Reconstruction of a Long-Term Storm Frequency Index at the Site of the Historic World War I Shipwreck of the U.S.S. San Diego (ACR-6)

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Abstract

The *USS San Diego* (ACR-6), a WWI armored cruiser, sank off the coast of Long Island, NY on 19 July 1918. In September 2017, the Naval History and Heritage Command (NHHC), researchers from the University of Delaware (UD), the U.S. Naval Academy (USNA), and other collaborators surveyed the wreck of the *USS San Diego* as part of an effort to manage and preserve this historic Navy shipwreck. This site has been subject to forcing from major episodic storm events for the last ~100 years. In this study, wave data from the National Oceanic and Atmospheric Administration (NOAA) National Data Buoy Center (NDBC) covering 2008-2017 were used to identify episodic storm/wave events surpassing a threshold that could impact the wreck site resulting in a site-specific storm frequency index (SFI) for the decade. Threshold criteria were then correlated to wind velocity allowing for a means of identifying episodic storm/wave events from historical wind data that may have impacted the wreck site since the 1940's. Results were compared to the NOAA storm events database from 1950-present to develop a long-term, site-specific SFI for the historic shipwreck site of the *USS San Diego* that can be used to help assess the state of the wreck and aid in future management and preservation efforts.

Background

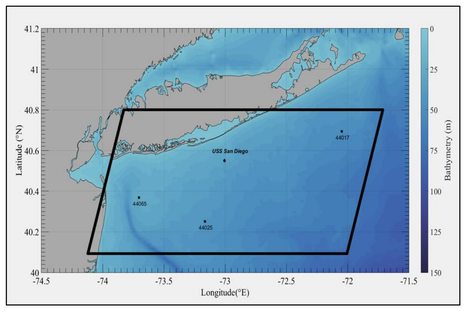


Figure 1. Study area in the Atlantic Ocean southwest of Long Island, NY showing bathymetry and location of 3 NDBC buoys (44017, 52.4 m; 44025, 36.3 m; 44065, 24.7 m) and the wreck of the *USS San Diego* (ACR-6).

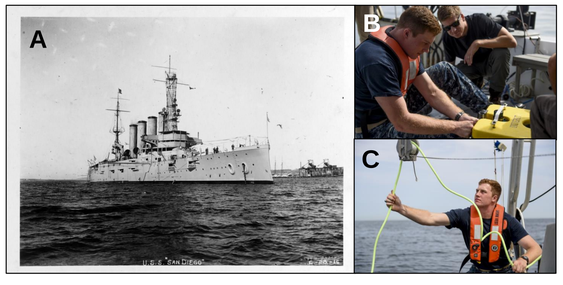
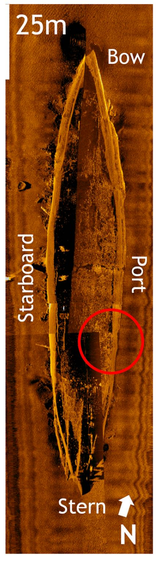


Figure 2. (**A**) *USS San Diego* (U.S. NHHC Photo); (**B**) MIDN 1/C Nolan Brandon working on a Remotely Operated Vehicle (ROV), and; (**C**) Deploying a ROV during a September 2017 wreck survey (Photo by MC1 E. Lockwood, USN).



In July 1918, the *USS San Diego*, an armored cruiser, was sailing to New York to meet with and escort a convoy across the Atlantic as part of the effort to defend against German U-Boats. On 19 July 1918, the ship experienced an explosion of unknown cause and sank in ~34 m of water off the Atlantic coast of Long Island, NY with minimal loss of life (**Fig. 1**). For ~100 years, the wreck has experienced decay from both chemical and physical processes such as storms. Preliminary analysis of data from an NHHC-led survey with UD and USNA in September 2017 (**Fig. 2**; www.history.navy.mil) suggest that wreck has deteriorated to a large extent and may have been partially buried by sediments, been crushed, and/or settled into the seafloor (**Fig. 3**). The NHHC requires a means to estimate storm frequency at the site to aid in future management and preservation of this historic shipwreck.

Figure 3. Side scan sonar imagery of the wreck of the *USS San Diego*. The red circle indicates a region of suspected critical damage (*Trembanis, UD, unpublished*).

Approach, Results, and Discussion

Wave Buoy Data
Buoy Data downloaded from NDBC, trimmed to equal length, and interpolated to the same time step

→

Interpolate/Calculate
Interpolate buoy data from buoys to wreck site and calculate orbital velocities for buoy record. Identify threshold velocity effects on wreck

→

Identify/Correlate
Identify events above velocity threshold and correlate those events to the historical wind record

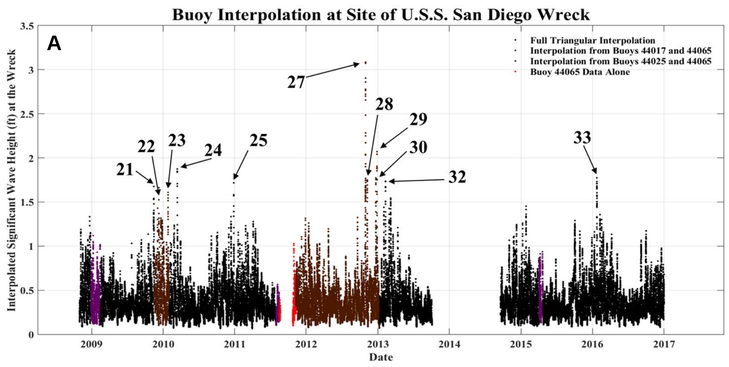
→

Analyze/Index
Analyze historical wind records for all events above threshold and classify. Create storm index for historical wind data

→

Predict
Use calculated storm indexes to predict future storms that will impact the wreck

Wave data from 3 NOAA NBDC buoys was interpolated and used to estimate near-bottom orbital velocities at the site of the wreck (**Fig. 4A** & **B**). A threshold of 0.9 m/s was estimated as the minimum orbital velocity necessary to exceed a critical bottom shear that would initiate suspension of sandy sediments < 750 μm in diameter. Events over this threshold were correlated to storms listed in the NOAA Storm Events Database (SED) and assigned a number in the storm table (**Table 1**). Storm events that exceeded threshold values were matched to peaks in wind speed in the historical wind record (**Fig. 5**). A common threshold for wind speed was established to identify storm events that could exceed estimated wave/orbital velocity thresholds. Storms events back to 1934 were identified from the NOAA-SED (**Fig. 4C**) and identified in the historical wind record (**Fig. 5**). The total number of storms per decade, as identified from NOAA-SED, was recorded and averaged. This average was then used to calculate a storm frequency index ($\mathbf{SFI_{NOAA\text{-}SED}}$) described by *Nebel et. al. (2013)*. The SFI is equal to the number of storms over the total number of years (*n/y*). The process was then repeated to include all storm events above threshold wind speed in order to estimate a threshold $\mathbf{SFI_{TM}}$ specific to the wreck site of the *USS San Diego*.



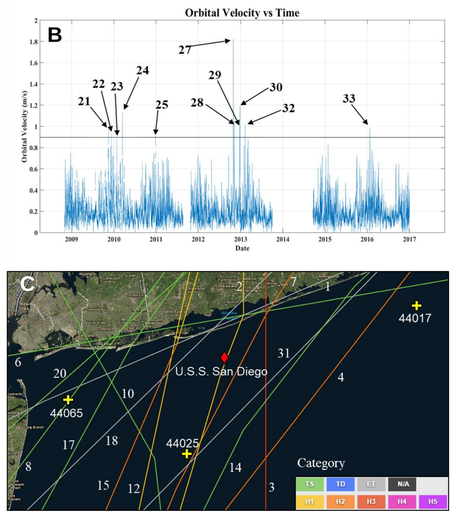


Figure 4. (**A**) Interpolated significant wave height (H_s) data from 3 NOAA NBDC Buoys (44017, 44025, and 44065) with significant episodic storm events indicated and numbered; (**B**) estimated orbital velocities (m/s) at 30 m with a threshold velocity of 0.9 m/s indicated by the solid line, and (**C**) major storm tracks that passed through the area near the wreck site of the *USS San Diego* from 1950 – 2017 as recorded in the NOAA SED (https://coast.noaa.gov/hurricanes/).

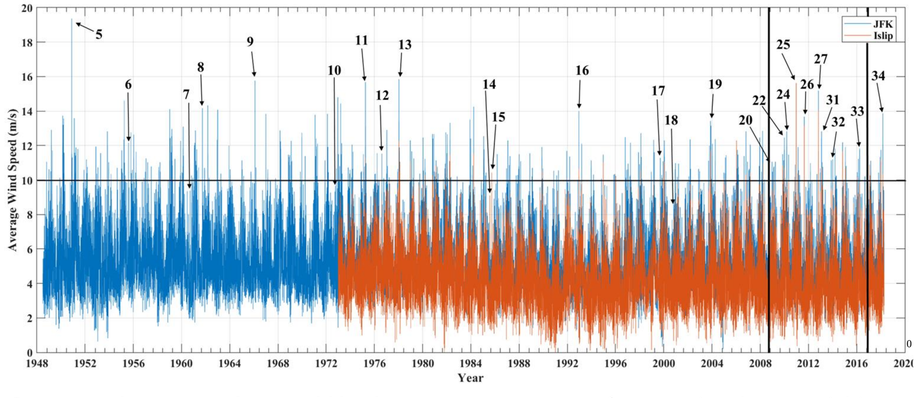


Figure 5. Historical ASOS-AWOS-METAR wind speed (m/s) data from Islip (red) and JFK International (blue) airport near the *USS San Diego* wreck site (Iowa State University Environmental Mesonet site; https://mesonet.agron.iastate.edu/). Identified storms are marked by numbers logged in **Table 2**. Period of buoy data record is delineated by vertical black lines. Storm wind threshold is marked by horizontal black line.

Long-term buoy wave data would be the most accurate means for assessing the potential impacts of episodic storm events on the wreck site of the *USS San Diego*, but these long-term records are not available. Interpolation of data from NOAA NBDC buoys near the site does allow for assessment over the last decade. The approach used in this study relies on some general assumptions but does present a methodology to use recent buoy data to establish identification thresholds for storm events in the longer-term wind record that could potentially impact the wreck. The $\mathbf{SFI_{NOAA\text{-}SED}}$ estimated from the NOAA-SED alone underestimates the number of storm events that could have affected the wreck site of the *USS San Diego* because it only includes major events listed in the historic record. The $\mathbf{SFI_{TM}}$ estimated in this study includes any local event above threshold and therefore provides a more realistic estimate of the frequency of storm events that could impact the wreck site. **Table 2** compares the SFIs for each of the two approaches. The average $\mathbf{SFI_{TM}}$ estimated using the threshold method is 2.83 +/- 0.36 events/year. This estimate provides a first-order estimate of the number of episodic storm events that could impact the wreck along with an estimate of the decade-to-decade variability in such events.

***Conclusions:** Buoy data can be used to estimate a wave/wind threshold to initiate suspension of seafloor sediments. This threshold can be correlated with historic storm event records and historical wind data to identify episodic storm events that can impact an historic wreck site. A threshold SFI can then be developed to provide a site-specific, first-order estimate of episodic storm events that can potentially impact historic shipwrecks like the USS San Diego and aid in future management and preservation efforts.*

Table 1. Storms events identified from the NOAA-SED and historical records (buoy, wind, track) with corresponding date and wind speed (m/s). Events covered by the buoy record are highlighted in yellow.

Event #	Year	Month	Day	Name
1	1934	6	15	Unammed
2	1934	9	7	Unammed
3	1938	9	17	Unammed
4	1944	9	12	Unammed
5	1950	11	25	Great App. Storm
6	1955	8	15	TS Diane
7	1960	8	8	Hurricane Donna
8	1961	9	13	Unammed
9	1966	1	31	Blizzard
10	1972	6	19	TS Agnes
11	1975	4	4	Blizzard
12	1976	8	8	Hurricane Belle
13	1978	1	10	Great Blizzard
14	1985	9	23	TS Henri
15	1985	9	25	Hurricane Gloria
16	1992	12	11	Nor'Easter
17	1999	9	15	TS Floyd
18	2000	9	18	ET Gordon
19	2003	11	14	Blizzard
20	2008	9	3	TS Hanna
21	2009	11	14	Nor'Easter
22	2009	12	9	Blizzard
23	2010	1	25	Blizzard
24	2010	3	14	Nor'Easter
25	2010	12	27	Blizzard
26	2011	8	28	Hurricane Irene
27	2012	10	29	Hurricane Sandy
28	2012	11	7	Nor'Easter
29	2012	12	21	Winter Storm
30	2012	12	27	Nor'Easter
31	2013	6	6	ET Andrea
32	2013	2	9	Blizzard
33	2015	12	29	Winter Storm
34	2018	3	3	Nor'Easter

Table 2. Results showing number of threshold-level storm events per decade, the decadal $SFI_{NOAA\text{-}SED}$, and the decadal SFI_{TM} from this study. SFI is in units of storms events/year.

Years	# Storms	$SFI_{NOAA\text{-}SED}$	SFI_{TM}
1950-1960	33	0.2	3.3
1960-1970	29	0.3	2.9
1970-1980	30	0.4	3.0
1980-1990	29	0.2	2.9
1990-2000	28	0.2	2.8
2000-2010	28	0.5	2.8
2010-2018	21	1.2	2.1
Average	**29.0**	**0.43**	**2.83**
Std. Dev. (σ)	2.1	0.36	**0.36**

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