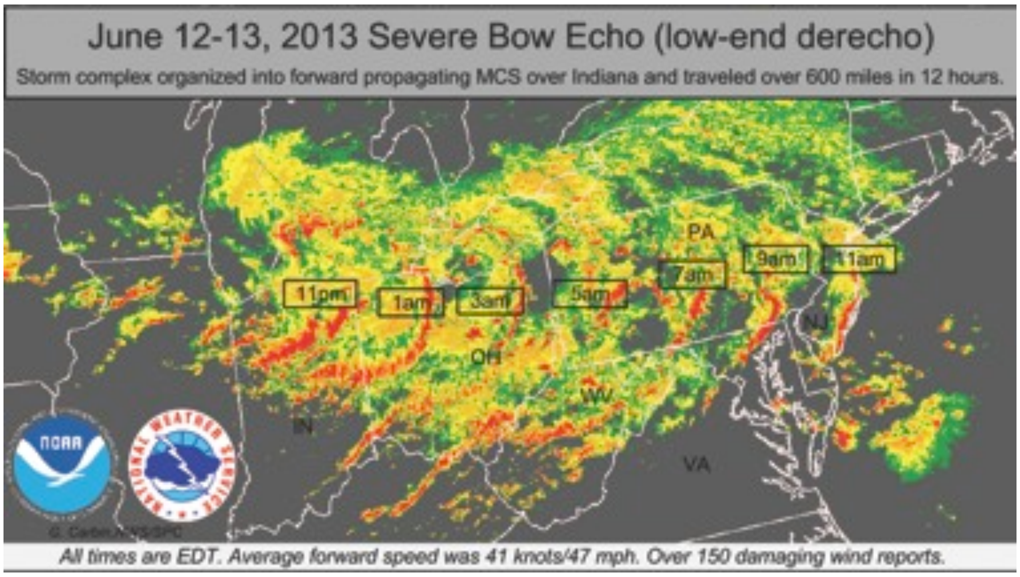
Meteotsunami Signature Found in New Jersey CODAR Data



Storm system that induced a Meteotsunami off the New Jersey coastline 13 June 2013. Image credit: G. Carbin U.S. National Weather Service / SPC.

A strange series of blogs and anecdotal community gossip described people getting swept off breakwaters and out to sea in New Jersey on June 13. It received only local attention for several days. Later someone put these together with an unusual storm system that had raced Eastward across the country, commonly called a "derecho" and proposed it may have launched a "meteotsunami". Meteotsunamis occur regularly in the Mediterranean region (Adriatic, Aegean, and Black Seas), but are rarely mentioned in the U.S. The National Oceanographic & Atmospheric Administration (NOAA) stepped in to investigate this 13 June event, and put forward another possible origin besides meteorological: an undersea landslide in the Hudson Canyon.

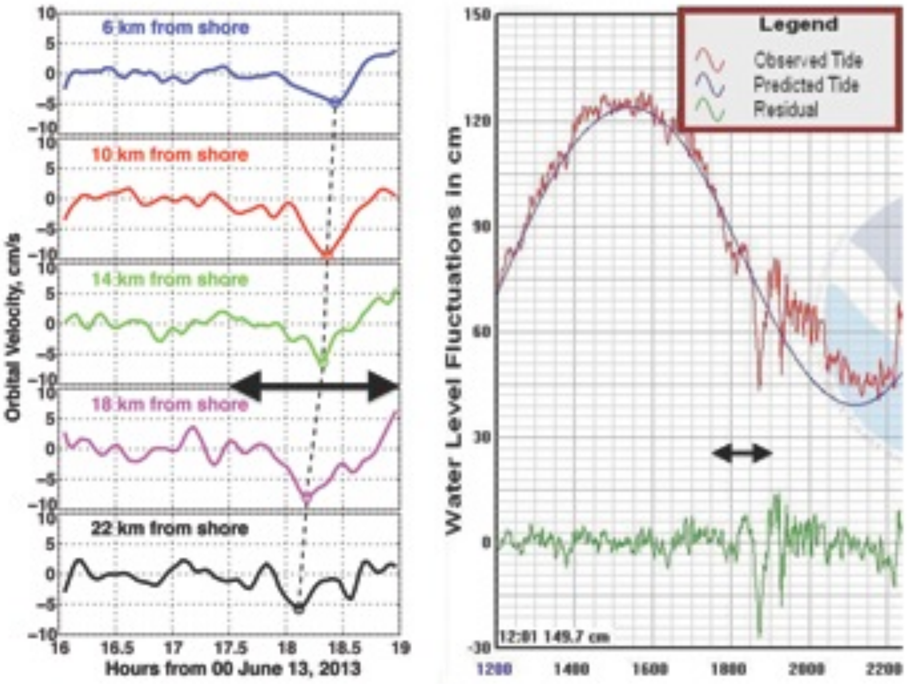
The fact that it was indeed a tsunami was confirmed by 30 tide gages along the East coast up through New England, and as far away as Puerto Rico. The NOAA DART buoy 4402 confirmed it, as well as another bottom-pressure sensor-of-opportunity in the region, a Sonardyne BPR. All of these outputs give a measure of the tsunami wave height.

A panel of scientists was convened by NOAA to study this event, with the first goal to pinpoint the nature of the source (meteorological or undersea landslide). Examination of New Jersey SeaSonde data by scientists at Rutgers University and CODAR company headquarters revealed not only the meteotsunami signature but also helped the team confirm its origin. Examination focused first on the 13-MHz SeaSonde at Brant Beach, NJ.

How a coastal HF radar sees the tsunami and what it sees, compared to other sensors.

- A tsunami is a shallow-water wave, meaning the depth determines its properties and how they evolve. The radar measures its orbital velocity, not its height. The orbital velocity of any wave at its crest moves in the direction of wave propagation; at its trough, velocity opposes that direction.
- All other sensors provide point measurements. The radar maps the velocity with distance from shore. Mapping distance depends on bathymetry and tsunami strength.
- For the orbital velocity observed by the radar as a current, a single radar is adequate (unlike normal 2D current mapping that requires two or more with overlapping coverage). However, multiple sites producing 2D maps will give a more complete picture of the near-field dynamics.

What did the single radar see at Brant Beach?

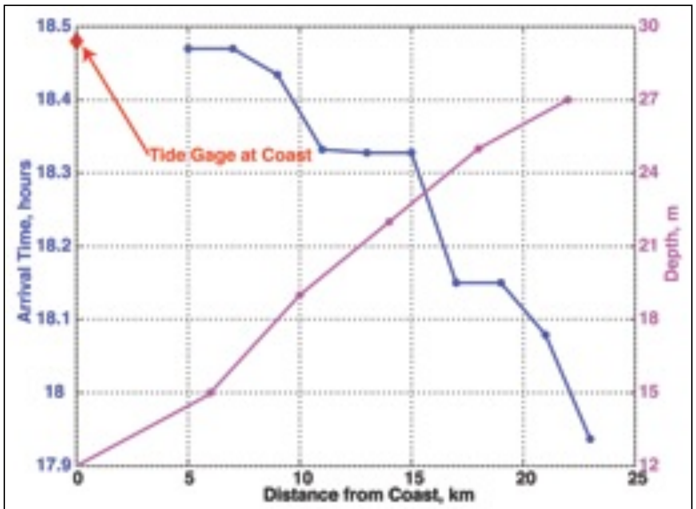


Left Panel:
Brant Beach NJ orbital velocity seen by CODAR SeaSonde with distance offshore. Data have been detrended and filtered around tsunami bandwidths. Negative velocity means water is moving offshore. Dash line tracks the first trough minimum of the tsunami event.

Right Panel:
Water level seen by nearby coastal tide gage at Atlantic City. Bottom panel is detrended (detided) height. Heavy arrows delineate common period when tsunami occurred.

Here are the salient features:

- The first tsunami signal deviation was a "trough". The SeaSonde-observed velocity was offshore, and the closest tide gage at Atlantic City also saw a trough (depression).
- Nonetheless, the wave itself was approaching the coast. The SeaSonde observed the event at the most distant ranges first, confirming this statement.
- The panels on the left highlight the velocity minimum at the trough as a dash line, as it progresses toward shore.
- Adjacent lower Figure to the right the time vs. range of the SeaSonde trough detection, along with the water depth vs. distance. New Jersey has a wide continental shelf (typical of the East and Gulf coasts) where shallow water extends to 120 km with depths less than 100 m.
- ***The SeaSonde observed the tsunami 33 minutes before it arrived at the coast, 23 km offshore.***
- The tide-gage height reading provides both qualitative and quantitative confirmation of the radar observations.



Blue Curve: Arrival time of first tsunami trough in hours from 00:00 June 13, 2013 vs. distance from shore seen by CODAR SeaSonde at Brant Beach, NJ. **Red Diamond** at top left shows time of trough arrival recorded by coastal tide gage at Atlantic City. **Magenta Curve**: Average water depth with distance from shore off Brant Beach.

These results were presented by Belinda Lipa and Don Barrick to a NOAA science group convened on July 18, the first panel session to study this event.

Conclusions

A number of tentative conclusions were reached, supported by the SeaSonde data as well as model backtracking of the tsunami genesis:

- The tsunami was definitely spawned by the "derecho" atmospheric event depicted in the first figure, not an undersea landslide.

Although the atmospheric pressure anomalies moved offshore toward the East, the first observed tsunami wave advanced onshore. How is this possible? This counterintuitive behavior was explained as follows:

- A pressure anomaly above the sea causes its level to rise or fall depending on whether it is a low or high (pulling water up or pushing it down).

- The resulting sea-level peaks/troughs move in the direction of the weather fronts, i.e., to the East.
- The average speed was ~40 knots, according to NOAA/NWS. The pressure anomalies are most effective in generating the tsunami when this velocity matches the phase speed of a shallow-water tsunami wave (a "resonance" condition); the latter velocity is equal to the square root of depth times the acceleration of gravity.
- This happens in the region off New Jersey where the depth is about 47 meters at a distance about 65 km.
- The NOAA tsunami models show that a strong reflection occurs at the shelf edge, where the water quickly gets deeper, referred to as the beginning of the continental slope. This happens about 120 km offshore, where depth drops from 100 m to 1000 m over about 10 km.
- Both the NOAA and our own tsunami models show (again counterintuitively) that a stronger reflection happens when the water drops to the seafloor than when it rises (i.e., the latter would be a Westward moving wave hitting the slope).
- This model prediction was confirmed by the SeaSonde HF radar observations presented above, where the wave was first observed farther offshore, moving toward the coast to the West.
- ***Hence, the SeaSonde and the models were key in deducing the genesis of the meteotsunami.***

Future Investigations

Where do we go from here? Since this event is considered a "first" in the U.S., supported by extensive observations and modeling (also a "first" for any HF radars), there will be additional panel sessions to further refine the science and initiate potential development of real-time warning systems. CODAR and Rutgers scientists intend to examine data from several other SeaSondes along the New Jersey coast, producing 2D animations of this and another event seen four hours later. It is indeed rare that any tsunami is ever observed on the U.S. East coast where the water is shallow. This has offered a treasure-trove of invaluable data from which to discern the nature and evolution of these events. Already, special AGU and Ocean Sciences sessions are being planned to present our collective findings.


13 MHz SeaSonde at Brant Beach, New Jersey