What are Coastal Hazards ?

Dr. Tom Herrington

Stevens-New Jersey Sea Grant
Cooperative Extension in Coastal Processes

Sea Grant New Jersey

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STEVENS Institute of Technology

Natural Hazards

- First Talk will focus on the hazards associated with living in the coastal zone
- Second Talk will focus on viable all-hazard mitigation techniques

Natural Hazards Unique to the Coastal Zone

- Coastal Flooding
- Wave Attack (structures)
- Waterborne Debris
- High Winds
- Shoreline Change
  - Short-term Shoreline Change
  - Long-term Shoreline Change
  - Episodic Shoreline Change
- Sea Level Rise

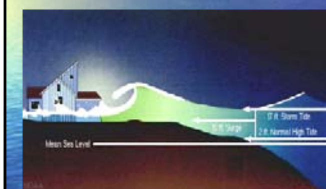
Other Natural Hazards in NJ

- Flash Flooding
- Earthquake
- Tsunami
- Tornados and Waterspouts
- Lightning
- Blizzards and Ice
- Landslides
- Forest Fire

Coastal Flooding:
3 Components

1. Extreme astronomical tides can generate nuisance flooding along low-lying coasts
2. Storm surge generated by intense cyclones (hurricanes) or prolonged onshore winds can generate significant departures from predicted water elevations
3. Mass transport of water toward coast by large wind-generated waves increases flood levels

Coastal Storm Surge

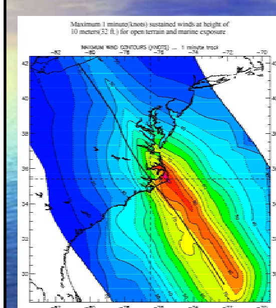


- Greatest potential for damage and loss of life
- 3 components; low pressure, wind stress and bottom slope
- Along shallow water coasts a surge of 15+ feet not uncommon
- Allows larger waves to penetrate farther inshore

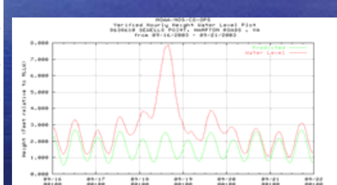
NJ Coast Exposed to 2 Types of Coastal Storm Surges

- Intense, short duration surges generated by tropical cyclones
- Prolonged flood events generated by Nor'easters and large wave attack

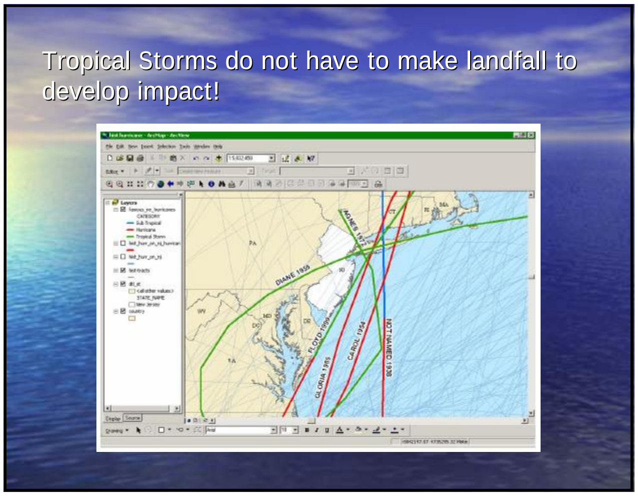
Short-duration surge generated by Hurricane Isabel, 2003

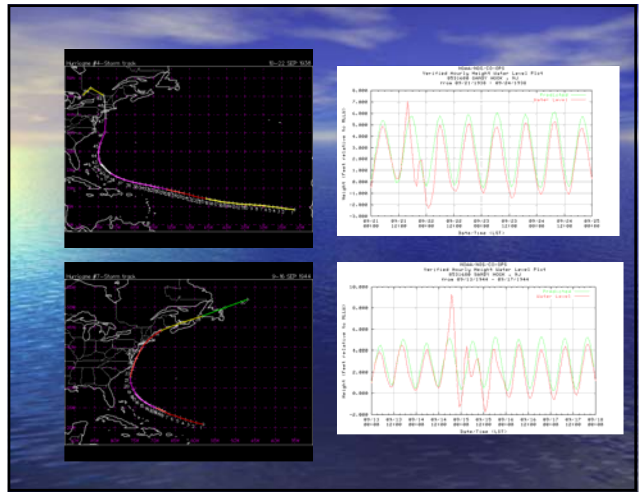


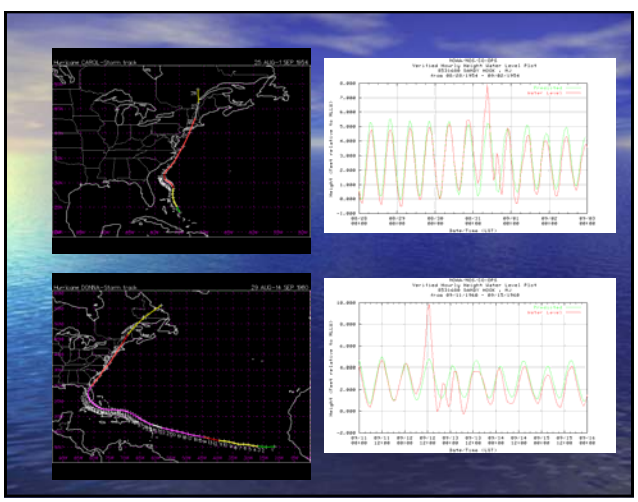
Max winds along track of Hurricane Isabel

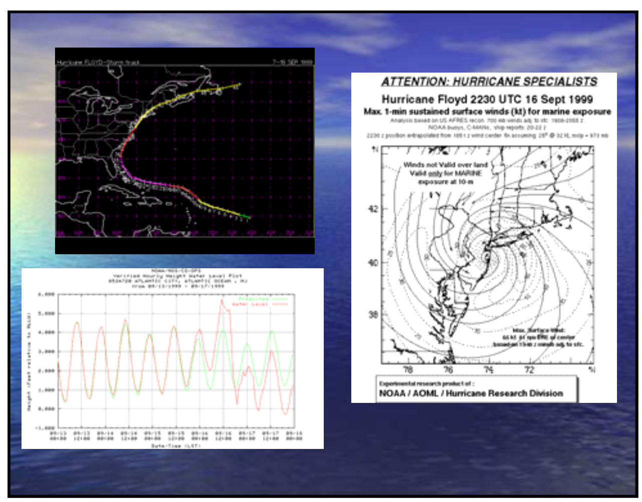


Water Level recorded at Hampton Roads, VA


Tropical Storms do not have to make landfall to develop impact!





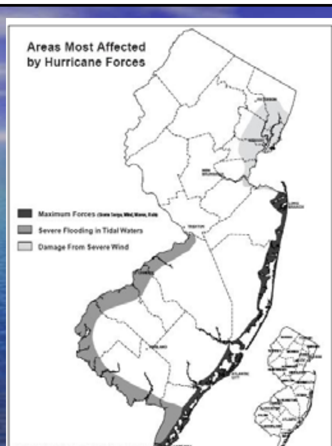

ATTENTION: HURRICANE SPECIALISTS
Hurricane Floyd 2230 UTC 16 Sept 1999
Max. 1-min sustained surface winds (kt) for marine exposure
NOAA / AOML / Hurricane Research Division

Damage due to Tropical Surge

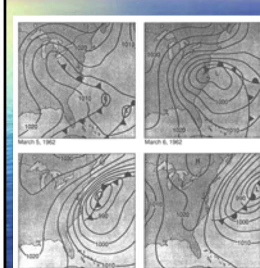
Significant damage caused by surge in Holgate, NJ during the Hurricane of 1944.

Localized Catastrophic Damage

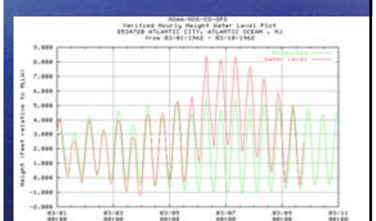
Hatteras Village



Prolonged storm surge at Atlantic City during March 1962 Nor'easter



Storm Evolution March 5 – 8, 1962



Water Level recorded at Atlantic City Steel Pier

Nor'easter Surge

- Extratropical Storm Surge elevation is related to 4 factors:
  - The distance over the ocean in which the wind blows toward the coast (fetch)
  - The strength of the wind
  - The duration over which the wind blows in one direction
  - Mass transport of water toward the coast by large waves.

Dolan-Davis Nor'easter Scale

- In order to assess the damage potential of Nor'easters, Dolan and Davis developed a power index analogous to the Saffir-Simpson Hurricane Scale:

  $P = D*H^2_{1/3\ max}$ $[m^2s]$

  Where D = duration and H = max significant wave height
- From hindcast analysis of known storms, 5 classes designated based on damage

Dolan-Davis Nor'easter Scale

CLASS	Power Range (m^2s)
I	0-72
II	72-164
III	164-929
IV	929-2322
V	2322-6610

- Class I-III occur any time, IV & V typically occur in Oct. Jan., & March

Waves and Surge

- Wind stress over the ocean during a Nor'easter can generate wave heights of 5ft to 30 ft.
- Storm surge is generated by onshore directed wind stress (onshore transport of water) and pressure drop associated with the cyclone
- Long duration storms (stalled or slow moving) can create prolonged periods of surge and large wave attack along the coast.

Coastal Impacts of Nor'easters

- Major impact of Nor'easters is felt along the coast
- Winds are not the most serious hazard
  - Winds generally much less than Hurricane
- Fetch (distance over water affected by unidirectional winds) and duration are the most important variables
- Waves and Storm surge generate the most significant impacts

Large-scale Damage

Ocean City, NJ. Note the transport of water across the island by waves

Impact of the March 1962 Storm in New Jersey:

NJDEP Archives

Beach Haven, Long Beach Island. Inlet cut through barrier island. Notice waves over two stories hig

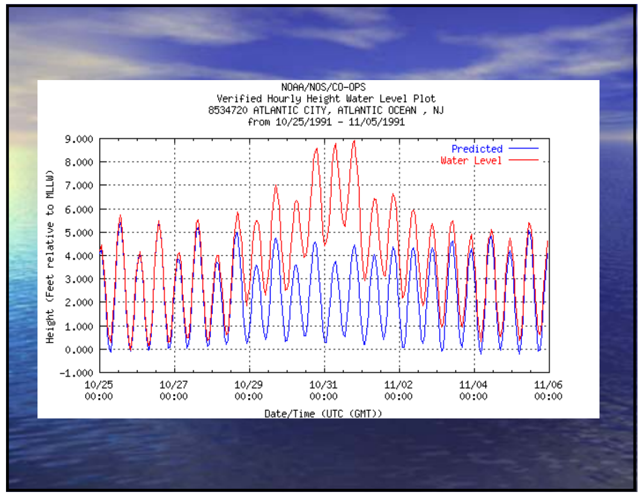
Impact of the March 1962 Storm in New Jersey:

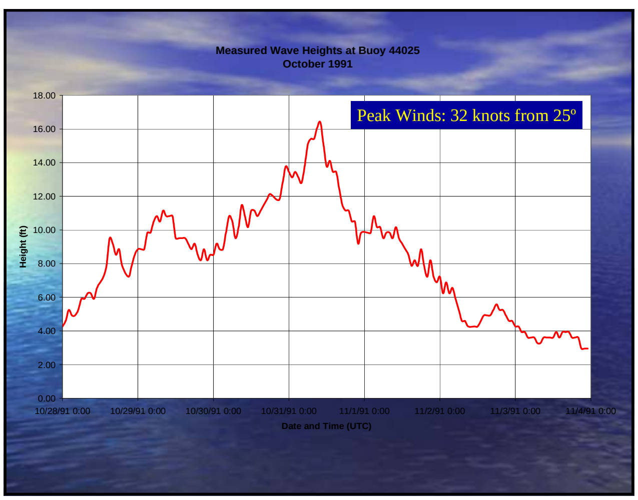
NJDEP Archives

One of five inlets formed on Long Beach Island during the Storm

Other Historic Nor'easters

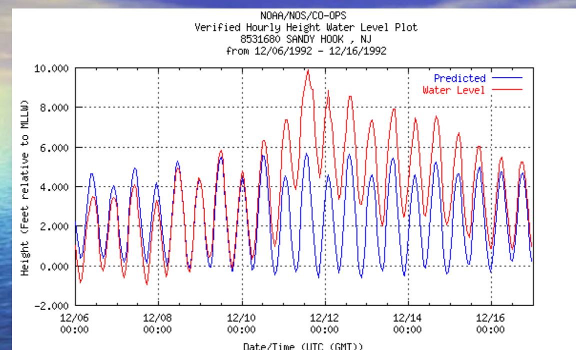
- October 31, '91: 16 to 23 ft waves
  storm surge 4.5 feet above high tide
- December 10-14, '92: 30 to 44 ft waves,
  storm surge 4.3 feet above high tide
- March 13-14, '93: 24 to 34 ft waves,
  storm surge 3.7 feet above high tide

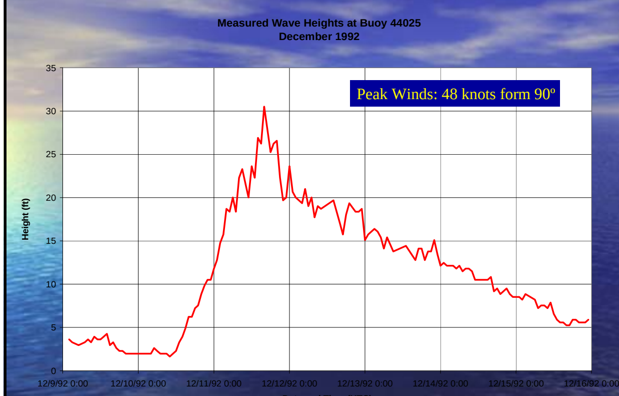




Other Nor’easters

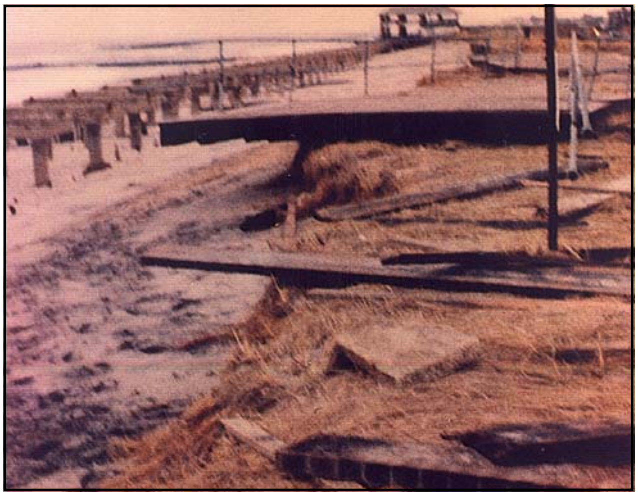
The October 1991 Halloween Nor’easter generated the most energetic wave field ever measured off of the east coast. Wave breaking over the seawall at Longport, NJ





Other Nor’easters

December 1992 Nor’easter destroys a section of boardwalk in Ocean City, NJ.



Where do these rank on the DD scale

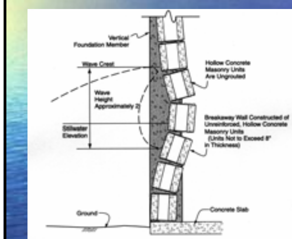
- March 1962: 72 hrs, H = 33ft, surge = 7.6ft
  P=7200, Cat: V
- Oct. 1991: 114 hrs, H=35ft, surge=8.0ft
  P=13051, Cat:V
- Dec. 1992: 48 hrs, H=30ft, surge=8.3ft
  P=4063, Cat: V
- March 1993: 48 hrs, H=30ft, surge =7.1ft
  P=4063, Cat: V

Wave Attack on Structures

- Waves generate one of three loadings on coastal structures:
  – Horizontal Pressure due to non-breaking waves
  – Uplift Forces due to Vertical motion of water as waves propagate along surface
  – Compression Loads during wave breaking

Wave-induced Uplift Loads

Breaking Wave Loads



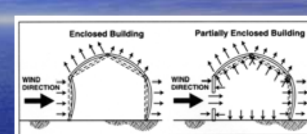
Compression Loads generated by a breaking wave 5ft high can exceed 5,000 lb/sq. ft.

Debris Impact

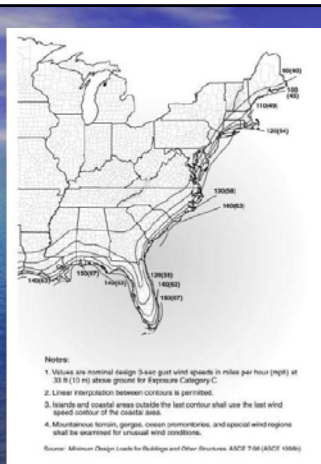
Raft of debris left on Beach Ave. (Ocean Blvd.) just landward of the seawall in Cape May as a result of the March 1962 "Great Atlantic Storm." Note segments of destroyed boardwalk with attached benches still bolted on in center (Photo courtesy of Dr. Susan D. Halsey).

High Winds

Wind Damage is caused by either the wind breaching the building envelop and pressurizing the interior of a structure



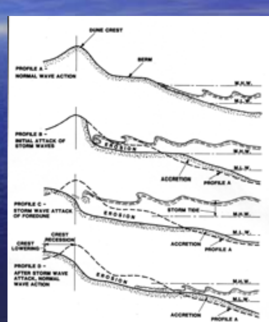
or by impact loads generated by flying debris



What can we expect?

Short-term Shoreline Change

- The cross-shore extent of sandy beaches undergo erosion and accretion on a seasonal basis:
  - In the summer and fall, small waves transport sand up onto the beach.
  - In the winter and spring, large storm waves erode sand.
  - Transition provides natural protection for the beach.



Episodic Shoreline Change

Permanent changes to the coast generated by extreme surge and wave attack. Pictured above is North Captiva Island before and after the passage of Hurricane Charlie

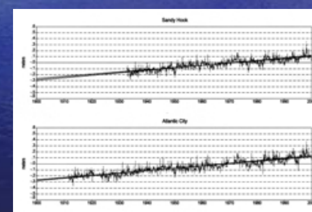
Long-term Shoreline Change

- Persistent wave action at an angle to the coast results in a net transport of sand in the direction of wave approach.

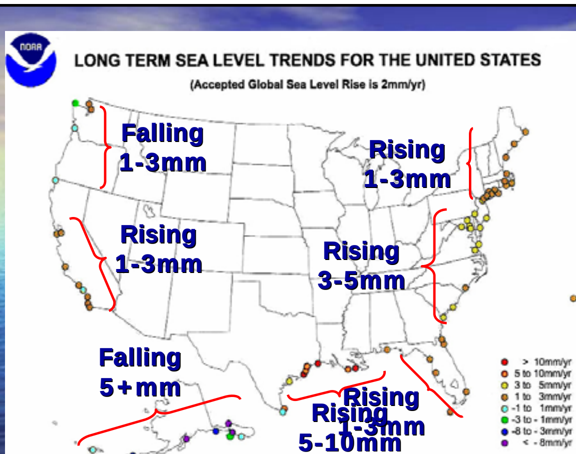
Pictured is the variation in sand transport on the NJ coast. Reversal is due to blocking effect of Long Island on large SW propagating storm waves

Long-term Shoreline Change

- Changes due to seasonal wave climate and Sea Level Rise lead to long-term shoreline change
  - Sea level rise translates into a net shoreline recession



Long-term water elevation change at Sandy Hook, NJ and Atlantic City, NJ



What can we expect in the future?

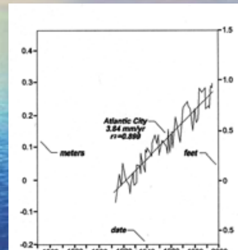


Figure 2. Tide gauge records for Atlantic City and Sandy Hook, New Jersey (modified from Psuty and Collins, 1996).

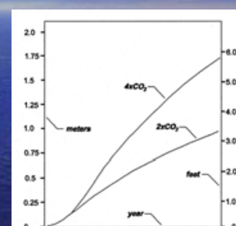


Figure 5. Sea-level rise projections based on a model of projected CO_2 increases of 2x and 4x present levels (Manabe and Stouffer, 1994). These projections only include thermal expansion of ocean waters and do not take into consideration melting continental ice sheets.

Adjusted Flood Levels at Atlantic City

Storm	Meas. Elev.*	Surge	2002
Sept. 1944	8.96 ft	4.17 ft	9.69 ft
March 1962	8.80 ft	3.43 ft	9.30 ft
Dec. 1992	9.14 ft	4.28 ft	9.27 ft
Oct. 1991	8.93 ft	4.48 ft	9.07 ft

*Relative to MLLW at Atlantic City
Subtract 2.23 ft to convert to MSL
Subtract 2.97 ft to convert to NAVD-88

Projected MLLW Water Elevation of '62 Storm in:

2002	2022	2052	2102
9.30 ft	9.55 ft	9.93 ft	10.55 ft

1992 Atlantic City Ocean Stage Frequency Data

Return Period (yr)	Elevation (MLLW)
20	9.34 ft
50	10.43 ft
100	11.43 ft

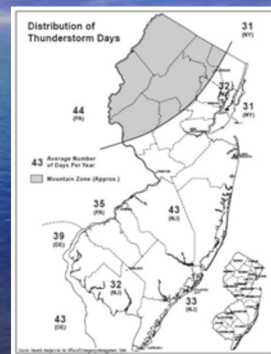
Flash Flooding

Acres in 100 Year Flood Plain by County

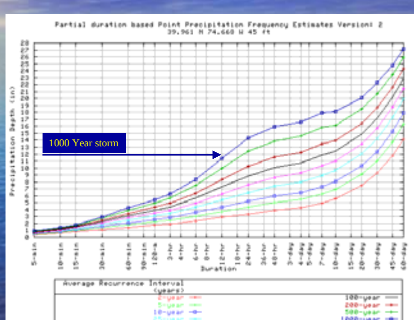
County	Acres in 100 Year Flood Plain	% of County in 100 Year Flood Plain
Atlantic	135,365.79	34.61%
Bergen	26,070.43	16.50%
Burlington	98,257.03	18.74%
Camden	16,437.96	11.29%
Cape May	94,356.14	51.66%
Cumberland	96,652.40	30.05%
Essex	13,235.36	15.97%
Gloucester	35,288.71	16.37%
Hudson	20,413.46	51.32%
Hunterdon	14,322.21	5.11%
Mercer	15,515.83	10.60%
Middlesex	31,776.57	15.38%
Monmouth	30,787.15	9.93%
Morris	41,830.51	13.61%
Ocean	167,528.68	34.50%
Passaic	15,322.94	12.17%
Salem	63,351.99	28.47%
Somerset	20,037.46	10.27%
Sussex	25,259.86	7.35%
Union	9,048.64	13.42%
Warren	13,100.32	5.64%
Grand Total	983,959.46	19.74%

Source: Analysis of FEMA Q3 Flood Plain Data, 1996

Can Occur Anywhere at Anytime

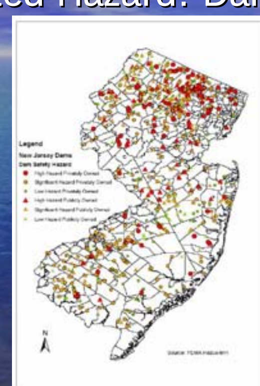


Rainfall Rates can be Intense



Burlington County 2004 event was a 1000 yr storm event...not uncommon in NJ

Associated Hazard: Dam Failure

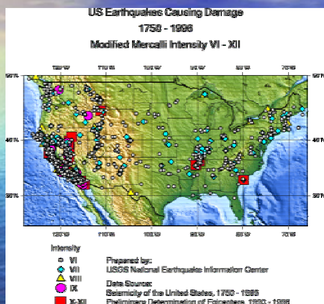


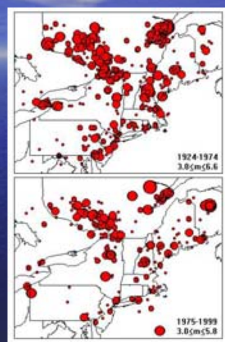
Associated Hazard: Tornados

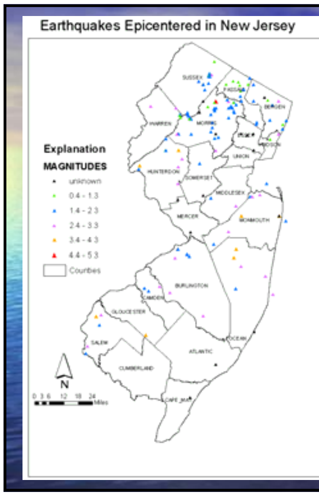
Waterspouts

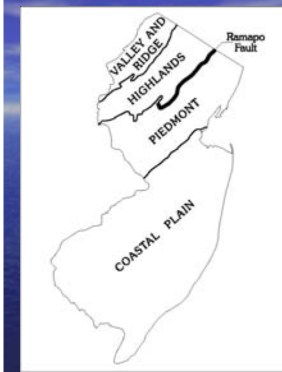
Associated Hazard: Lightning

Earthquakes



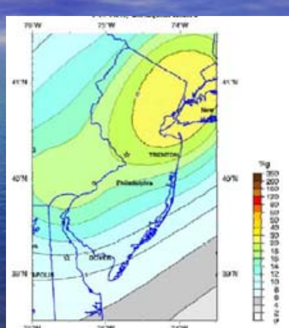






Physiographic provinces of New Jersey, and location of the Ramapo Fault.

Peak Ground Accelerations



Peak Acceleration (%g) with 2% Probability of Exceedance in 50 Years
site: NEHRP B-C boundary
National Seismic Hazard Mapping Project

Tsunami

Table 5: Probable Tsunami Events that Impacted New Jersey (1755-1992)

Country	Name
PORTUGAL	OFF COAST OF LISBON
USA	PHILADELPHIA, PENNSYLVANIA
USA	LONG ISLAND, NEW YORK
USA	PHILADELPHIA, PENNSYLVANIA
USA	LONG ISLAND, NEW YORK
USA	PUERTO RICO, USA
DOMINICAN REPUBLIC	DOMINICAN REPUBLIC, HAITI & PUERTO
DOMINICAN REPUBLIC	DOMINICAN REPUBLIC
USA	NORTHEAST COAST UNITED STATES

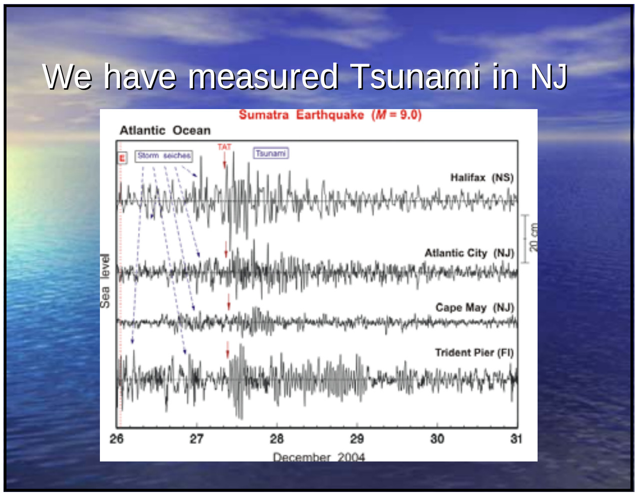
*For detailed information of data presented see: http://www.ngdc.noaa.gov/seg/hazard/tsu.shtml

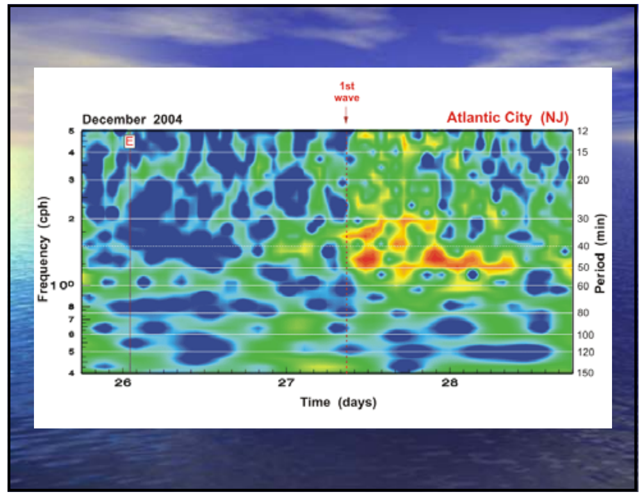
Table 6: Probability of Tsunami Occurrence in New Jersey

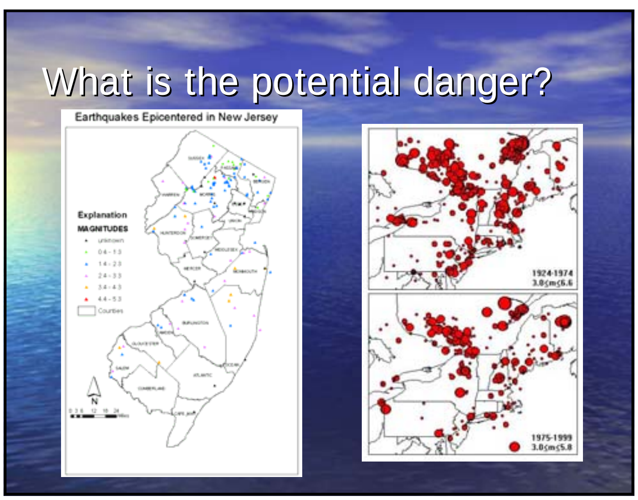
Years	Probability of one Tsunami (%)
1	2.7
10	24.0
25	50.0
50	75.0
100	94.0

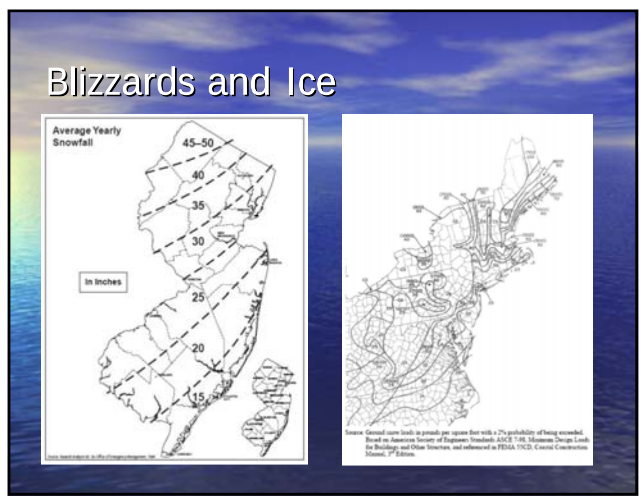
Table 7: Probability of Extreme Tsunami (>1.0m) Occurrence in New Jersey

Years	Probability of one Tsunami (%)
1	0.3
10	2.9
25	7.2
50	13.9
100	26.0


We have measured Tsunami in NJ
Sumatra Earthquake (M = 9.0)
Atlantic Ocean
Storm seiches
TAT
Tsunami
Halifax (NS)
Atlantic City (NJ)
Cape May (NJ)
Trident Pier (Fl)
Sea level
20 cm
26
27
28
29
30
31
December 2004


1st wave
December 2004
Atlantic City (NJ)
Frequency (cph)
Period (min)
26
27
28
Time (days)

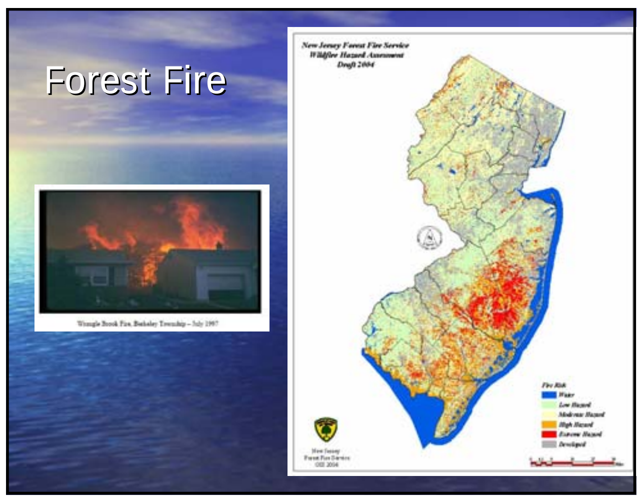

What is the potential danger?
Earthquakes Epicentered in New Jersey
Explanation
MAGNITUDES
1924-1974
1975-1999


Blizzards and Ice
Average Yearly Snowfall
In Inches
45-50
40
35
30
25
20
15


Associated Hazards: High wind, Large waves, Flooding, and Erosion:
2003/12/06


Ice


Landslide
Landslide Susceptiblity/Incidence
for the state of New Jersey


Forest Fire
New Jersey Forest Fire Service
Wildfire Hazard Assessment
Draft 2004