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# Hurricane Michael Brought Water Levels Over 20' High to the Coast

[Dr. Jeff Masters \(/cat6/author/jeff-masters\)](#) · November 16, 2018, 5:22 PM EST



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**Above:** A man walks through a beachfront neighborhood that was decimated by Hurricane Michael on October 16, 2018 in Mexico Beach, Florida. The neighborhood, which had homes most of the way to the beach before the storm, was flattened by Michael's storm surge. Image credit: Scott Olson/Getty Images.

As an intensifying Hurricane Michael roared ashore in Florida's Panhandle as a top-end Category 4 storm with 155 mph winds on October 10, 2018, it pushed a massive and destructive storm surge to the coast. The peak storm surge, located along the right side of where the eyewall made landfall, hit the town of Mexico Beach, which suffered devastating storm surge damage. Michael killed 45 people and caused damage in excess of \$15 billion, according to an estimate last week from insurance broker Aon. In a post-storm survey, the United States Geological Survey (USGS) [found \(https://stn.wim.usgs.gov/STNPublicInfo/#/HWMPage?Site=27713&HWM=34678\)](https://stn.wim.usgs.gov/STNPublicInfo/#/HWMPage?Site=27713&HWM=34678) at least three high-quality still-water marks between 17 - 19' above mean sea level (MSL) in Mexico Beach, taken inside of buildings where waves could not reach. These marks are likely a good measure of Michael's peak storm tide (height above MSL of the storm surge plus the tide), according to [Dr. Robert Young \(https://psds.wcu.edu/about/psds-staff/robert-s-young-director/\)](https://psds.wcu.edu/about/psds-staff/robert-s-young-director/), director of Western Carolina University's Program for the Study of Developed Shorelines.



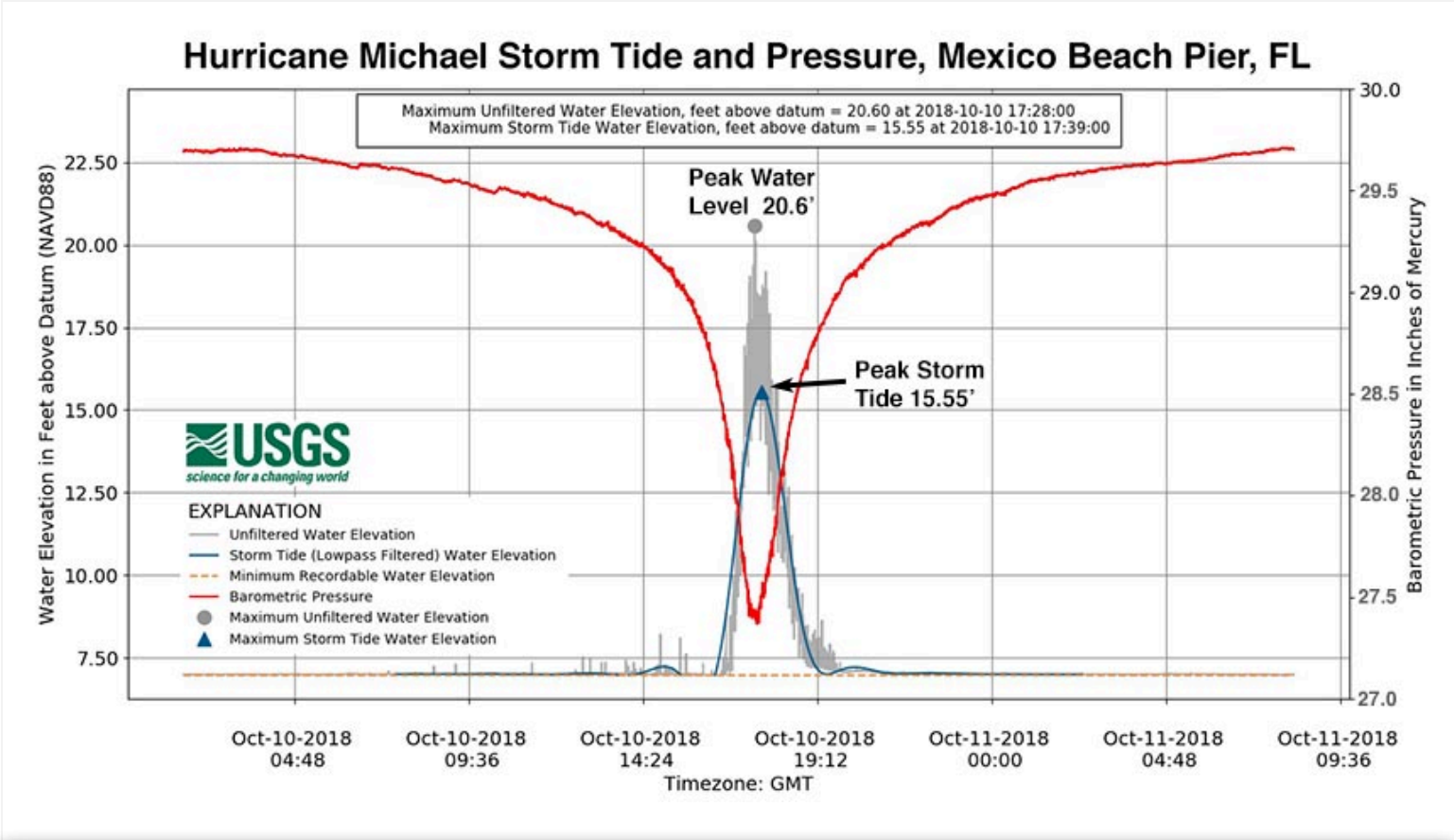
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**Figure 1.** A high-water mark 19.06' above mean sea level from Hurricane Michael was recorded inside this home in Mexico Beach, FL. The horizontal layering of the debris lines show that waves could not reach this location, so 19.06' may be an accurate measure of the hurricane's storm tide. Image credit: [USGS](https://stn.wim.usgs.gov/STNPublicInfo/#/HWMPage?Site=27713&HWM=34678) (<https://stn.wim.usgs.gov/STNPublicInfo/#/HWMPage?Site=27713&HWM=34678>).

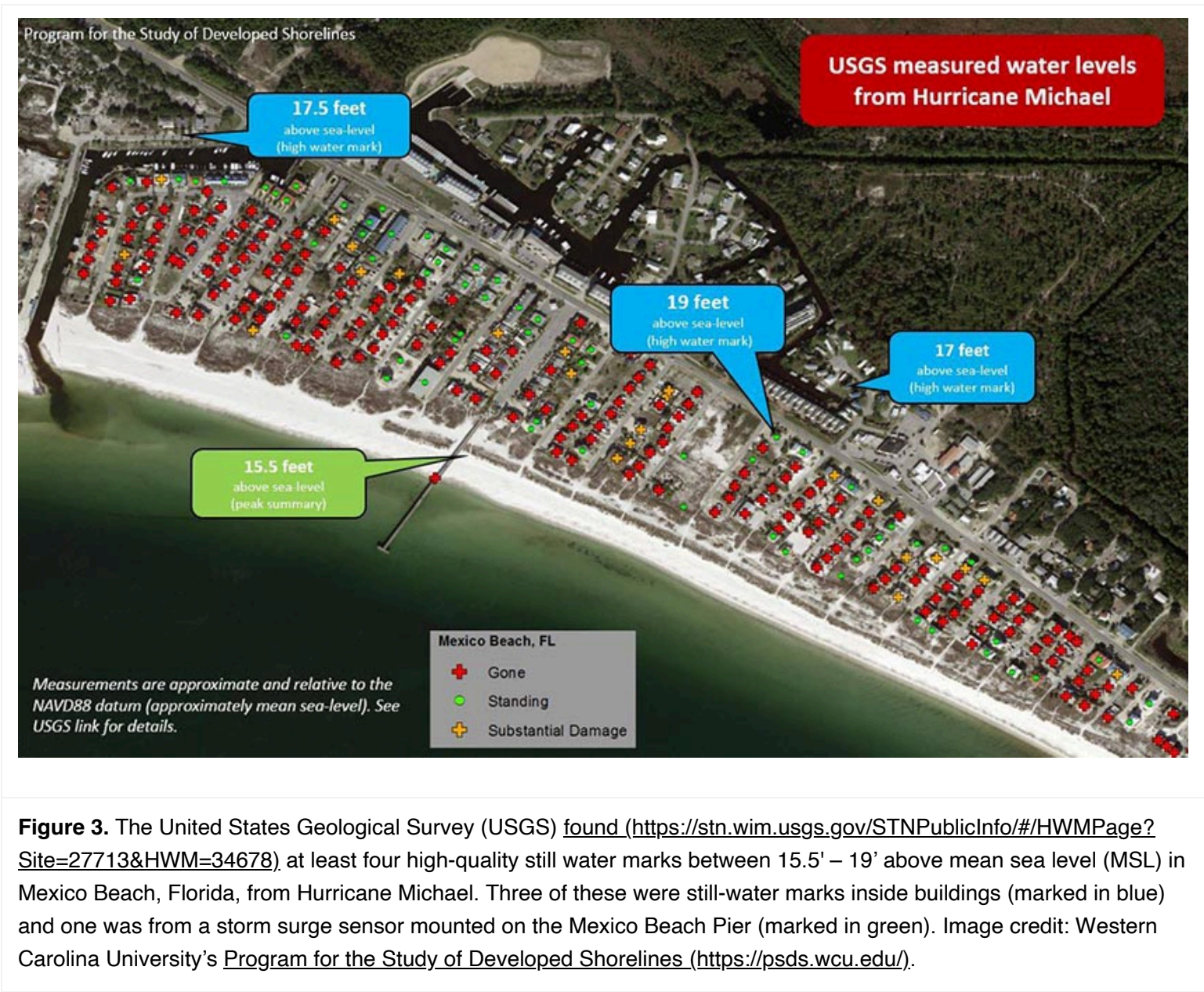
Michael's storm tide, when combined with waves on top of the surge, brought a high water mark (HWM) of 20.6' above mean sea level to a [storm tide sensor attached to the Mexico Beach Pier](https://stn.wim.usgs.gov/STNPublicInfo/#/SensorPage?Site=3283&Sensor=9486) (<https://stn.wim.usgs.gov/STNPublicInfo/#/SensorPage?Site=3283&Sensor=9486>). The mobile sensor, installed just before the storm by the USGS, measured a storm tide of 15.5', so waves on top of the surge were about 5' high. A higher HWM of 21.2' [was measured](https://stn.wim.usgs.gov/STNPublicInfo/#/HWMPage?Site=27658&HWM=34579) (<https://stn.wim.usgs.gov/STNPublicInfo/#/HWMPage?Site=27658&HWM=34579>) in the interior of a home in Port St. Joe, which adjoins Mexico Beach to the southeast. This mark was considered of lower quality ("fair").



**Figure 2.** Water level (grey line) and storm tide (blue line) from a [storm tide sensor attached to the Mexico Beach Pier](https://stn.wim.usgs.gov/STNPublicInfo/#/SensorPage?Site=3283&Sensor=9486) (<https://stn.wim.usgs.gov/STNPublicInfo/#/SensorPage?Site=3283&Sensor=9486>) during Hurricane Michael. The sensor measured a maximum storm tide of 15.55', and 5' waves of the surge brought a peak water level of 20.6'. Data from a pressure sensor attached to a nearby post is shown in red. Image credit: [USGS](https://stn.wim.usgs.gov/STNPublicInfo/#/HWMPage?Site=27713&HWM=34678) (<https://stn.wim.usgs.gov/STNPublicInfo/#/HWMPage?Site=27713&HWM=34678>).

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and an additional 2” correction needs to be made for the conversion between MSL and the NAVD 88 vertical datum), we get an estimate of 15' – 18.5' for the peak storm surge from Hurricane Michael. NOAA has not yet announced their official numbers for Michael’s storm surge, however.



## Michael's high water mark one of the six highest in 85 years of U.S. records

According to a [database](http://stormsurge.wcu.edu/download_data.php) ([http://stormsurge.wcu.edu/download\\_data.php](http://stormsurge.wcu.edu/download_data.php)) of high water marks of landfalling U.S. hurricanes from 1933 – 2017 compiled by Katie Peck of Western Carolina University, the peak high water marks of 20.6' - 21.2' in Mexico Beach would place Michael in fifth or sixth place for highest water levels ever recorded from a U.S. landfalling hurricane since 1933. The database, which culls data from 36 sources —primarily publications by NOAA, USGS, and FEMA—lists twenty hurricanes with maximum high-water marks in excess of 15 feet above normal (including Michael):

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Katrina, 2005: 34.11' above MSL at Biloxi, MS (Cat 3)

Camille, 1969: 24.6' above MSL at Pass Christian, MS (Cat 5)

Carla, 1961: 22' above MSL at Calhoun County, TX (Cat 4)

Opal, 1995: 21.5' above MSL at Mirimar Beach, FL (Cat 3)

**Michael, 2018: 20.6' - 21.2' above MSL at Mexico Beach, FL (Cat 4)**

Irene, 2011: 20.77' above NAVD at Lido Beach, NY (Cat 1)

Audrey, 1957: 20.3' above MSL at St. James Parrish, LA (Cat 3)

Hugo, 1989: 20.2' above NGVD at Awendaw, SC (Cat 4)

Isaac, 2012: 19.7' above NAVD at Harrison County, MS (Cat 1)

Ike 2008: 19.4' above NGVD at High Island, TX (Cat 2)

Sandy, 2012: 18.98' above NAVD at Monmouth, NJ (Cat 1)

Hazel, 1954: 18' above MSL at Sunset Beach, NC (Cat 4)

Rita, 2005: 17.8' above NGVD at Creole, LA (Cat 3)

Andrew, 1992: 17.2' above MSL at Perrine, FL (Cat 5)

Isabel, 2003: 16.24' above NGVD at Kill Devil Hills, NC (Cat 2)

Long Island Express, 1938: 15.8' above MSL at Providence/Kent County, RI (Cat 3)

Fran, 1996: 15.4' above MSL at New Hanover County, NC (Cat 3)

Carol, 1954: 15.1' above MSL at Kent County, RI (Cat 3)

Ione, 1955: 15.1' above MSL at River Bend, NC (Cat 3)

Floyd, 1999: 15' above NGVD at New Hanover County, NC (Cat 2)

Technical note: all storm surge measurements are referenced either to MSL or to a vertical datum, NGVD 29 or NAVD 88. NGVD 29 is a geodetic reference system developed by the National Geodetic Survey that is based on surveys taken in 1929. Due to subsidence of the land and the global sea level rise of about 8 inches over the past century, the 26 coastal stations used for these surveys have changed in their elevation relative to true MSL considerably since 1929. In the Mid-Atlantic states, NGVD 29 thinks mean sea level lies 0.5 - 1.9 feet below present-day mean sea level (PDF File). The more recent NAVD 88 reference system is of superior accuracy in most locations. The difference between NAVD 88 and MSL in the Florida Panhandle is only about 2 – 3”.

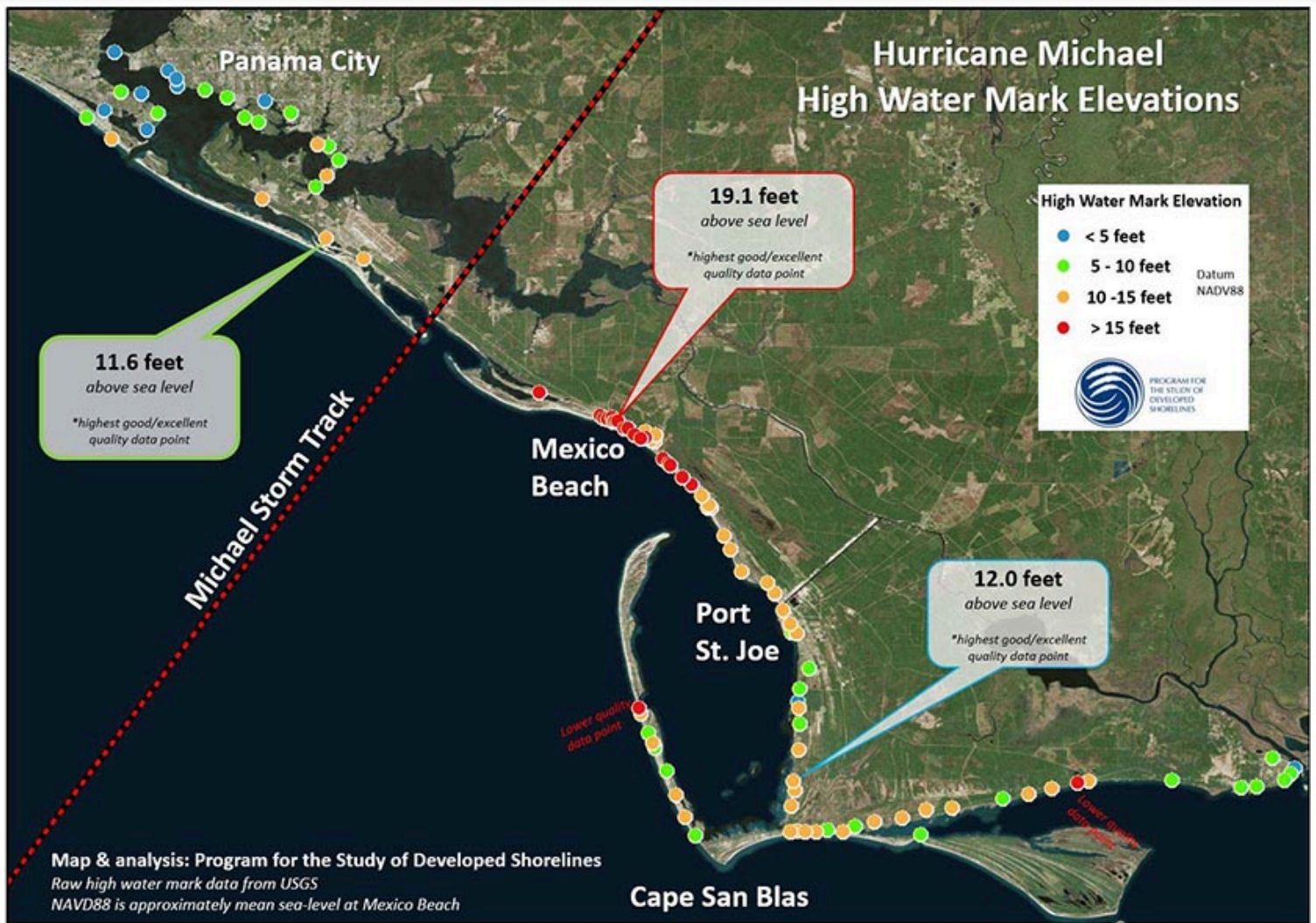
The all-time record for highest U.S. storm surge is Hurricane Katrina's 27.8 feet in Pass Christian, Mississippi in 2005 (measured from a “still water” mark found inside a building where waves couldn't reach). However, the highest high-water mark from Katrina was much higher: a mind-boggling 34.1 feet above mean level, measured on the outside of a building in Biloxi, Mississippi, where a high tide of about 1 foot combined with 11-foot high waves on top of the 22-foot storm surge to create the 34.1-foot high water mark. Note that the database does not have information from the strongest hurricane ever recorded to hit the U.S.—the 1935 Labor Day storm in the Florida Keys (185 mph winds, 892 mb pressure). That hurricane was reputed to have caused a storm surge of up to 20 feet, but there were no reliable measurements of the surge taken.



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**Figure 4.** Larger-scale view of high-water marks from the United States Geological Survey (USGS) for Hurricane Michael. Image credit: Blair Tormey, Katie Peek, Rob Young, Western Carolina University's Program for the Study of Developed Shorelines.

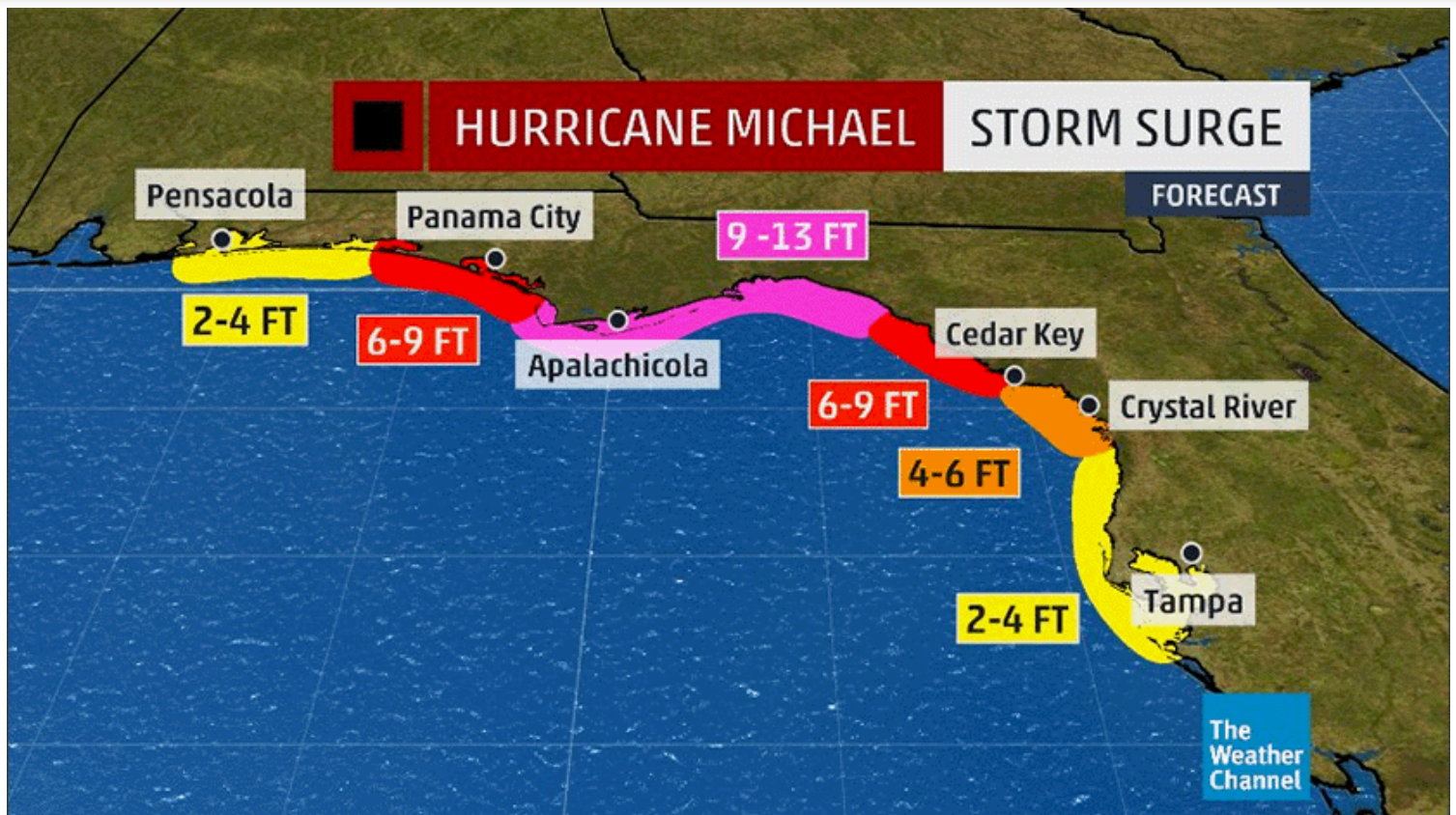


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**Figure 5.** Forecast from October 9, 2018 of storm surge heights above dry ground by NHC. The surge forecast was good, generally within two feet of the actual water heights measured (note that since NHC references their forecasts to the high tide mark, not MSL, one needs to add about another foot to these numbers to compare them to the high-water marks in Figures 3 and 4, since Michael did not hit at high tide). Image credit: weather.com.

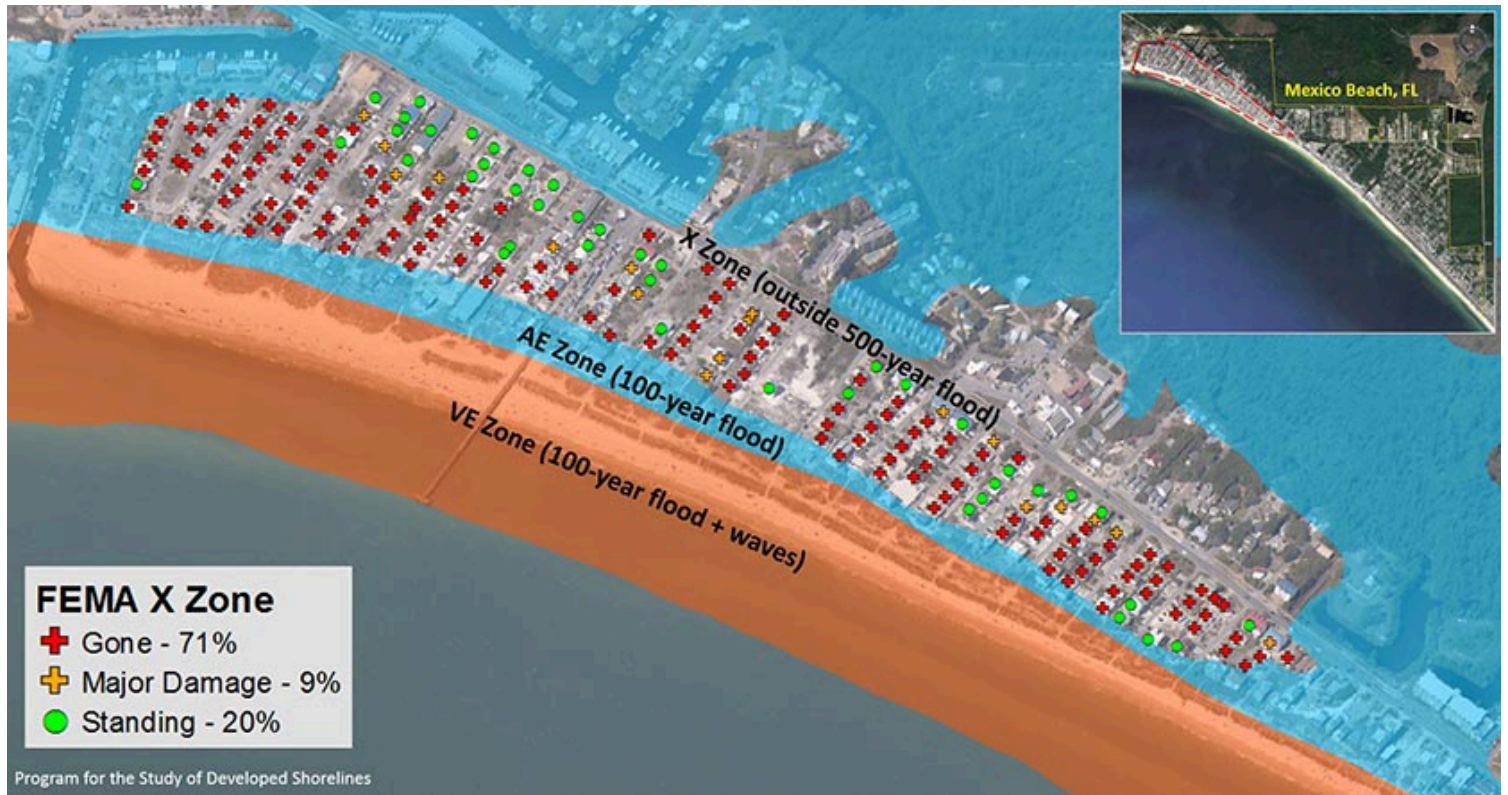
Similar findings were sent to us by John Garner, a structural engineer who surveys damaged buildings after floods and storms:

“I’ve been working in Panama City and Mexico Beach...wow. What a mess. The worst wind damage I’ve seen since Andrew, and a storm surge pretty close to Ike.

“Part of what we do is delineate wind damage versus flood damage, and today I was surveying some water heights. I measured two in Mexico Beach, both along the canal that you may have seen photos of. These are still water heights, where floodwaters rose and stood before receding, and both readings were inside the remains of buildings, and didn’t include wave heights.

“In both cases I measured between 16.5’ and 17’ a  sea level. That’s about a match for the highest I found in Ike, and slightly higher than Ivan. I found another high-water mark that looks like it is close to 18’, but I have not verified the survey data so it’s only preliminary. Looking at the devastation here it is amazing that the loss of life was as small as it was. Even though Panama City was really hammered by the west eyewall, we were fortunate that the storm took a right turn. Had the eye gone to the left of the city and driven an 18’ storm surge up that bay, it could have been much worse.

“For the record, a proprietary radar wind program from a private company showed 152 mph 3-second gusts in Mexico Beach. That is top end EF3 damage, and it's pretty consistent with the damage I saw.”



**Figure 6.** Approximately 80% of all the structures in Mexico Beach were destroyed or severely damaged by Hurricane Michael’s storm surge in an area mapped as minimal flood hazard (FEMA’s X Zone, grey color). None of these 200 structures would have been required to carry flood insurance (only zones V and A, orange and blue colors, were required to). Image credit: Blair Tormey and Katie Peek of Western Carolina University.

## FEMA flood maps for Mexico Beach were outdated

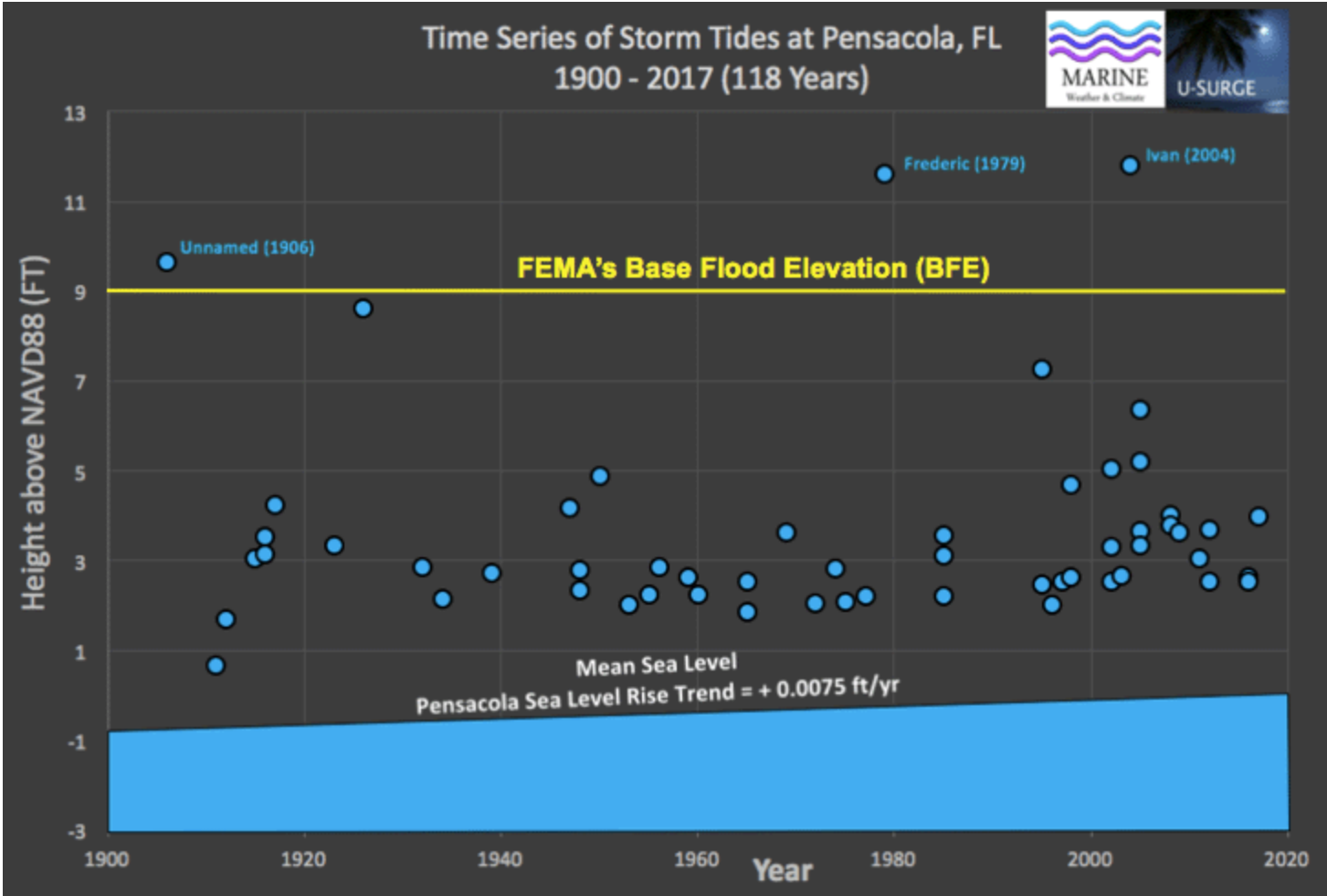
A property owner is required to carry flood insurance when the official Federal Emergency Management Agency (FEMA) flood map for the location shows a 1-in-100-year risk or higher of flooding (an event that has at least a 1% chance of happening in any given year). However, approximately 80% of all the structures in Mexico Beach were destroyed or severely damaged by Hurricane Michael’s storm surge in an area defined as an area of minimal flood hazard, outside of the 0.2% annual chance flood (or 1-in-500-year flood). These homes were generally at an elevation of 6 to 17 feet above sea level. Given that Hurricane Michael was the third or fourth strongest hurricane on record ever to hit the continental U.S., a 1-in-500 year flood risk estimate may not have been far off. However, with sea level rise accelerating and climate change expected to make the strongest hurricanes stronger and more numerous, the coastal flood risk will be steadily increasing in the coming decades.

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FEMA is supposed to review their maps every five years to make sure they still properly indicate flood risk, but a 2017 report (<https://www.bloomberg.com/graphics/2017-fema-faulty-flood-maps/>) by Bloomberg found some FEMA flood maps to be as old as from the 1970s. Only 42 percent of the FEMA maps “adequately identified the level of flood risk”, according to a 2017 report (<https://www.documentcloud.org/documents/4066233-OIG-17-110-Sep17.html>) from the Department of Homeland Security’s Inspector General’s Office.



**Figure 7.** Storm tide history for Pensacola, Florida, from the [U-Surge Project](https://www.u-surge.net/) (<https://www.u-surge.net/>). The highest water levels (storm tides) since 1900 are plotted, along with FEMA's threshold for a 1-in-100 year flood (the Base Flood Elevation, or BFE, shown as a yellow line at 9 feet above sea level). Three storm tides since 1900 have exceeded FEMA's BFE, and if sea level rise is added to the 1926 storm tide, that event also would exceed BFE today. Thus, what FEMA calls a 100-year-flood would actually be more like a 25- or 30-year water level from a data-driven perspective. Image credit: Dr. Hal Needham, [U-Surge Project](https://www.u-surge.net/) (<https://www.u-surge.net/>).



FEMA generates their flood maps based on historic flood data, and through modeling of the risk in the current climate. According to storm surge expert [Dr. Hal Needham](#), this process is often questionable: "When I have built storm surge histories for coastal cities, typically 3 or 4 historical storm surge events have exceeded FEMA's Base Flood Elevation (BFE), which is synonymous with the 100-year flood level. So what FEMA calls a 100-year flood level would actually be more like a 25- or 30-year water level from a data-driven perspective."

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FEMA does not take into account anticipated future sea levels or climate change. This might be OK if the FEMA maps were updated every five years as required, but old FEMA maps from decades ago are going to seriously underestimate flood hazards in many cases, due to climate change. Bad information about an area's flood risk can leave the National Flood Insurance Program (NFIP) and homeowners vulnerable to high costs from flood damage. NFIP is currently (<https://fas.org/sgp/crs/homesec/IF10988.pdf>) \$20.5 billion in debt, even after Congress cancelled \$16 billion in debt due to 2017 claims from the destruction wrought by Hurricanes Harvey, Irma and Maria.

In the case of fresh water flooding, more than 40 million Americans are exposed to flood risk at the 1-in-100-year flood level, about three times more than the 13 million when calculated using FEMA's flood maps, a February study (<http://iopscience.iop.org/article/10.1088/1748-9326/aaac65>) in the journal Environmental Research Letters concluded.

### Hurricane MICHAEL Blasts the Florida Panhandle (2018)



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## Dr. Jeff Masters

Dr. Jeff Masters co-founded Weather Underground in 1995 while working on his Ph.D. in air pollution meteorology at the University of Michigan. He worked for the NOAA Hurricane Hunters from 1986-1990 as a flight meteorologist.

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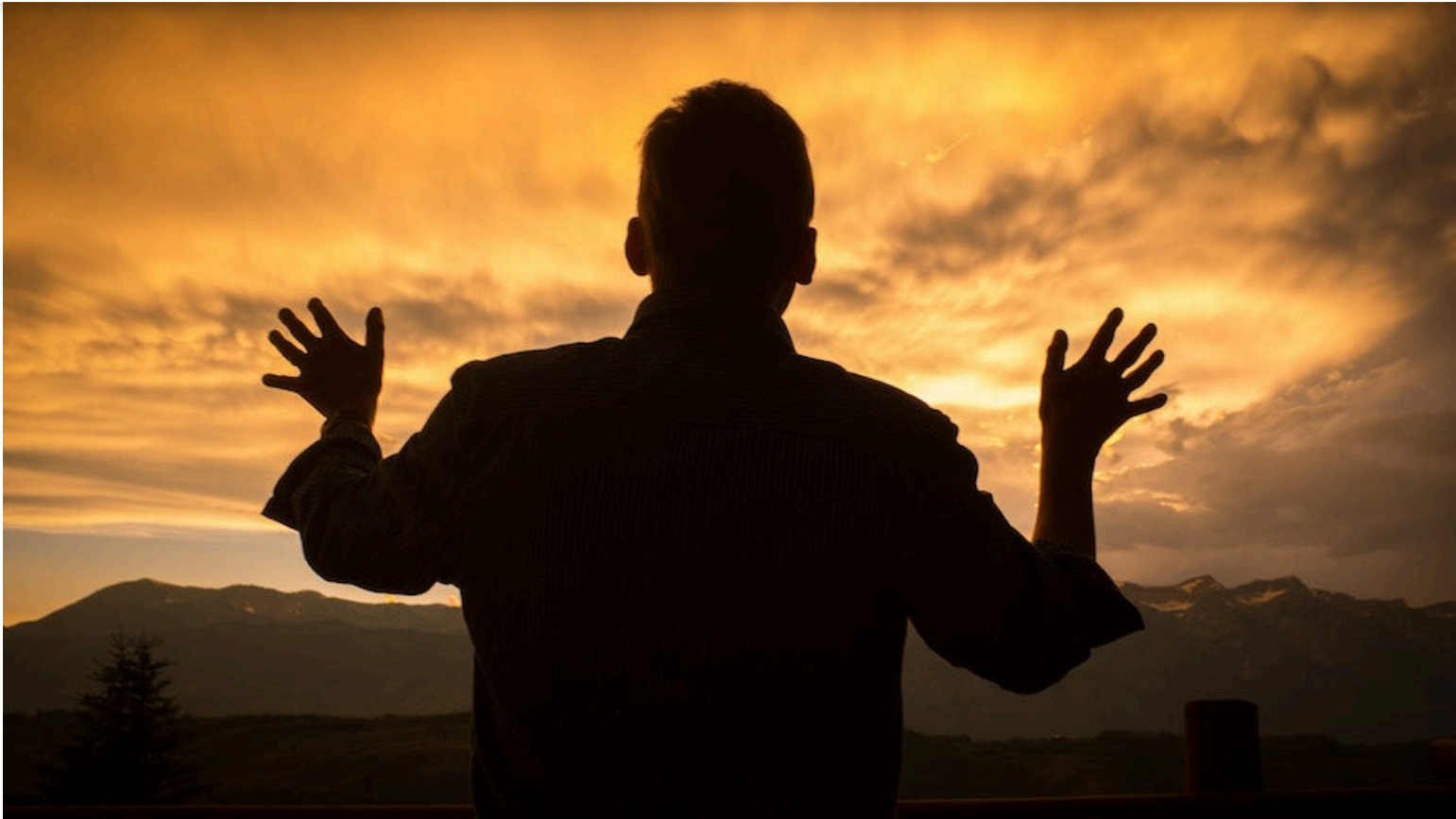
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utm\_source=taboola&utm\_medium=cpc&utm\_content=The+5+Stupidest+Things+Americans+Overspend+On+%28Hint%3A+Coffee+Isn%E2%80%99t+O  
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(https://lp.nuviasmiles.com/philadelphia-eval-taboola?

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## Revolutionary 24hr Teeth Replacement Now Available in Philadelphia

### Nuvia Dental Implant Center

(https://lp.nuviasmiles.com/philadelphia-eval-taboola?

utm\_source=Taboola&utm\_term=wunderground.com&utm\_medium=Desktop&utm\_content=3926785968&utm\_campaign=Taboola-philadelphia-  
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## Cinnamon: The greatest enemy of blood sugar (Learn how to use it)

### Better Health News

(https://d.daily2tips.com/67a0b7baee971fb1d0eb9de0?sub1=43648563&utm\_source=Taboola&sub3=4089781026&sub4=theweatherchannel-

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(https://wellnessguide104.com/go/677fe045ee31c99c71071332?aff=1169&sub=3A Bio\_Complete\_3\_Desk\_MaxC&xcode=GiCTcRX7G-

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JLPw\_q2CxKvhEfPbk1Eh9EIDQb0ID0yQZ3HCCcvE4onl6fsa6tj9dHMNr1SA)

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### WellnessGuide

(https://wellnessguide104.com/go/677fe045ee31c99c71071332?aff=1169&sub=3A Bio\_Complete\_3\_Desk\_MaxC&xcode=GiCTcRX7G-

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## Cardiologists Reveals: How to Quickly Lose a Hanging Tummy

Health Wellness Journal

(https://healthwellnessjournal.com/go/67767878f92d2882160ae3d3?aff=1169&sub=110\_Mitolyn\_Desk\_Max&xcode=GiCTcRX7G-  
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## This Eye Bag "Balm" Sold Out at Target in 2 Days

The Beauty Edit

(https://xeiourl.cc/f8fdf998-72e1-491b-ac68-056b84021091?utm\_source=taboola&utm\_medium=referral&site=theweatherchannel-  
wunderground&campaign=lumibalm\_us\_desk\_maxconv&thumbnail=http%3A%2F%2Fcdn.taboola.com%2Flibtrc%2Fstatic%2Fthumbnails%2Fa23dae940  
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## Actress Spills Hollywood Trick For Slim Body: "We All Do It"

Experts In Getting Slim

(https://trk.expertsinggettingslim.co/d1bbd876-e6e9-4eee-b93a-e4a44324abcc?  
campaign\_id=44075273&campaign\_item\_id=4092441795&site\_id=1194714&site=theweatherchannel-  
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