As close to the advisory release time as possible



This experimental graphic shows the overall chance that storm surges will be greater than 2 feet above normal tide levels during the next 3 days. The graphic is based upon an ensemble of Sea, Lake, and Overland Surge from Hurricanes (SLOSH) model runs using the current National Hurricane Center (NHC) official hurricane advisory. Storm surge probabilities depend on the historical accuracy of NHCs forecasts of hurricane track, and wind speed, and an estimate of storm size.

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Goggle Map Interface



- Available in real time in NHC home page.
- Gives zoom, pan navigation capability.
 - Datum used: NGVD1929.

Tropical Cyclone Storm Surge Probabilities Chance of Storm Surge >= 2 feet (NGVD-1929) at individual locations Hurricane Test (2009) Advisory 15 For the 77 hours from 05 PM EDT Tue May 12 to 10 PM EDT Fri May 15 Select Level: Probability of Surge > 2 feet Load Data ~ Natchitoches \wedge Brookhave $\in + \Rightarrow$ ↓ ational Forest Hattiesburg Alexandria McCom De So National Eore Bogalusa 59 Zachary Eunice Gulfpor -Alak Legend Probability 40% - < 50% 5% - < 10% 80% - < 90% 50% - < 60% 90% - 100% 10% - < 20% 20% - < 30% 60% - < 70% 30% - < 40% 70% - < 80%

Gustav Advisory 30 Category 3 Landfall in 12 hours Tropical Storm and Hurricane wind field expanded increasing storm surge



Gustav Advisory 30 Single Track - Deterministic Run



Advisory 30



10 Pct Exceedance – Increase in surge values noted all areas. Forecasted landfall strength had decreased, but wind field expanded.





Gustav Advisory 30 – KMZ format Probability Storm Surge GTE 8 Feet Highest probability east of MS River







Hurricane Gustav - Post Event Tide Gage Observations

Total Water Elevation - Storm Tide in NAVD88 Subtract ~1 ft to arrive at "Pure" Storm Surge Note High Storm Tide Values East of MS River



