

RESPONDING TO A RISING TIDE

NWS Resources for Coastal Storm Response



Bob Thompson, National Weather Service Taunton, MA

COASTAL STORMS

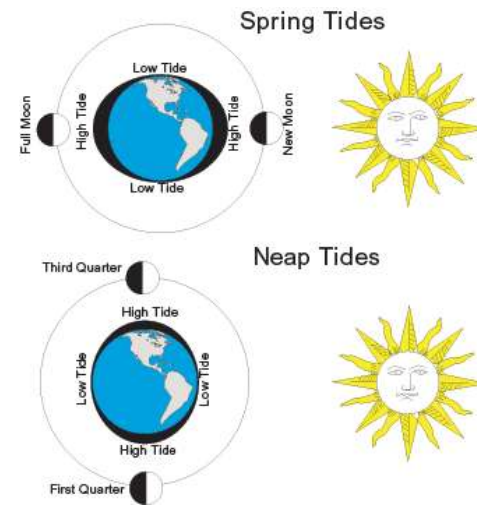
- **Coastal storm impact basics**
 - Water level and waves
- **Two types of coastal storms**
 - Tropical Cyclones (e.g. hurricanes)
 - Extratropical Cyclones (e.g. nor'easters)

The Basics

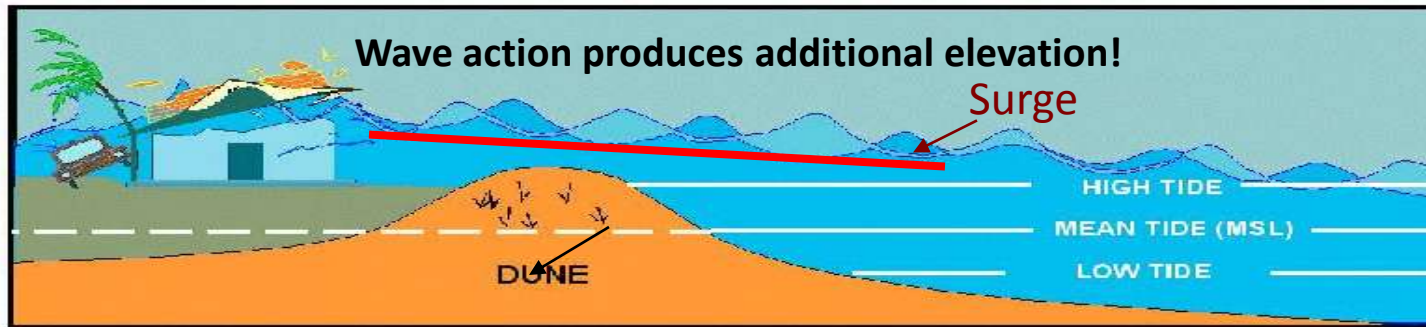
- **Astronomical tide amplitude (Spring Tide?)**
- **Wind fetch (distance over water)**
- **Duration of winds headed toward shore**
- Angle of wave train to shoreline
- Storm motion (approaching on great circle route?)
- If tropical cyclone, consider:
 - Intensity Category
 - Size
 - Radius of max winds

ASTRONOMICAL TIDES

- Spring Tide
 - During full and new moons
 - Moon and sun gravitational forces in alignment
- Neap Tide
 - Quarter moon phases
 - Moon and sun gravitational forces offsetting



Hurricanes and Nor'easters both impact coastline with storm surge and waves



Coastal flooding and erosion result from storm surge on top of the astronomical tide and wave action on top of the storm tide.

Timing of the maximum storm surge is an important issue for those locations (e.g. New England) that have large tidal ranges.

Storm Tide (Total Still Water Level) = **Astronomical Tide** + **Storm Surge**

Waves contribute the following:

- Add to water level behind barrier beach via **overwash** (from wave runup)
- Cause damage to structures (sea walls, docks, homes, etc.) via **wave battery**
- Scour and transport beach sand via **erosion**

MORE TERMINOLOGY



Overwash



Splashover

Rule of thumb:

Along exposed coast, overwash and splashover can become important when waves about 10 miles offshore reach 20 feet or more

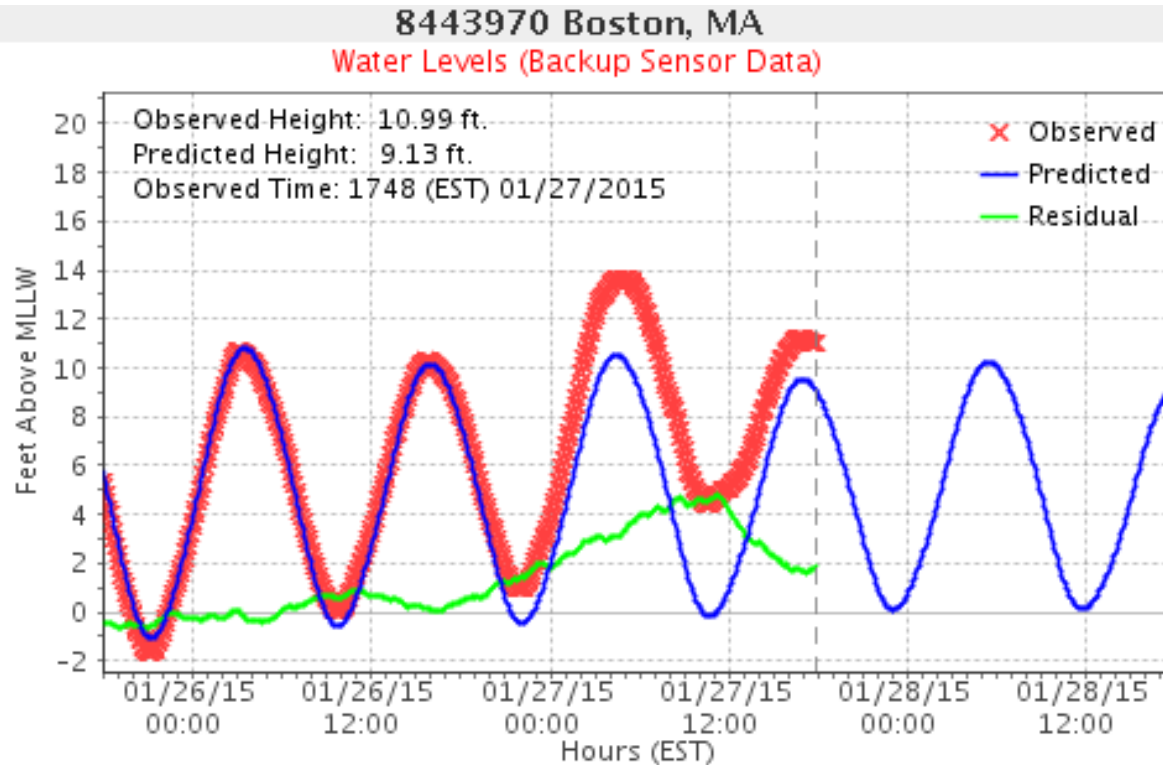
TIMING MATTERS!

JANUARY 27, 2015 COASTAL FLOODING



January 27, 2015 morning Scituate, MA – courtesy Dave Laroche

January 27, 2015 High Tide at Boston



Max Storm Tide = 13.65 feet MLLW (approx. 30 minutes after time of astronomical high tide)

Storm Surge at max storm tide = **3.35 feet** (3.12 feet at time of actual astronomical high tide)

Max storm surge = **4.78 feet** (approx. 30 minutes after time of low tide)

WHAT IF...

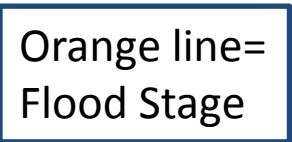
- The storm was about 6 hours faster and peak surge occurred at high tide:
 - $10.5 + 4.78 =$ **storm tide of 15.28 feet MLLW**
 - **Just above record water level of 15.1 feet MLLW set during the 1978 Blizzard**
- The storm occurred the week before when we had a 12 foot MLLW astronomical tide:
 - **Potential storm tide near 16.8 feet (would bring us to uncharted territory)**

WAVES MATTER!

- Structural damage from wave battery
- Contribution to inundation via overwash
- Scouring/erosion



A Tale of Two Tides



A Tale of Two Tides

- February 8, 2013 Evening High Tide
 - Storm Tide about 13 feet above MLLW
 - **Waves 15 to 20 feet** just offshore
- February 9, 2013 Morning High Tide
 - Storm Tide about 13 feet above MLLW
 - **Waves 30 to 35 feet** just offshore
 - With 12 to 14 second periods

Wave Overwash

7th Avenue



Elevation of top of staff gage is El 16.6 which is approx level of ic

2/11/2013 9:37:14 AM

And Erosion Can Be a Big Issue

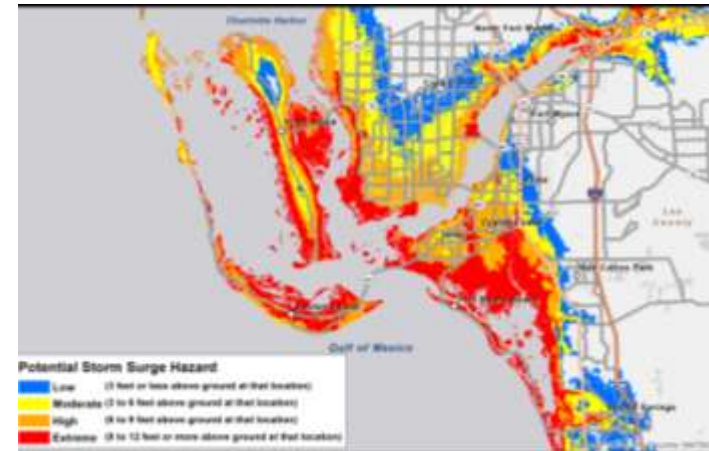
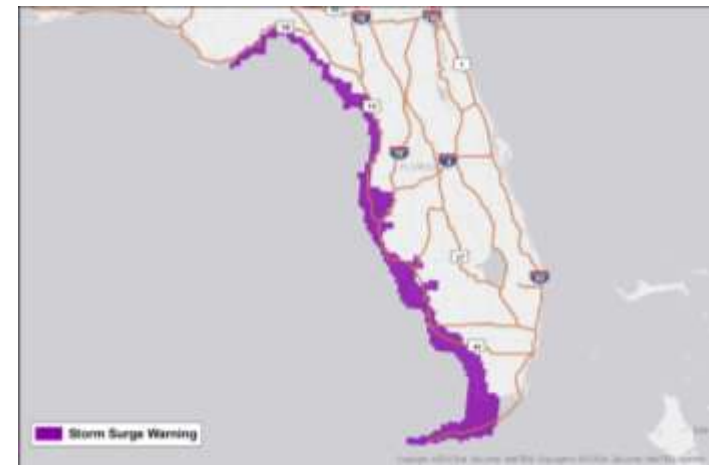


Misquamicut Beach – Westerly, RI (2 days after Sandy)



New Products from National Hurricane Center

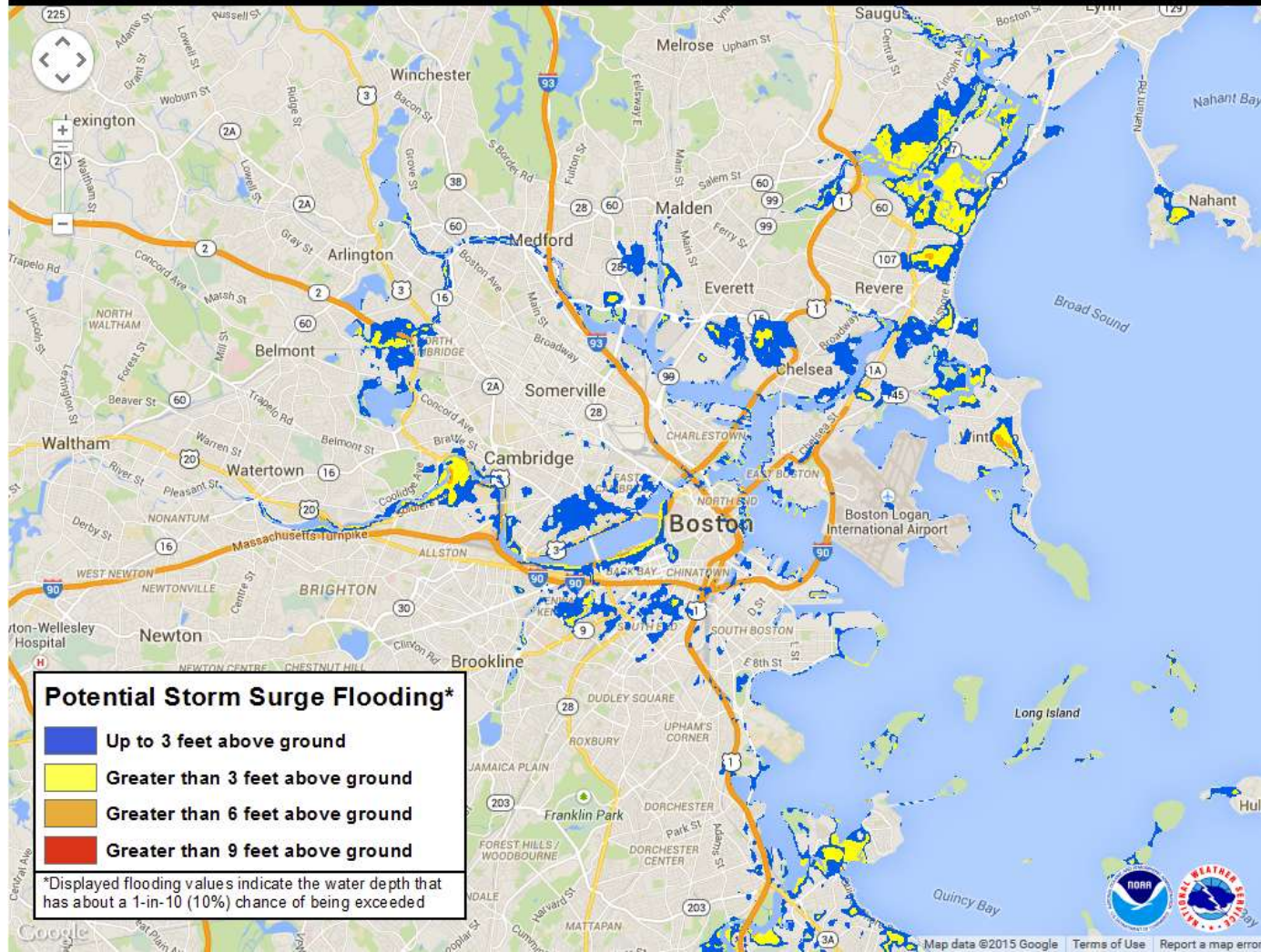
- Storm Surge Warnings
 - Explicit Storm Surge Warning
 - versus implicit by a Hurricane Warning
 - Recommended by social scientists
- Dynamic inundation mapping
 - Visualization of inundation **possible** from a specific storm
 - Represents plausible worst case scenario (10% exceedance)
 - Does not incorporate wave runup/overwash
 - Currently only for tropical cyclones



NHC FORECAST INUNDATION MAP FOR PLAUSIBLE WORST CASE SCENARIO

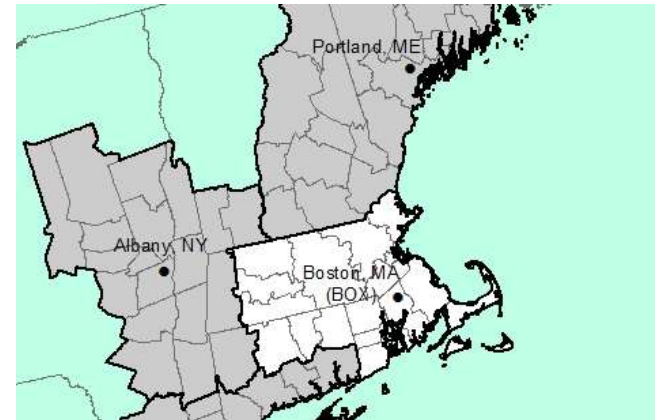
10% CHANCE OF BEING EXCEEDED

Hurricane TRAVIS - Advisory 16 - EXPERIMENTAL MAP



LOCAL WEATHER INFORMATION

**National Hurricane Center and
local Weather Forecast Office work
as a team**



- **Hurricane Local Statements (& TCV)**
- **Hurricane Threat and Impact Graphics**
- **Marine Weather Warnings**
- **Hazardous Weather Outlooks**
- **Area Forecast Discussion**
- **Decision Support Services Briefings**

HURRICANE LOCAL STATEMENT

- **Purpose: provide concise overview of evolving hurricane threat for more effective response**
 - Executive weather summary of evolving weather situation
- **Primary focus:**
 - Hazard(s) of greatest concern
 - Areas where threat is greatest
 - Critical time frame

COASTAL FLOOD HEADLINES

Extratropical Storms (e.g. Nor'easters)

- **Coastal Flood Watch**
 - Potential for moderate or greater coastal flooding
 - Generally 36 to 48 hours lead time
- **Coastal Flood Warning**
 - Moderate or major coastal flooding likely/expected
 - Generally 24 to 36 hours lead time
- **Coastal Flood Advisory**
 - Minor coastal flooding likely/expected
 - Generally 24 to 36 hours lead time

HEADLINE CRITERIA

- Minor – Coastal Flood Advisory
- Moderate or Major = Coastal Flood Warning



Minor



Moderate



Major



COASTAL FLOODING DEFINITIONS

Minor Coastal Flooding – Flooding of the most vulnerable shore roads and/or basements due to height of storm tide or wave splashover. Majority of roads remain passable with only isolated closures. There is no significant threat to life and any impact on property is minimal. This type of event is covered by a **Coastal Flood Advisory**.

Moderate Coastal Flooding – Widespread flooding of vulnerable shore roads and/or basements due to height of storm tide and/or wave action. Numerous road closures are needed. Lives may be at risk for people who put themselves in harm's way. Isolated damage of very vulnerable structures such as docks or house decks/porches near the high tide line may be observed. This type of event is covered by a **Coastal Flood Warning**.

Major Coastal Flooding – Coastal flooding severe enough to cause *at least* scattered structural damage along with widespread flooding of vulnerable shore roads and/or basements. Some vulnerable homes or businesses are severely damaged or destroyed. Numerous roads are impassable, some with washouts severe enough to be life threatening if one attempted to cross on foot or by vehicle. Some neighborhoods are isolated. Evacuation of some neighborhoods is necessary. This type of event is covered by a **Coastal Flood Warning** with additional language to indicate that the flooding will be major, severe, destructive, damaging, etc.

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Local forecast by
"City, St" or ZIP code

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Click on the map below to zoom



Last Map Update: Tue, Dec. 1, 2015 at 5:06

Forecasters' Discussion
Hourly View
Map View
Activity Planner
Aviation
Marine
Fire Weather
Coastal Flood Threat
Zone Forecast (text)
Beach & Surf

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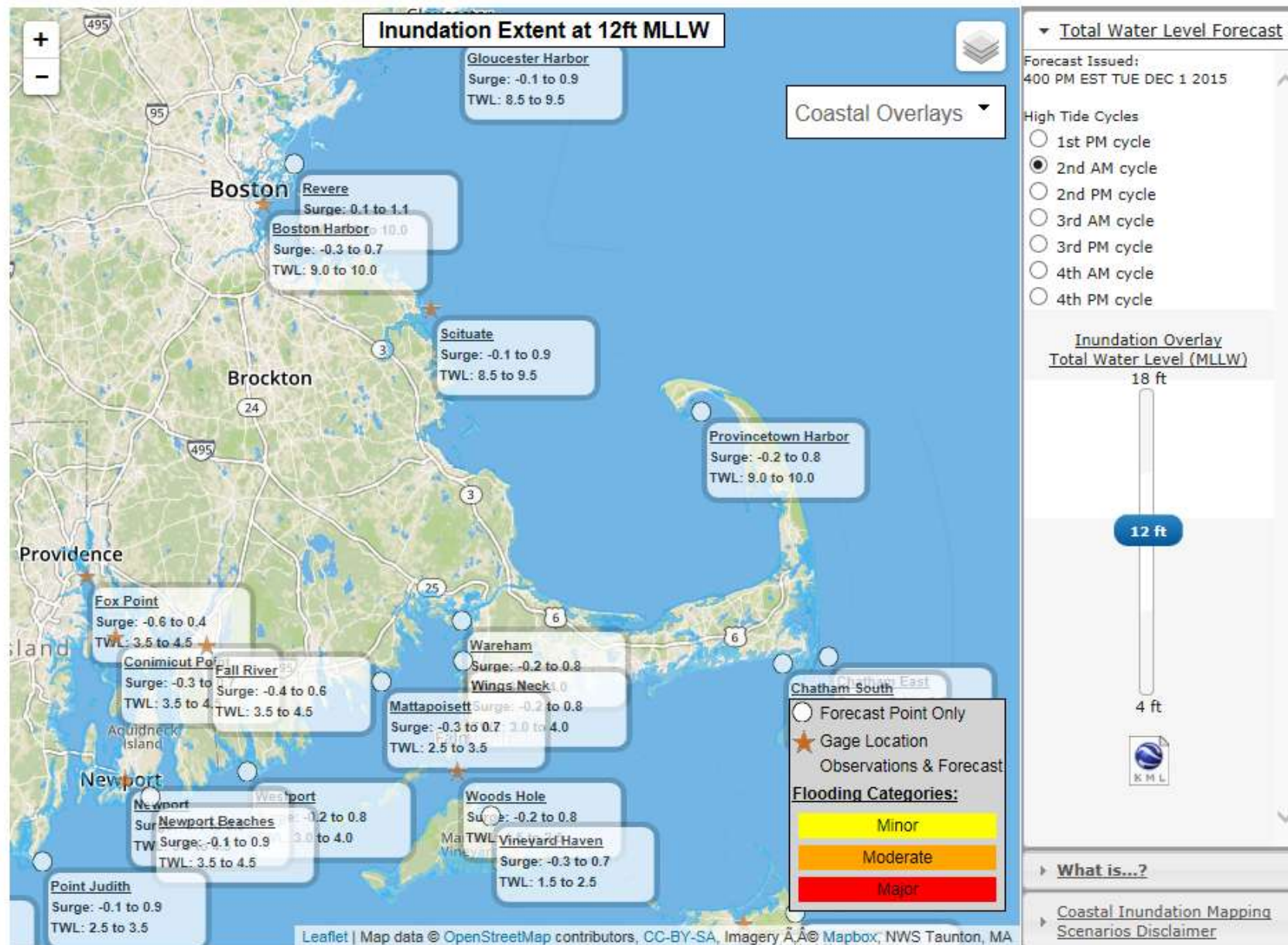
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Coastal Flood Threat and Inundation Mapping

Weather.gov > Boston, MA > Coastal Flood Threat and Inundation Mapping

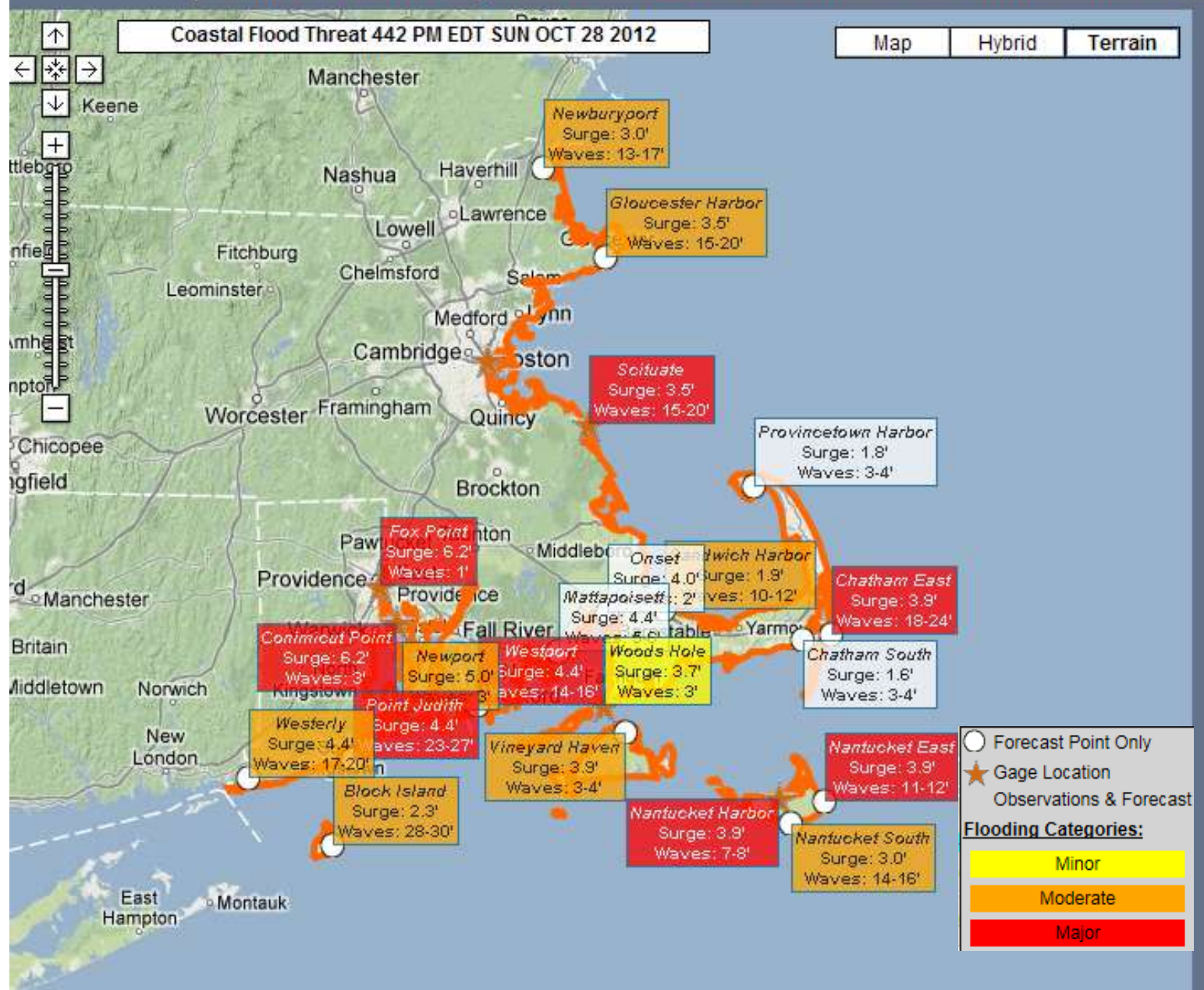
Boston, MA

Weather Forecast Office



NOTE: During times when the area is under a Tropical Storm/Hurricane Watch or Warning, the storm tide or total water level forecast will reflect a plausible worst case scenario (versus the usual most likely scenario).

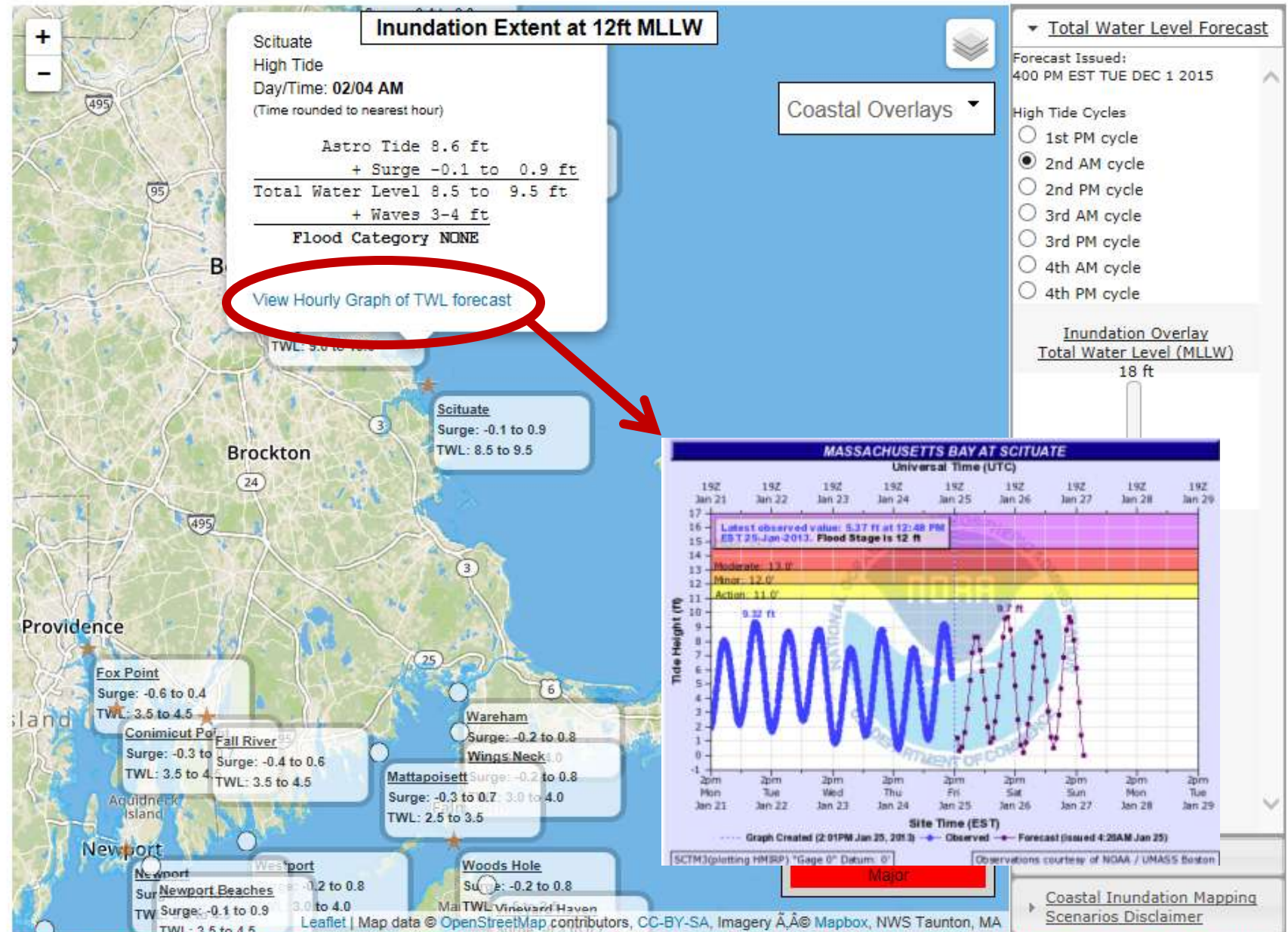
Southeast New England Water Level Forecast & Coastal Flood Threat



Coastal Flood Threat and Inundation Mapping

Weather.gov > Boston, MA > Coastal Flood Threat and Inundation Mapping

Boston, MA
Weather Forecast Office

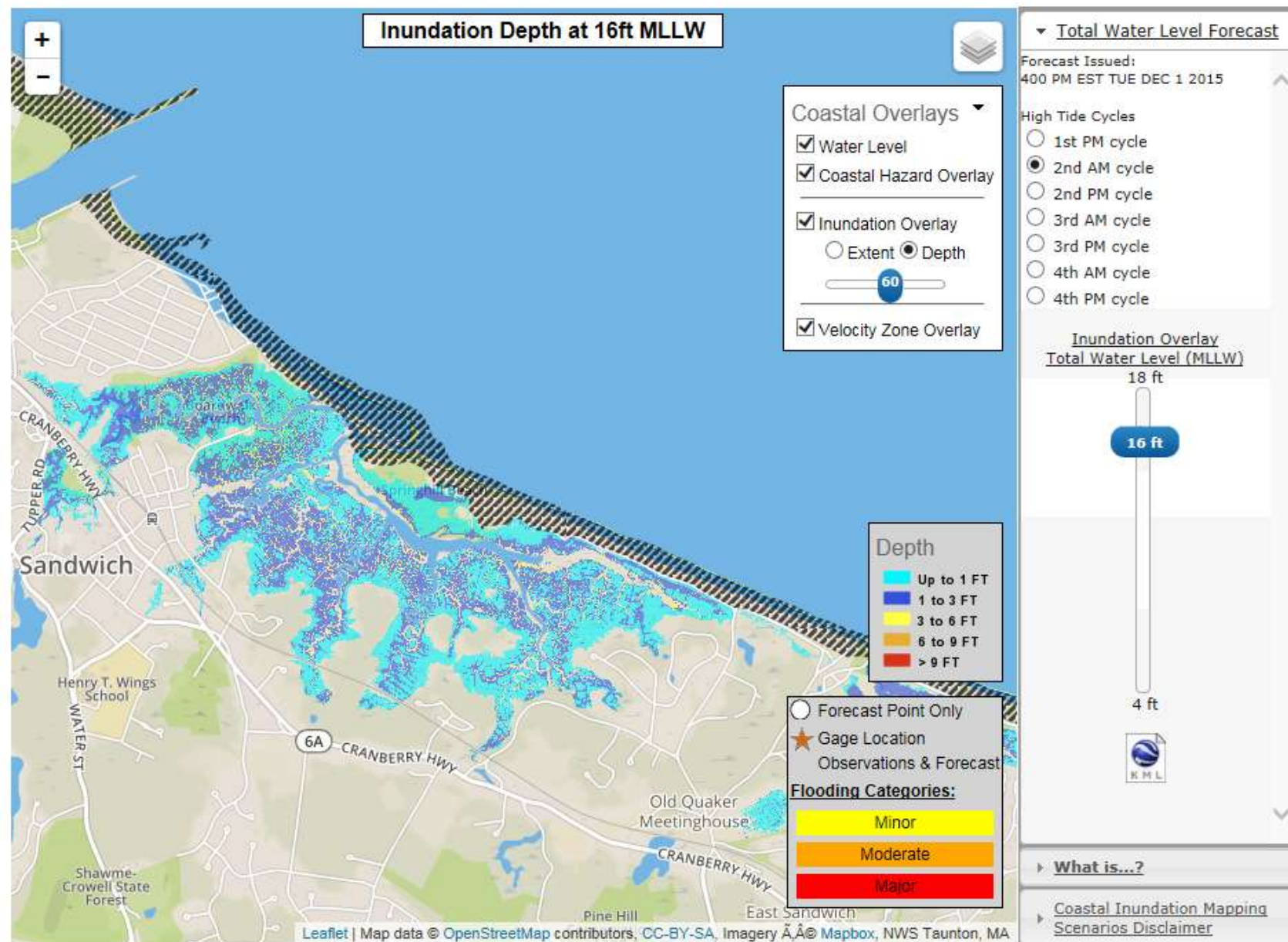


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Boston, MA
Weather Forecast Office



NOTE: During times when the area is under a Tropical Storm/Hurricane Watch or Warning, the storm tide or total water level forecast will reflect a plausible worst case scenario (versus the usual most likely scenario).

REFERENCE INUNDATION MAPS

- Intended to be a first cut tool
 - Depict areas prone to flooding with various static water levels
 - The 100 year velocity zone overlay depicts areas at risk for overwash and wave damage in high end events
- Limitations
 - No contribution from wave overwash
 - Impact of barriers (dams, hurricane barriers, etc.) not well-handled everywhere
 - Resolution only as good as available LIDAR value
 - Storm tide referenced only to MLLW datum

Product Example

COASTAL HAZARD MESSAGE
NATIONAL WEATHER SERVICE TAUNTON MA
443 PM EST FRI FEB 8 2013

...COASTAL FLOOD WARNING FOR THE MASSACHUSETTS EAST FACING
COASTLINE AROUND THE TIME OF THIS EVENINGS AND SATURDAY MORNINGS
HIGH TIDES...

A POWERFUL COASTAL STORM WILL PRODUCE MODERATE COASTAL FLOODING
THIS EVENING AND MODERATE TO MAJOR COASTAL FLOODING SATURDAY
MORNING ALONG WITH SEVERE EROSION IN SOME SPOTS. VERY LARGE WAVES
ON TOP OF AN ABOVE NORMAL TIDE WILL LIKELY CAUSE A NUMBER OF
VULNERABLE SHORE ROADS TO BECOME IMPASSABLE FOR A WHILE...AND MAY
CAUSE DAMAGE TO HOMES ALONG THE IMMEDIATE SHORELINE FROM HULL TO
SANDWICH DURING THE SATURDAY MORNING HIGH TIDE. VERY LARGE
BREAKERS CRASHING ONTO THE SHORELINE MAY MAKE IT UNSAFE TO REMAIN
IN SOME EXPOSED OCEAN FRONT HOMES.

MAZ007-015-016-019-022>024-090545-
/O.CON.KBOX.CF.W.0001.130209T0100Z-130209T1700Z/
EASTERN ESSEX MA-SUFFOLK MA-EASTERN NORFOLK MA-
EASTERN PLYMOUTH MA-BARNSTABLE MA-DUKES MA-NANTUCKET MA-
443 PM EST FRI FEB 8 2013

...COASTAL FLOOD WARNING REMAINS IN EFFECT FROM 8 PM THIS EVENING
TO NOON EST SATURDAY.

* LOCATION...EAST FACING COASTLINE OF MASSACHUSETTS

* COASTAL FLOODING...MODERATE COASTAL FLOODING IS LIKELY FOR
THIS EVENINGS HIGH TIDE AND MODERATE TO MAJOR COASTAL FLOODING
IS LIKELY FOR THE SATURDAY MORNING HIGH TIDE...WITH THE MOST
SEVERE IMPACT EXPECTED ALONG EAST AND NORTH FACING SHORELINES
SOUTH OF BOSTON.

* TIMING...THIS EVENING AND SATURDAY MORNING HIGH TIDES

* IMPACTS...A NUMBER OF SHORE ROADS WILL LIKELY BECOME
IMPASSABLE FOR A TIME FRIDAY EVENING. COASTAL FLOODING AROUND
THE SATURDAY MORNING HIGH TIDE WILL LIKELY CAUSE NUMEROUS
SHORE ROADS TO BECOME IMPASSABLE AND PUT SOME STRUCTURES AT
RISK ALONG THE IMMEDIATE SHORE...ESPECIALLY THOSE VULNERABLE
LOCATIONS SOUTH OF BOSTON FROM HULL TO SANDWICH. SEVERE BEACH
EROSION WILL ALSO OCCUR IN SOME LOCATIONS...ESPECIALLY DURING
THE SATURDAY MORNING HIGH TIDE. THE PRIMARY CONCERN WITH THE
SATURDAY MORNING HIGH TIDE WILL BE VERY LARGE BREAKERS
CRASHING ONTO THE SHORELINE.

SCITUATE

TOTAL TIDE /FT/	DAY/TIME	ASTRO TIDE /FT/	SURGE /FT/	WAVES /FT/	FLOOD CATEGORY
12.6	08/10 PM	9.8	2.8	10-17	MODERATE
13.4	09/10 AM	11.2	2.2	20-22	MAJOR
10.1	09/11 PM	10.1	0.0	9-10	NONE
11.3	10/11 AM	11.3	0.0	5-6	MINOR
10.0	11/12 AM	10.0	0.0	3	NONE
2.9	11/11 AM	2.9	0.0	2-3	NONE

SANDWICH HARBOR

TOTAL TIDE /FT/	DAY/TIME	ASTRO TIDE /FT/	SURGE /FT/	WAVES /FT/	FLOOD CATEGORY
12.5	08/10 PM	9.4	3.1	7-11	MODERATE
15.2	09/10 AM	10.7	4.5	18-20	MAJOR
9.7	09/11 PM	9.7	0.0	6-7	NONE
10.8	10/11 AM	10.8	0.0	2-3	NONE
9.6	10/11 PM	9.6	0.0	1	NONE
6.1	11/11 AM	6.1	0.0	1-3	NONE

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HAZARDOUS WEATHER OUTLOOK (HWO)

- **Issued every early morning**
- **Potential hazardous weather out to 7 days**
- **May be your first clue of a local concern!**
- **Threat evolution**
 - May not appear too ominous at first (especially if time period is greater than 5 days)
 - But let that be your signal for higher situational awareness
 - Monitor evolution of threat with time (e.g. increasing or decreasing threat)
- **Check HWO daily to maintain situational awareness**

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- [Click here for the latest winter weather information throughout the 2014-2015 winter season](#)

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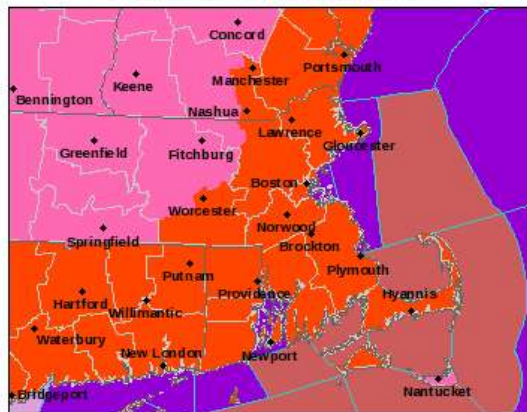
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[Storm Warning](#)



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AREA FORECAST DISCUSSION (AFD)

- **Explains the rationale behind the warning and forecast decisions (i.e., the “why” of the forecast)**
- **Favorite product for many broadcast meteorologists**
- **Confidence level and degree of uncertainty**
- **May indicate alternative scenarios possible**
- **A way to get inside our heads**

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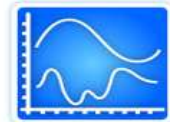
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WORK IN PROGRESS

- Fine tuning inundation mapping
- Tweaking tables with impact a function of total water level and waves
- Wave run-up initiative



Washington, DC circa 1930s



WFO Taunton, MA circa 2014

Coastal flood impacts appearing in TWLBOX are a function of water level and waves (derived from staff experience and local studies)

Scituate

Storm Tide	Wave Height					
	10	15	20	25	30	35
9.5	-	-	-	-	Minor	Minor
10.0	-	-	-	Minor	Minor	Minor-Mdt
10.5	-	Minor	Minor	Minor	Minor-Mdt	Moderate
11.0	Minor	Minor	Minor	Minor-Mdt	Moderate	Mdt-Major
11.5	Minor	Minor	Minor-Mdt	Moderate	Moderate	Mdt-Major
12.0	Minor	Minor-Mdt	Moderate	Moderate	Mdt-Major	Major
12.5	Minor-Mdt	Moderate	Moderate	Moderate	Mdt-Major	Major
13.0	Moderate	Moderate	Moderate	Mdt-Major	Major	Major
13.5	Moderate	Moderate	Mdt-Major	Major	Major	Major
14.0	Moderate	Mdt-Major	Major	Major	Major	Major
15.0	Mdt-Major	Major	Major	Major	Major	Major
15.0	Major	Major	Major	Major	Major	Major

Sandwich

Storm Tide	Wave Height					
	5	10	15	20	25	30
10.0	-	-	-	-	Minor	Minor
10.5	-	-	-	Minor	Minor	Minor-Mdt
11.0	-	-	Minor	Minor	Minor-Mdt	Moderate
11.5	-	Minor	Minor	Minor-Mdt	Moderate	Moderate
12.0	Minor	Minor	Minor-Mdt	Moderate	Moderate	Mdt-Major
12.5	Minor	Minor-Mdt	Moderate	Moderate	Mdt-Major	Major
13.0	Minor-Mdt	Moderate	Moderate	Mdt-Major	Major	Major
13.5	Moderate	Moderate	Mdt-Major	Major	Major	Major
14.0	Moderate	Mdt-Major	Major	Major	Major	Major
14.5	Mdt-Major	Major	Major	Major	Major	Major
15.0	Major	Major	Major	Major	Major	Major

New Developments

Wave Run-up

- Experimental program to help understand and forecast wave impact
 - Empirical technique being applied to “hot spots”



Input parameters (green only)	Feet	Meters
Beach Slope	0.03	
Deep water wave height	18.00	5.49
Deep water wave length	414.70	126.40
Deep water wave period	9.00	
Tide	11.7	3.57
Storm Surge	1.6	0.49
Dune Base Elevation	11.10	3.38
Dune Crest Elevation	13.57	4.14

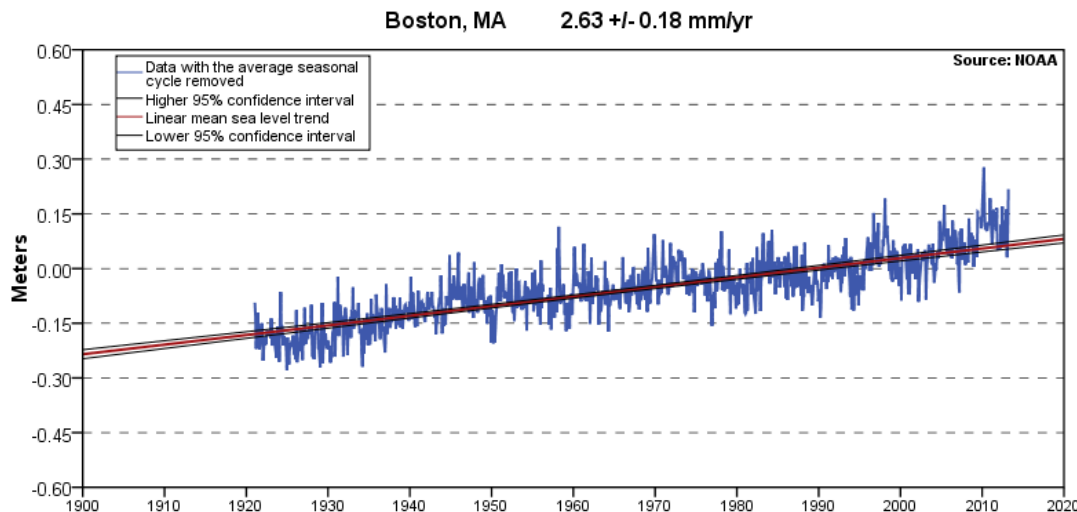
These are the individual output parameters	$R_{2\%}$	4.19	1.28
	Swash	3.19	0.97
	Setup	1.00	0.30

Include Tide + Surge		
R_{low}	14.30	4.36
R_{high}	17.49	5.33
$R_{2\%}$	4.188	1.28
Erosion	Expected	
Overwash	Expected	
Inundation	Expected	



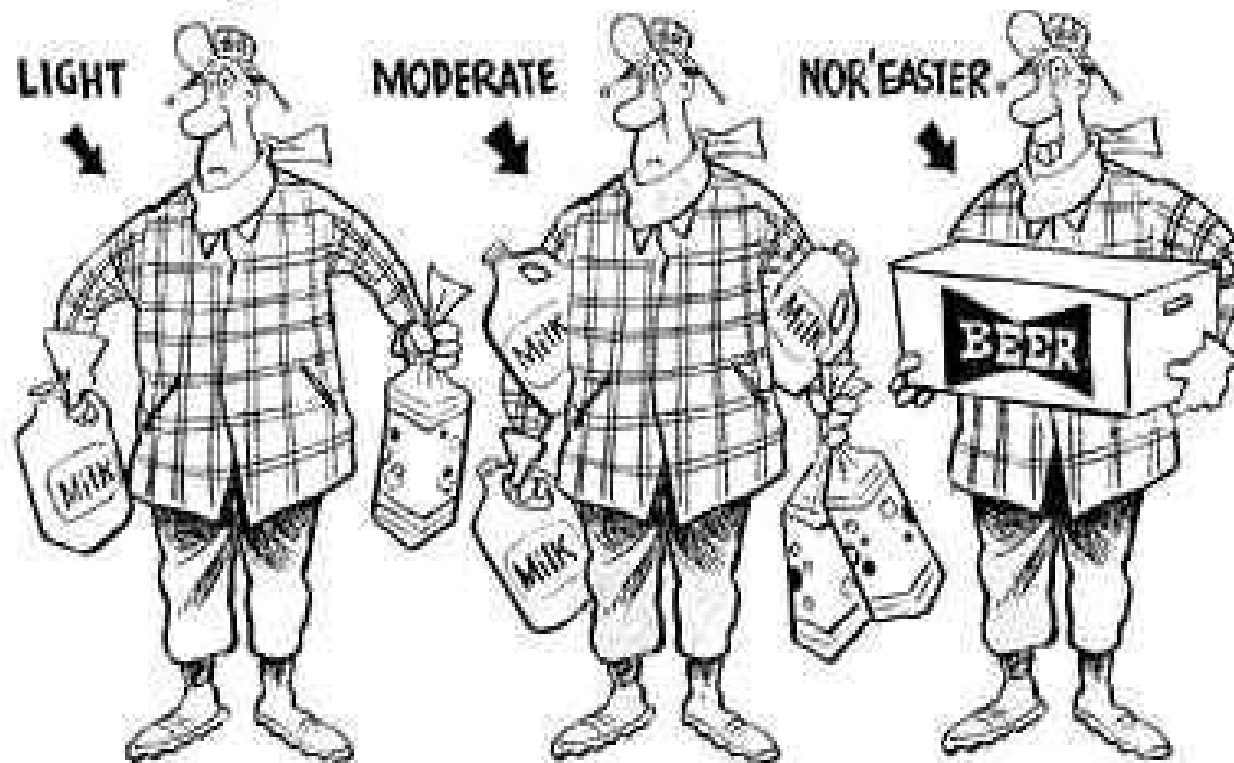
Looking to the Future

- Rising sea level
 - Expect more frequent coastal flooding
 - New record total water levels
 - Raises the impact stakes



PREPAREDNESS!

New England snowstorm indicators...



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www.davegranlund.com

“Natural calamity strikes at just about the time
that one forgets its terror.”

-- Japanese Proverb



THANK YOU!

