Sandy comes to the Jersey shore: Past, Present, and Future

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The New York Times

NEW JERSEY REELS FROM STORM'S THRASHING

The Philadelphia Inquirer

Swath of Destruction

Deluged Shore towns face daunting cleanup

Long Gas Lines, Clogged Roads, And Slim Hope for a Better Day

An Unlikely Political Pair, United by a Disaster

Lengthy outages 'A lot of help' will be needed to bounce back from Sandy
Past: “Before” pictures taken from flyovers done as part the First-year seminar *Global Warming and Sea-level Rise: Should I Sell My Shore House?*

Present: “After” pictures were taken from numerous sources. Focus on Ocean County (apologies Cape May to Long Island)

Future: what does a warming world portend for the Jersey shore?

Dedicated to:
Those who lost their lives in this disaster;
Shore residents on the front line who were directly impacted by Sandy’s mayhem, and
8.8 million Jerseyians whose lives were disrupted by the superstorm.

We are Jersey strong!
Satellite image Tuesday, Oct. 30, 2012 (AP Photo/NOAA)
Effects of Storms

Wind
Bull Run Rd., Hopewell after Sandy

Rain
Rt. 18 after Irene

Surge
AC during Sandy
Peak wind gusts

70-75 MPH

Courtesy of D. Robinson, RU/State Climatologist

http://climate.rutgers.edu/stateclim/?section=menu&target=sandy
Sandy storm total rainfall

1.5-2 inches

10 inches

Courtesy of D. Robinson, RU/State Climatologist

http://climate.rutgers.edu/stateclim/?section=menu&%20target=sandy
Tide Gauges: 7-14 ft surge
Storms: Extreme sea-level events

**Storm surge** = water piled up by storm (a transient sea-level rise)
Tide: 4-5 ft at Atlantic City 5 ft = “spring” = astronomically high tide
**Storm tide** = surge + tide = flood level (referenced to MLLW)

http://www.nhc.noaa.gov/surge/
Galveston 1900: surge overwashes island, kills 10,000

AFTER THE DISASTER
Atlantic City tide gauge record: 8.9 ft
Physically based assessment of hurricane surge threat under climate change

Ning Lin¹, Kerry Emanuel¹, Michael Oppenheimer² and Erik Vanmarcke³
Sandy Hook tide gauge goes offline 13.5 ft
Battery Park tide gauge: 13.9 ft relative MLLW

2.69 meters above MHHT

Verified Water Level vs. Predicted Plot
NOAA/NOS/CO-OPS
8518750 The Battery, NY
from 2012/10/28 - 2012/11/12

Predicted Tide
(Obs-Pred)
Observed WL
Ash Wed. Nor’easter Harvey Cedars, 1962
Donna hits New York 1960

http://www.netquake.net/2012/10/photos-the-most-devastating-hurricanes-in-new-york-history/
Governor Cuomo said it best “... the frequency of extreme weather situations... is not political... There’s only so long you can say, “this is once in a lifetime and it’s not going to happen again.””

Battery Park tide gauge

Modified after Zervas (2005)
Sandy comes to the Jersey shore: Seaside (Heights) destruction
Worst hit: Houses and areas destroyed

Seaside-Mantoloking (1167), Long Branch-Highlands (1457), Hoboken (891), Queens (2,973) and Long Beach (2670)

Funtown Pier, Seaside Heights, NJ

Funtown pier after

Funtown pier after

Destruction of Ortley Beach, NJ
Joey Harrison's Surf Club in ruins in Ortley Beach in an aerial view of devastation along the barrier islands of Ocean County after Hurricane Sandy wreaked havoc on the Jersey Shore. 10/31/12 (Andrew Mills/The Star-Ledger) http://photos.nj.com/star-ledger/2012/10/aerial_views_of_hurricane_sand_2.html
Ortley Beach in an aerial view of devastation 10/31/12
(Andrew Mills/The Star-Ledger) http://photos.nj.com/star-ledger/2012/10aerial_views_of_hurricane_sand_2.html
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Ortley Beach

Mantoloking Inlet
Mantoloking Inlet on the ground
http://www.hjnews.com/blogs/seeingthebigpicture/?p=262
Mantoloking Inlet (closed Nov. 6, 2012)
The burning of Normandy Beach and Camp Osborn
Camp Osborn, Normandy Beach, NJ (box in red in next photo)
Camp Osborn
Camp Osborn, note washover fan

Bayside destruction
Waretown and Mystic Islands
Clark house, Clearwater Drive
Should I sell my shore house?

My shore house is an island during four “100-year” storms: Halloween ‘91 (“perfect storm”), Dec. ‘92, Oct. ’05, Sandy.
© R. Clark
Waretown, NJ tide gauge record

Reference NAVD88

USGS 01409110 Barnegat Bay at Waretown NJ

Sandy

“100 year flood”

nor’easter

Provisional Data Subject to Revision
Clark house, Waretown
before, during, and after
Clark house, Waretown
before and after
Marsh and Grand Bay Harbor, Waretown 2009 Byrne overflight
Note marsh south of harbor protects houses
Marsh south of Grand Bay Harbor, Aug. 26, 2012
Flooded by sea-level rise
Dec. 4, 2012 Marsh and Grand Bay Harbo after Sandy Marsh loss due to sea-level rise allowed southerly winds to cause more flooding
Grand Bay Harbor, Waretown dock destroyed © R. Clark
Grand Bay Harbor, Waretown flotsam and jetsam © R. Clark
The flooding of Tuckerton Beach

http://www.youtube.com/watch?v=cIV_kOCjmBE
The flooding of Tuckerton Beach


Flood Insurance, Already Fragile, Faces New Stress
The drowning of Holgate & Beach Haven

Long Beach Island, NJ

Human stabilized

Natural movement

Holgate
400 m

Courtesy N. Psuty
Mayhem in Holgate

http://www.facebook.com/LindysLbi/photos_stream

http://www.state.nj.us/governor/media/photos/2012/eventphotos/20121110/20121110Sandy118.JPG
Beach Haven Destruction


http://www.youtube.com/watch?v=qT_xAPOMtcg
27th Street, Ship Bottom Oct. 30, 2012
27th Street Ship Bottom became an icon for Sandy’s effects on LBI
Is there a relationship between hurricanes like Sandy and global warming?

A. Yes, very likely

B. Absolutely not

C. Possibly but no one storm can be attributed to global warming

D. “Global warming is the greatest hoax ever perpetrated on the American people” Sen. Inhofe
Which of Barry Bonds’ home runs can be attributed to steroids?

“If Bonds did not use steroids, he would have hit many of the same home runs, just fewer.” Tony Broccoli

Sandy cannot be attributed to global warming but increased storm intensity can.

We are putting storms on steroids
Extreme events as rolling dice

Add a dot to every side.

What is average roll? 8 vs. 7 of regular dice (+1 or +14%)

What are odds of:

- Roll ≤ 3? 1/36
- Roll ≥ 12? 3/36

1/3 as likely or 66% less
3x likelier or 200% more

Slide courtesy of Gabe Vecci, GFDL, Princeton
Evaporation increases increases in a warmer world and as a result, there are more floods and more droughts.

In a warming world, the dice are loaded for wet and warm
Tropical storm intensity = tropical temperature

No trend in frequency

Power (PDI) related T

Slides courtesy of K. Emanuel, MIT
Why worry about 1-3 ft of sea-level rise?
Global sea level is rising

1880-2006 ~1.7 mm/yr tide gauges Church & White (2006)

17 cm 20\textsuperscript{th} century
= 7 inches = 0.6 ft

Acceleration
0.013 mm/yr\textsuperscript{2}

Satellite data
3.2±0.4 ’93-10

http://sealevel.colorado.edu/

12 inches per 100 yr

http://sealevel.colorado.edu/
Jonathan Gregory surprised at press reaction to 2007 AR4 report "reduction" in amount of sea-level rise to < 60 cm by 2100 since table indicates it excludes melting in Greenland and Antarctica.

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<thead>
<tr>
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<tbody>
<tr>
<td></td>
<td>Best estimate</td>
<td>Likely range</td>
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<tr>
<td>Constant Year 2000 concentrations</td>
<td>0.6</td>
<td>0.3 – 0.9</td>
</tr>
<tr>
<td>B1 scenario</td>
<td>1.8</td>
<td>1.1 – 2.9</td>
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<tr>
<td>A1T scenario</td>
<td>2.4</td>
<td>1.4 – 3.8</td>
</tr>
<tr>
<td>B2 scenario</td>
<td>2.4</td>
<td>1.4 – 3.8</td>
</tr>
<tr>
<td>A1B scenario</td>
<td>2.8</td>
<td>1.7 – 4.4</td>
</tr>
<tr>
<td>A2 scenario</td>
<td>3.4</td>
<td>2.0 – 5.4</td>
</tr>
<tr>
<td>A1FI scenario</td>
<td>4.0</td>
<td>2.4 – 6.4</td>
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"Model-based range excluding future rapid dynamical changes in ice flow" i.e., Greenland and Antarctica.
Observed sea level and the contributions are almost in balance, implying a positive (but small) Antarctic contribution. The observed sea level and the sum of contribution has accelerated.

IPCC 40 cm (1.25 ft) rise by 2100, 1 m (3.3 ft) by 2200
IPCC 2001 error estimate: 20-80 cm
IPPC 2007 error: 20-60 cm (does not include ice sheet melting)

2001

2007

http://www.realclimate.org/images/sealevel_1.jpg
Observed sea level rise > predicted by IPCC

Slide courtesy of S. Rahmstorf

Rahmstorf, Cazenave, Church, Hansen, Keeling, Parker and Somerville (Science 2007)
New record of melting: Rignot et al. (2011)

Two independent techniques:
1) mass budget estimates;
2) dense time series of gravity from GRACE

Acceleration of the contribution of the Greenland and Antarctic ice sheets to sea level rise

E. Rignot, I. Velicogna, M. R. van den Broeke, A. Monaghan, and J. Lenaerts
Revised mass loss figures

Revised figures from community paper Shepard et al. (2012)
20th Century Global, Regional, and Local Effects

NY/NJ/DE region higher sea-level rise

Processes:
- Global (eustatic) rise 1.8 mm/yr
- Regional subsidence flexural unloading Laurentide removal ~1 mm/yr
- Local subsidence due to water withdrawal & compaction 1 mm/yr

Miller et al. (2009) modified after Psuty and Collins (1986)
Atlantic City had a 41cm (16 inch) rise from 1911-2012; regression is 4.1 mm/yr
The excess relative to global rise (1.7 mm/yr) is due to subsidence.
The Battery 2.8 mm/yr
Philadelphia 2.9 mm/yr

20th century global
1.75 mm/yr

Glacial Isostatic Adjustment
1.3 mm/yr
Horton et al. (in press)

Long-term thermoflexural subsidence 0.01 mm/yr
Kominz et al. (2008)

Atlantic City 4.1 mm/yr
Sandy Hook 4.1 mm/yr

Geologic map drafted after Benson, 1984
Remove global and GIA effects

Residual is due to compaction subsidence

Atlantic City 1 mm/yr due to groundwater withdrawal

Norfolk hot spot (1.5 mm/yr anomaly: groundwater explains 1-4 mm/yr (Pope and Burbey, 2004))

Sandy Hook compaction of the 73 m section formed over past ~1-2 kyr

0.9 m = 0.45-0.9 mm/yr

Kominz (pers. Comm.)
Subsidence and oceanographic effects

NJ subsidence 1-2 mm/yr (4-8 inches/century)

Dynamic oceanographic effects
Reduction in Gulf Stream flow raises sea level in NJ by 10-20 cm (4-8 inches)
Future sea level in NJ: Miller & Kopp

Total sea level rise projections for New Jersey.

<table>
<thead>
<tr>
<th></th>
<th>Total cm</th>
<th>Total inches</th>
<th>Total feet</th>
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<tbody>
<tr>
<td>2050 best</td>
<td>40</td>
<td>16</td>
<td>1.3</td>
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<tr>
<td>2050 low</td>
<td>23</td>
<td>9</td>
<td>0.7</td>
</tr>
<tr>
<td>2050 high</td>
<td>60</td>
<td>24</td>
<td>2.0</td>
</tr>
<tr>
<td>2100 best</td>
<td>96</td>
<td>38</td>
<td>3.1</td>
</tr>
<tr>
<td>2100 low</td>
<td>50</td>
<td>20</td>
<td>1.6</td>
</tr>
<tr>
<td>2100 high</td>
<td>147</td>
<td>58</td>
<td>4.8</td>
</tr>
</tbody>
</table>

All values with respect to a year 2000 baseline.

Based in the slightly lower melting figures of Shepherd et al. (2012), subsidence rates of 1-2 mm/yr in excess of global, and dynamic oceanographic effects.
**Effects of sea-level rise: Coastal flooding**

Increased effects of storm surges

By 2100, the equivalent of a “2 to 5-year storm” will have the flooding of a “100 year storm”

Note FEMA new Advisory Basal Flood Elevation used to compute flood insurance rate maps

Miller, Kopp, Browning, Horton
Effects of sea-level rise: Coastal flooding

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Miller, Kopp, Browning, Horton
Soft stabilization
Beach nourishment

Fighting back

Hard stabilization: groins, jetties, seawalls, breakwaters
Beach Nourishment
Surf City, NJ 2007

http://graphics8.nytimes.com/images/2007/05/15/nyregion/190-sand-03.jpg
http://loveladies.org/news.php
27th St. Ship Bottom 2008 overflight after nourishment in 2007

© K. Miller
Though Ship Bottom flooded, by Nov. 6 the floods had receded and destruction was less than in Holgate.

http://storms.ngs.noaa.gov/storms/sandy/
Sea-level Rise Impacts http://slrviewer.rutgers.edu/

Ship Bottom 1 ft (2050)

Ship Bottom 3 ft (2100)

Barnegat Bay 3 ft (2100)

Viewer from R. Lathrop
The Saving of Harvey Cedars & Loveladies
Mercer Ave., Harvey Cedars before and after beach nourishment

U.S. Army Corps of Engineers nourished Harvey Cedars Sept. 2009 to June 2010 for $19 million; borough and Ocean County splitting a $2 million share.

www.nj.gov/dep/ec/docs/harvey_cedars_overview.pdf

© Google
North Beach to south Harvey Cedars, Long Beach Island
2008 Byrne overflight
North Beach to south Harvey Cedars: sand washover, beach narrowed, houses survived

http://storms.ngs.noaa.gov/storms/sandy/
Stew Farrell, Stockton University: "In general beach nourishment prevented a great deal of additional damage with LBI being the poster child for such conclusions."
Harvey Cedars lawsuit

Karan v Harvey Cedars: $375 k award
68th Street dune view issue

OCEAN COUNTY — For the past 20 years, beaches have been rebuilt in dozens of communities along the New Jersey coastline as the U.S. Army Corps of Engineers has pumped sand onto the shore to push back against the tide.

To complete the work, municipal officials must get permission from beachfront property owners. The landowners are often compensated at a nominal rate and in return, the Army Corps creates wider beaches and massive dunes to protect the beachfront, especially during storms.

Over the years, however, there have been numerous height of the dunes to loss of privacy to the decline in

Perhaps the most significant of those cases played a role in the decision granting a couple hundreds of thousands of dollars to a few people, who owned or rented up and down the coast as mayors and officials looked on.

"When the government does a cost-benefit analysis of the projects, they have to take into consideration what the impact is on the property owners," said Lakewood attorney Peter Wegener, who represented Harvey and Phyllis Karan, the Harvey Cedars homeowners. "There is a benefit, and everybody has to pay for the project one way or another."

In its ruling, a state appeals court upheld a $375,000 jury award for the Karans, who claimed a
Karan house Harvey Cedars before and after Sandy: Beach nourishment and dune saves Harvey Cedars
Holdouts Responsible

To the Editor:

As mayor of Long Beach Township, I want to take this opportunity to provide current information to property owners in Long Beach Township. First and foremost, I want to offer good news: The portion of our township that received the federal beach replenishment project earlier this year suffered minimal damage. Oceanfront properties, as well as homes, structures and businesses to the west, withstood the destructive components of Hurricane Sandy. The project worked.

Unfortunately, beaches that had not been included in the Army Corps project due to lack of executed easements from property owners proved vulnerable to the vast devastation wreaked by the hurricane. Damage assessment continues here in our community, and it appears few structures remain unaffected in these areas. In fact, most buildings, homes, businesses and churches not in proximity to the replenished beach area have suffered significant damage from those non-participating oceanfront properties, westward.

Utilities are slowly and painstakingly being restored, streets are being cleared and debris is being removed. At the current time, the total cost of recovery is incalculable. We feel it only fair to Long Beach Township taxpayers that the cost of cleanup and restoration in sections of our town not protected by the federal beach replenishment project be borne by those oceanfront property owners who refused to join in the project by executing their deeds of easement.

I assure you that the Long Beach Township Board of Commissioners will continue to work tirelessly to restore our community and our Island. We look forward to working with each of you as we rebuild our cherished town.

Joseph Mancini, mayor
Long Beach Township

Job Well Done

To the Editor:

There are no words that I am able to find in my thesaurus that can adequately express my gratitude, thankfulness and commendations to the mayor and elected officials of Harvey Cedars for their foresight, perspicacity and tenacity in pursuing and accomplishing the beach replenishment program.

Sincerely put, it saved my home as well as any other home in the borough. I am certain most homeowners feel the same way, especially after visiting their homes following the terrible onslaught of storm Sandy.

Unfortunately, not all signed off on the easements for replenishment. I understand that one resident collected in excess of $350,000 for obstructed views, or some egregious sum of that sort. And another case is still pending in the courts, waiting final adjudication. I still cannot understand the rationale of the court system that favored the importance of personal ocean views over the safety and wellbeing of an entire community.

Perhaps, The SandPaper could publish the names and addresses of all those who obstructed the replenishment program. Individuals ought to suffer the consequences of bad decisions, for whatever rationale they may have. The safety of the entire community ought to take precedence over individual concerns for aesthetics.

If the mayor asked me if I were willing to pay an additional, yearly tax for beach replenishment, I wouldn’t like it, but I would do it out of necessity because it would be the right thing to do. Why? Because I still have my home. Thank you, mayor, and elected officials, for the job you did for us. Well done!

Robert Kucharski
Bound Brook, N.J., and Harvey Cedars

Mayor Mancini Long Beach Twp. Beach Haven Nov. 30: “Cost of cleanup and restoration...be bourne by those oceanfront property owner who refused to join the project”
Hard Stabilization: Seawalls


Seawalls exacerbate erosion
USGS before and after Long Branch, NJ.

Storm waves and currents removed sand from the beach exposing erosion control structures, including rock walls, concrete walls, and groins that protrude seaward perpendicular to the beach.
Hard Stabilization: Breakwaters

**Breakwaters** barriers built parallel to the coast in the water to cause waves to break offshore instead of onshore. Most breakwaters rise above the water surface to provide a calm area behind them for an artificial harbor.

Breakwater protects Asbury Park Convention Center
Left: 2009 overflight
Right: Nov. 1, 2012 post Sandy
Take-home points

Storms more intense, sea-level higher in warmer world

Sandy freak storm, but we must plan for Sandy-type storm surges 7-14 ft

Sea level rise is accelerating:
  NJ Plan for 1 ft of rise by 2050
  NJ Plan for 3 ft by 2100
add to surge:
  5-10 yr storm becomes 100 yr
Take-home points

Costs to protect shore will escalate: beach nourishment and dune building is needed to protect the barrier islands. >1 billion $ spent so far in NJ.

Hard stabilization (seawalls, groins, Mantoloking Bridge) exacerbate erosion.

Building in harms way has costs to all society. Should we subsidize insurance (FEMA) to build in risky locations? Should we allow rebuilding in the most hazardous areas or buyout (e.g., low areas of Bound Brook, Union Beach).

V. Solomeno/New Jersey National Guard
Is it time to retreat, to give up the Jersey shore?

There is talk of rebuilding smarter, but what is the reality?
New Jersey Kayak, Barnegat removed its boats before Sandy only to have “new” ones delivered by the storm.
Camp Lighthouse, Waretown Dec. 5 2012. Flooding of marshes due to sea level rise
Coastal Flooding

Episodic flooding w/ 0.61 m rise:
1,787 km²
9% land area

Cooper et al. (2005)
87th St Loveladies, Long Beach Island 2008 Byrne overflight

© K. Miller
Point Pleasant, NJ
Jenkinsons Night Club and Martells Tiki Bar
Jenkinson’s Night Club and Martells Tiki Bar
Jenkinson’s Night Club and Martells Tiki Bar

http://videos.nj.com/star-ledger/2012/11/onlookers_flock_to_point_pleas.html