

# A Geological Perspective on Sea-level Rise and Its Impacts: Past, Present and Future

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## Abstract

The geologic record places the modern sea-level rise into an historical context and can help inform discussions of the rates and magnitudes of future sea-level rise. During the Pliocene, CO<sub>2</sub> levels were similar to 2014 (400 ppm), yet temperatures were globally 2°C warmer and global average sea level stood globally 22±10 m above present.

With the development of large Northern Hemisphere ice sheets at 2.7 Ma, amplitudes of sea-level change increased, reaching over 100 m at times. A globally average sea-level rise of ~130 m followed the last ice age, with rates that at times exceeded by ten times the modern rate of rise (> 40 mm/yr versus ~ 3 mm/yr). Rates of rise along the U.S. Gulf and much of the U.S. Atlantic coasts were higher due to Glacial Isostatic Adjustment and local subsidence.

The rate of relative sea-level rise in the U.S. mid-Atlantic region decreased from 3.5±1.0 m/yr at 7.5-6.5 ka, to 2.2±0.8 mm/y at 5.5-4.5 ka, to a minimum of 0.9±0.4 mm/yr at 3.3-2.3 ka. Relative sea level rose at a rate of 1.6±0.1 mm/yr from 2.2 ka to 1.2 ka (750 CE) and 1.4±0.1 mm/yr from 800-1800 CE. Geological and tide-gauge data show that sea-level rise was more rapid throughout the region since the Industrial Revolution (19th century = 2.7±0.4 mm/yr; 20th century = 3.8±0.2 mm/yr).

There is a 95% probability the 20th century rate of sea-level rise was faster than it was in any century in the last 4.3 kyr. These records reflect global rise (~1.7±0.2 mm/yr since 1880 CE) and subsidence from glacio-isostatic adjustment (~1.3±0.4 mm/yr) at bedrock locations (e.g., New York City, Philadelphia, Baltimore, and Washington D.C.). At coastal plain locations, the rate of rise is 0.3-1.3 mm/yr higher due to groundwater withdrawal and compaction. We construct 21st century relative sea-level rise scenarios including global, regional, and local processes.

We project a 22 cm rise at bedrock locations by 2030 (central scenario; low- and high-end scenarios with a range of 16-38 cm), 40 cm by 2050 (range 28-65 cm), and 96 cm by 2100 (range 66-168 cm), with coastal plain locations having higher rises (3, 5-6, and 10-12 cm higher, respectively). By 2050 CE in the central scenario, a storm with a 10-year recurrence interval will exceed all historic storms at coastal locations.

"All the News That's Fit to Print"

# The New York Times

Late Edition  
Today, heavy clouds obscure a  
mid-morning light in a bright, partly  
cloudy sky. The temperature is in the  
lows, with a high of 55 and a low of 45.  
In Weather: 5:00 to 5:30 Page 11

# The Philadelphia Inquirer

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## NEW JERSEY REELS FROM STORM'S THRASHING



### State Bays Brunt in Floods and Destruction

By David W. Rodriguez  
BRIDGEWATER, N.J. — Two towns  
are reeling on Wednesday from  
the impact of Hurricane Sandy,  
which has caused catastrophic  
flooding here in Hudson and in  
other New Jersey suburbs, de-  
stroyed entire neighborhoods  
across the state and ripped up  
roads throughout in some areas.  
High tides swamped hundreds  
of neighborhoods.  
Though the state lagged up the  
East Coast in late December, an  
overcast sky made that time  
hard to see. The height of the tide  
was estimated to be 10 feet or  
more in many places, a factor in  
the state's devastation.  
Some areas have entire neigh-  
borhoods without power, and  
hundreds of homes were carried  
off to sea.  
At least eight people died, and  
officials expressed deep concern  
that the toll would rise as more  
numbers of homes were carried  
off.

Death Toll  
Hurricane claims 50 on  
East Coast.



New York City  
Devastating  
blow cripples  
Big Apple.



Powerless  
Fallen trees  
leave railfans  
in dark.

## Swath of Destruction

### Deluged Shore towns face daunting cleanup

