

NOAA
National Centers for
Environmental
Information (NCEI)

January 2021

NCEI/WDS Integrated Tsunami Database:

Data for Improved Forecasts, Warnings,
Mitigation, and Research

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Introduction

Curation of data enabling community preparedness and resilience to coastal hazards, including:

- Maintaining the global historical tsunami events database
- Archiving and processing of Deep-ocean Assessment and Reporting of Tsunamis (DART®) and coastal tide-gauge data
- Creating coastal digital elevation models (DEMs)



Tsunami Program Mission

To provide support and manage the NOAA Tsunami Program on both domestic and international fronts, including reliable tsunami detection, forecasts, and warnings and education and outreach to promote community resilience

“End-to-End” Program

- ▶ **NCEI and co-located World Data Service for Geophysics provide long-term archive, data management, and access to global tsunami, earthquake and volcano data.**



Historical Hazards Data

Know the past to better understand the future

The Historical Database is an authoritative source for historical tsunami event data with the database continuously updated based on new sources. Includes wave/runup information as well as economic and human impacts.



About Earthquakes Tsunamis Volcanoes API Help Log In

NATURAL HAZARDS DATA

NCEI archives and assimilates tsunami, earthquake, and volcano data to support research, planning, response, and mitigation. Long-term data can be used to establish the history of natural hazard occurrences and help mitigate against future events. The natural hazards datasets are available through the HazEL (Hazardous Event Lookup) interface, developed by NCEI.

EARTHQUAKES

NCEI/WDS EARTHQUAKES
Earthquake DOI Information
The Significant Earthquake Database contains information on destructive earthquakes from 2150 B.C. to the present that meet at least one of the following criteria: Moderate damage (approximately \$1 million or more), 10 or more deaths, Magnitude 7.5 or greater, Modified Mercalli Intensity X or greater, or the earthquake generated a tsunami.

Tsunami

NCEI/WDS TSUNAMI EVENTS
Tsunami DOI Information
The NCEI/WDS Tsunami Event Database contains information on the source of the tsunami. It is related to the Tsunami Runup database which contains information on locations where tsunami effects occurred.

NCEI/WDS TSUNAMI DEPOSITS
Deposit Date Information

VOLCANOES

NCEI/WDS TSUNAMI RUNUP
Runup DOI Information
The NCEI/WDS Tsunami Runup Database contains information on locations where tsunami effects occurred. It is related to the Tsunami Source Event database which contains information on the source of the tsunami.

NCEI MARIGRAM RECORDS
NCEI converts tsunami marigrams from

Search Parameters
Year = 1900 Country = USA Validity = Probable Tsunami

Please cite DOI:10.7289/V5PN9347

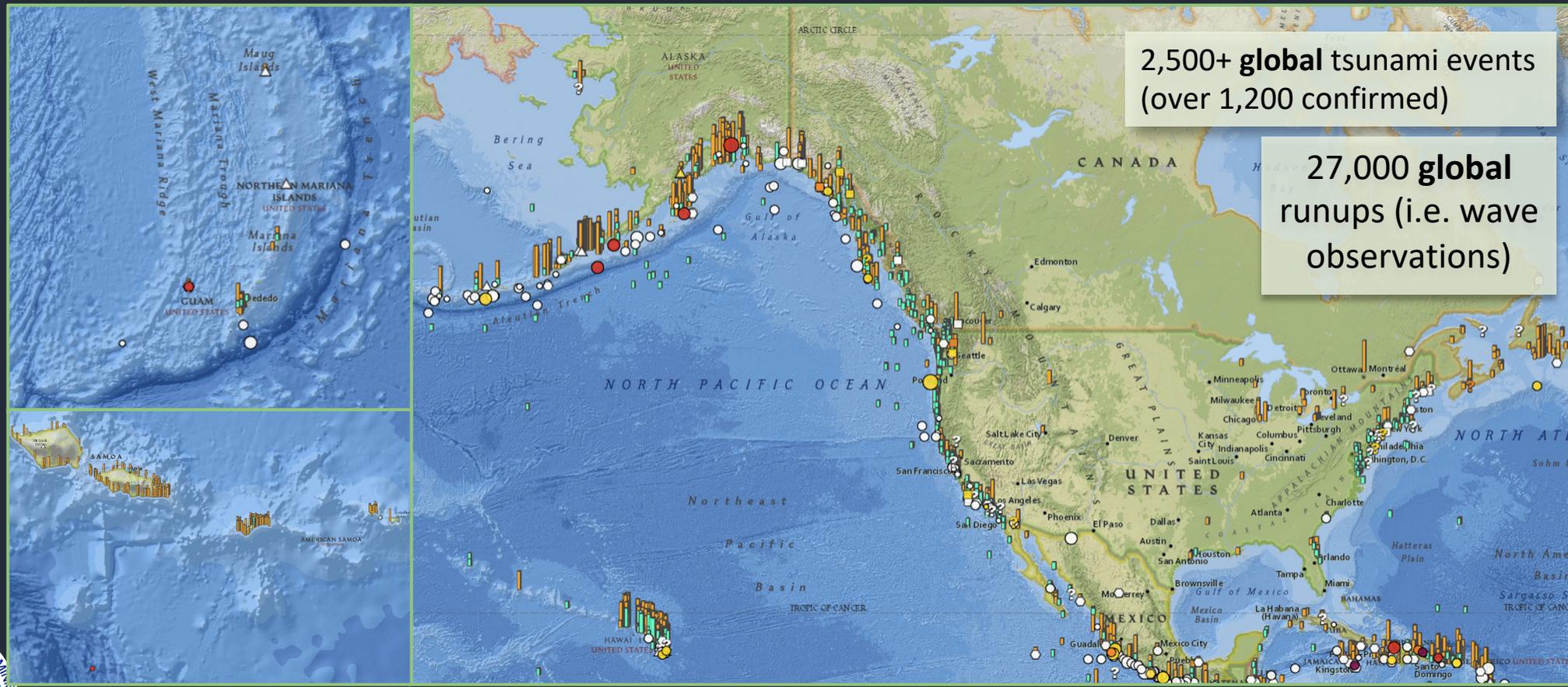
Tsunami Events - 89 Results Found

Year	Mo	Day	Magnitude	Sec	Event Validity	Tsunami Source Code	Earthquake Magnitude	Deposits	Country	Location Name	Latitude	Longitude
1900	8	11	4	40	4	3	5.2	0	USA	LITUYA BAY, AK	58.600	-137.50
1901	3	3	7	45	3	3	5.7	0	USA	MONTREY BAY, N CALIFORNIA	36.000	-120.50
1903	11	24			4	9		0	USA	HAWAII		
1905	7	4			4	8		0	USA	DEERHOUGHT BAY, AK	60.000	-139.50
1906	4	18	13	12	0	4	3	7.9	USA	N. CALIFORNIA	37.700	-122.50
1907	9	24	12	58	0	3	3	5.5	USA	SKAGWAY, AK	59.500	-135.50
1908	9	21	6	31	4	1	5.8	0	USA	HAWAII	19.000	-155.00
1917	8	16			3	8		0	USA	TAKU INLET, JUNEAU, AK	58.204	-134.14
1919	10	2			4	7		0	USA	ALHA, HAWAII	19.200	-155.50
1925	2	23	23	53	36	3	3	5	USA	GULF OF ALASKA, AK	60.000	-148.00
1925	10	4	16		4	9		0	USA	CALIFORNIA		
1927	10	24	15	59	44.8	3	3	2.1	USA	SE. ALASKA, AK	57.890	-136.07
1927	11	4	13	50	43	4	1	2.3	USA	S. CALIFORNIA	34.813	-120.77
1929	3	7	1	34	37.9	4	1	2.8	USA	FOK ISLANDS, ALEUTIAN ISLANDS, AK	50.880	-169.71
1930	8	31	0	40	38	3	3	5.2	USA	S. CALIFORNIA	34.030	-118.84
1936	10	27	15	50	5	4	6		USA	LITUYA BAY, AK	58.600	-137.00
1939	11	10	20	18	41.2	4	1	5.2	USA	SHAMON ISLANDS, AK	55.480	-158.37
1945	4	1	12	29	1.3	4	3	5.6	USA	UNIMAK ISLAND, AK	53.492	-162.83
1949	4	13	18	56	3	3	2		USA	RUGET SOUND, WA	47.167	-122.81
1949	4	16	10	56	4	3	3		USA			

<https://www.ngdc.noaa.gov/hazel>



Tsunami Source Events and Wave Observations



<https://maps.ngdc.noaa.gov/viewers/hazards>

Historical Tsunami Data Fields

Data is downloadable

Source and Runup **Location**: Regional, Country, State/Territory, Lat/Long

Source: cause (e.g. earthquake, landslide, volcanic, etc.), validity

Runups: type of measurement (e.g. tide gauge, eyewitness, BPR, post-event survey), heights, inundation, max arrival time, first arrival time, etc.

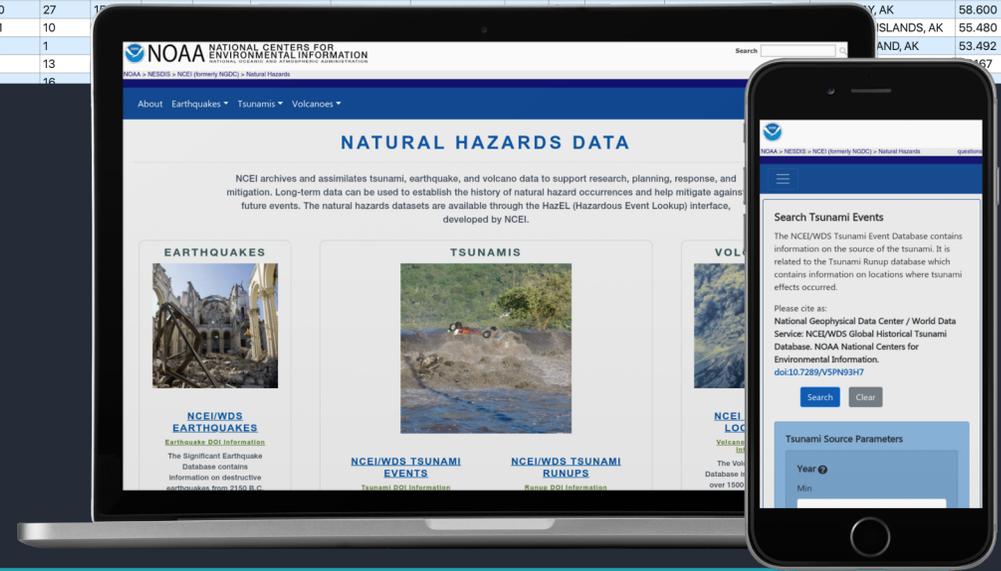
Source and Runup **Effects**: deaths, injuries, damage

Search Parameters
Year >= 1900 Country = USA Validity >= Probable Tsunami

Please cite DOI:10.7289/V5PN93H7

Tsunami Events - 69 Results Found

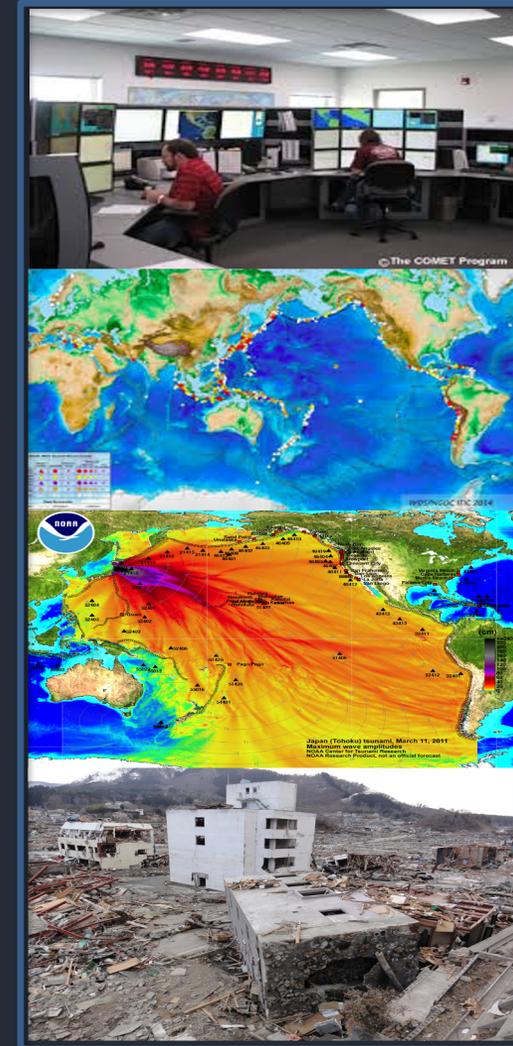
Year	Mo	Dy	Hr	Mn	Sec	Tsunami Event Validity	Tsunami Cause Code	Earthquake Magnitude	Vol	More Info	Deposits	Country	Location Name	Latitude	Longitude
1900	8	11	4	40		4	3			0	0	USA	LITUYA BAY, AK	58.600	-137.500
1901	3	3	7	45		3	3	6.7		0	0	USA	MONTEREY BAY, N. CALIFORNIA	36.000	-120.500
1903	11	24				4	9			0	0	USA	HAWAII		
1905	7	4				4	8			0	0	USA	DISENCHANTMENT BAY, AK	60.000	-139.580
1906	4	18	13	12	0	4	3	7.9		0	0	USA	N. CALIFORNIA	37.700	-122.500
1907	9	24	12	58	0	3	3	5.5		0	0	USA	SKAGWAY, AK	59.500	-135.500
1908	9	21	6	31		4	1	6.8		0	0	USA	HAWAII	19.000	-155.000
1917	8	16				3	8			0	0	USA	TAKU INLET, JUNEAU, AK	58.204	-134.147
1919	10	2				4	7			0	0	USA	ALIKA, HAWAII	19.230	-155.900
1925	2	23	23	53	36	3	3	6		0	0	USA	GULF OF ALASKA, AK	60.000	-146.000
1925	10	4	16			4	9			0	0	USA	CALIFORNIA		
1927	10	24	15	59	44.8	3	3	7.1		0	0	USA	SE. ALASKA, AK	57.690	-136.070
1927	11	4	13	50	43	4	1	7.3		0	0	USA	S. CALIFORNIA	34.813	-120.774
1929	3	7	1	34	37.9	4	1	7.8		0	0	USA	FOX ISLANDS, ALEUTIAN ISLANDS, AK	50.880	-169.710
1930	8	31	0	40	38	3	3	5.2		0	0	USA	S. CALIFORNIA	34.030	-118.643
1936	10	27	15									USA	AK	58.600	-137.100
1938	11	10										USA	AK	55.480	-158.370
1946	4	1										USA	AK	53.492	-162.832
1949	4	13										USA	AK	53.492	-162.832
1949	4	16										USA	AK	53.492	-162.832



Historical Tsunami Data Supports

Operations, Mitigation, Education, Resilience

- Outreach & Education
- NOAA Tsunami Warning Centers
 - Decision-making
 - Media response
- IOC/UNESCO and NTHMP
 - Assessing the Tsunami Hazard – US and Worldwide
- NOAA and other Tsunami Research
 - Model Calibration and Validation
- Land use / Codes / Engineering Criteria
 - Tsunami effects on structures (buildings, power plants)



Global, Regional and U.S. Tsunami Products

U.S. National Tsunami Hazard Assessment

(partnership w/ NTHMP and USGS)

Global Tsunami posters (partnership w/ ITIC and CTWP)

Regional Tsunami posters (partnership w/ ITIC and CTWP)

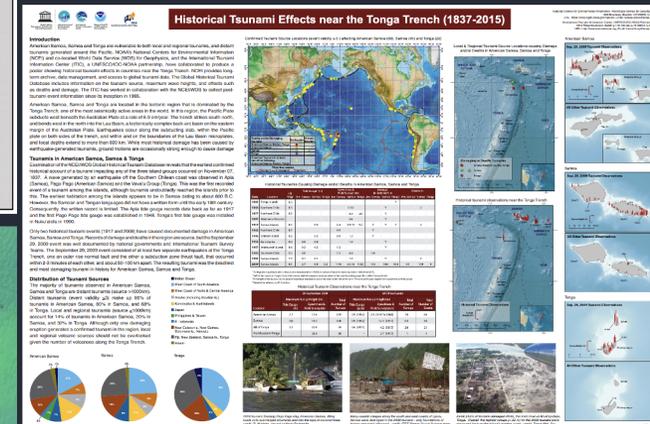
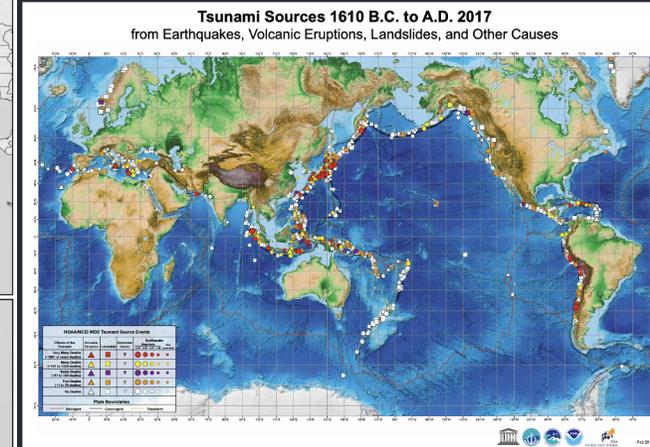
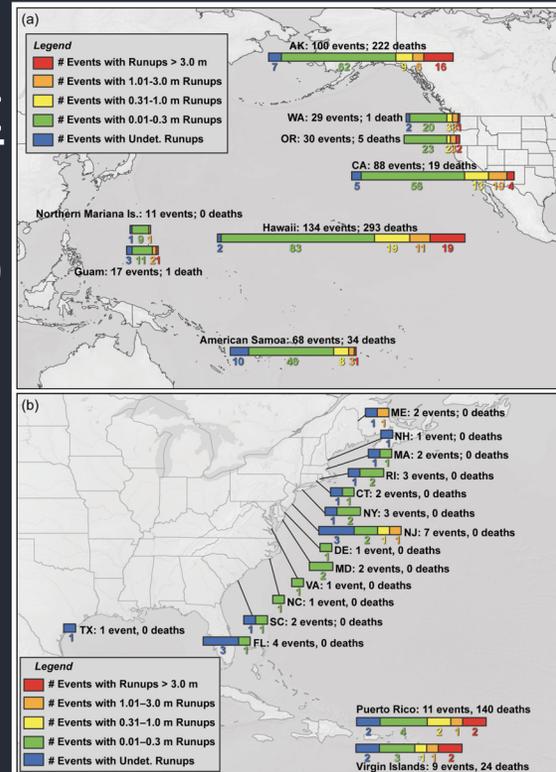
- Caribbean (Eng & Esp), Hawaii, New Hebrides Trench, Tonga Trench, Papua New Guinea and the Solomon Islands

Regional tsunami sources map viewer

(partnership w/ ICG/CARIBE-EWS)

U.S. Historic Tsunami Calendar

(partnership w/ NTHMP)



Natural Hazards Image Database

1550+ images, including
90+ tsunami events

- Free for public use
 - Lots of requests from textbook publishers
- Images are archived
- Please consider contributing!
- Partnerships have included: ITIC, CTWP, USGS



<https://www.ngdc.noaa.gov/hazardimages/>

NOAA NATIONAL CENTERS FOR ENVIRONMENTAL INFORMATION
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

Natural Hazards Image Database

Event search:

- Earthquake
- Tsunami
- Volcano
- Geology
- All

Usage please credit both:

- source (person/organization)
- NOAA/NCEI ([Details](#))

Recent and Notable Events

March 1964 Prince William Sound, USA Tsunami and Earthquake

The Prince William Sound magnitude 9.2 Mw earthquake on March 28, 1964 at 03:36 GMT (March 27 at 5:36 pm local time), was the largest U.S. earthquake ever recorded and the second largest recorded worldwide. The earthquake was felt over a large area of Alaska and in parts of western Yukon Territory and British Columbia, Canada. The area of the damage zone and the duration of the quake (3 to 4 minutes) were extraordinary. The earthquake caused 15 deaths and approximately \$284 million in property loss. The ensuing tsunami caused 124 deaths (106 in Alaska, 13 in California and 5 in Oregon) and \$116 million in damage. This set of slides shows geologic changes, damage to structures, transportation systems, and utilities and tsunami damage. It features the effects of four major landslides in Anchorage during the 1964 event.

Event Data: [earthquake](#), [tsunami](#)

[ISO Metadata Record](#)

enable gallery view

March 2011 To

Water Level Data

Archive ► NCEI is the long-term archive of water level data in support of the NOAA Tsunami Program.

Analog Tide Gauge Records (Marigrams)

- Tsunami event-related data from 1854-1981

Digital Tsunami-capable Tide Gauge Data:

- CO-OPS (~220), 2008+
- NTWC (9), 2014+
- PTWC (14), 2013+

DART Ocean Bottom Pressure Data:

- PMEL (R&D), 1983-2004
- NDBC (39), 2002+
- Some international



Water Level Data

- **Monitor** ➤ Monitor ingest and archive process and take action if problem
- **Rescue** ➤ Identify, recover, and backfill data gaps
- **Reformat** ➤ Reformat water level data to standard formats (netCDF, CSV)
- **Digitize** ➤ Digitize marigrams to make historic records “ready-for-use”
- **Quality-Control** ➤ Quality-control water level for instrumental issues
- **Tidal Analysis** ➤
 - Model tides to reveal tsunami-event signals
 - Tidal constituents for predictions
- **Discover** ➤
 - NOAA Catalog (ISO-compliant Metadata Records + DOI/How to Cite)
 - Map Viewers
 - Timeline Inventories
- **Access** ➤
 - Map Viewers and Timeline Inventories link to Station Pages
 - Station Pages link to data on THREDDS Data Server
 - RESTful API for CO-OPS to access and display NTWC data
- **Tsunami Event Pages** ➤ Gathers together water level data per tsunami
- **Customer Service** ➤ User Requests

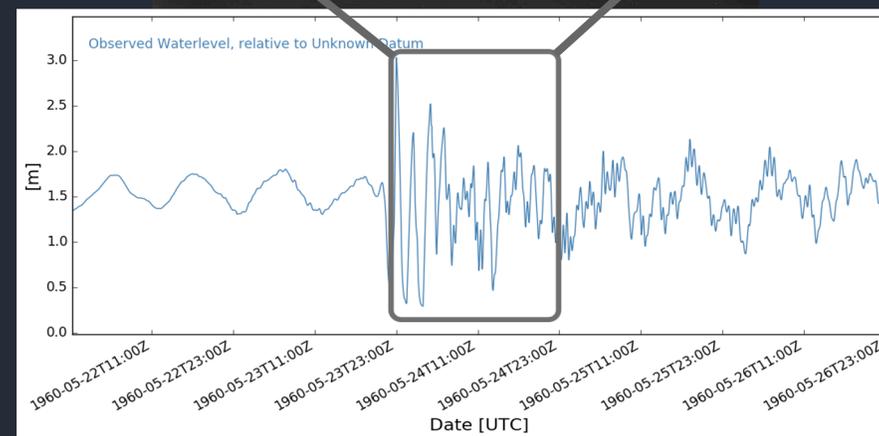
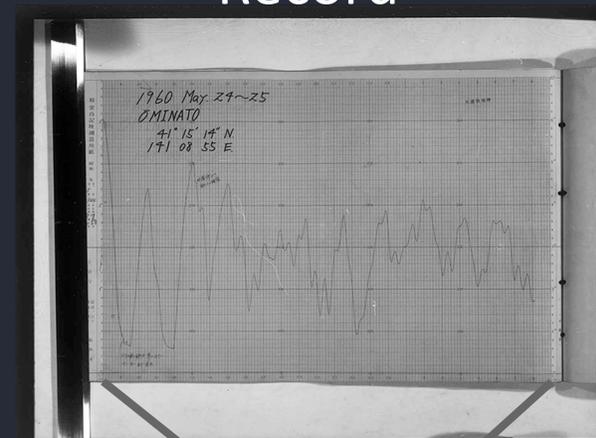


Marigrams

- Over 3,000 historic paper records (1854-1981)
- Converted from analog to digital media, some digitized time-series



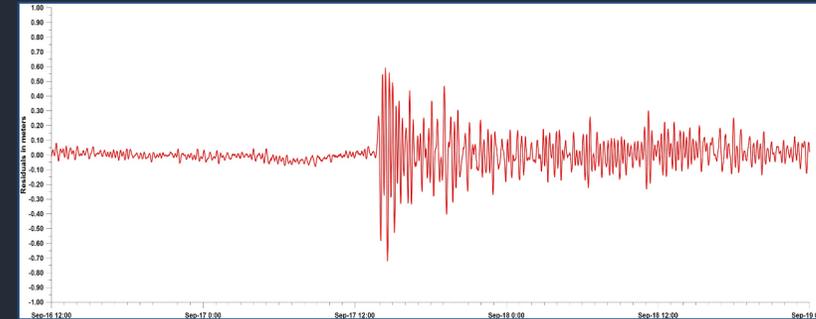
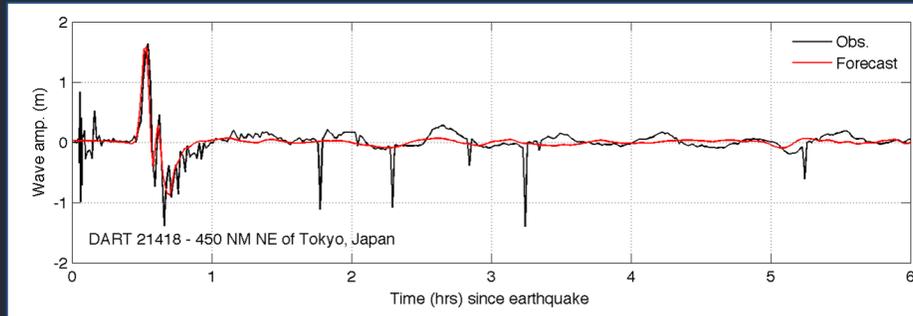
Scanned Image of Paper Record



height vs. time (point time-series)



Water Level: Quality-Control and Tide Modeling



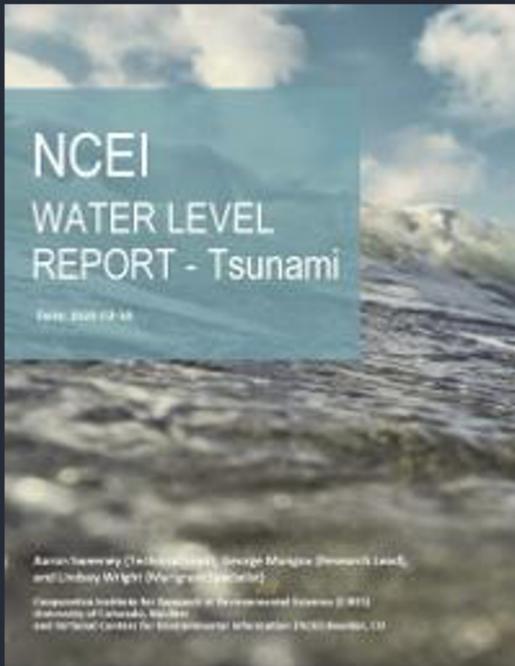
Quality Controlled water level data from a DART system (left) and tide station (right) to remove the tidal signal and reveal true height of tsunami wave. Japan 2011 event.

- **NCEI quality controls the data and models the tides** to isolate tsunami waves (and hurricane/storm surge).
- DART systems are the first to see tsunami waves as they travel across the ocean and give a more refined estimate of the tsunami source resulting in a more accurate forecast at the coast.
- Tide gauges confirm the arrival, size and direction of travel along the coast.



Water Level: Additional Products

NCEI Water Level Report - Tsunami (biannual)



Hurricane Analysis

Hurricane 2017 Season Data at NCEI Water Level Data Archive

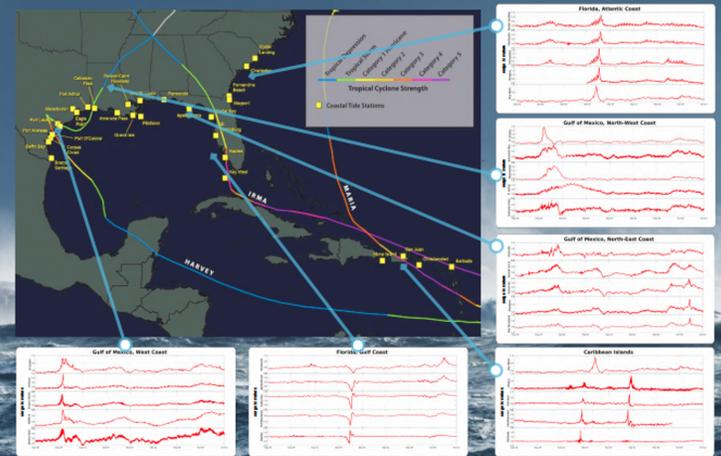
The 2017 Atlantic hurricane season was one of the most intense in U.S. history. Three Category 4 and 5 hurricanes — **Harvey**, **Irma** and **María** — severely impacted most of the Caribbean islands and made landfall in the continental United States between August 16 and September 28.

Hurricane **Harvey** made its way through the central Caribbean Sea, crossed the Yucatan Peninsula, turned to the north, and made landfall approximately five miles east of Rockport, Texas, on August 25. Harvey then turned east, weakened to tropical storm level, and made a second landfall west of Cameron, Louisiana, on August 30. Estimated damages were \$125 billion dollars according to NOAA Office for Coastal Management.

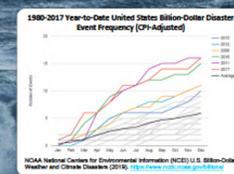
Hurricane **Irma** was a Category 5 when it made landfall on Barbuda on September 6, 2017. After that, Irma made its way up the north side of the Caribbean islands, destroying Haiti and Puerto Rico, and flooding Havana, Cuba. It then turned northwest, moved over the Florida Straits, and as a downgraded Category 4, made landfall 20 miles north of Key West. It then headed to Naples and quickly downgraded to a Category 1. Losses due to Irma were estimated to be \$50 billion.

Hurricane **María** started as a tropical storm on September 16, east of the Lesser Antilles. María underwent explosive intensification and reached Category 5 on September 18, when it made landfall on Dominica and then severely destroyed Haiti. On September 20, María weakened to a Category 4 and reached Puerto Rico. María was downgraded to a tropical storm on September 26 and quickly dissipated after that. Losses caused by Hurricane María were estimated to be \$90 billion.

NOAA National Centers for Environmental Information (NCEI) archives and processes water level data from the Deep-ocean Assessment and Reporting of Tsunamis (DART®) network and select coastal tide gauge stations. The data are quality controlled, de-tided, and used to estimate the parameters of tsunamis, storm surges, and other extreme events. Here we present storm surge data from the 2017 hurricane season when the U.S. Gulf of Mexico and South Atlantic coasts were hit by three hurricanes in less than two months.



Depending on the position of a hurricane's path, landfall location, and coastline features, we can see positive or negative storm surges with different intensity and duration. For example, when landfall is on the Atlantic coast of Florida, strong positive storm surges are observed, but landfall on the Gulf coast of Florida produces negative storm surges. The same is seen along the coast of Texas, where negative storm surges are observed in the navigational channels parallel to the coastline. Along the open Gulf coasts, we see strong positive storm surges.



NOAA National Centers for Environmental Information partners with:

- National Tsunami Hazard Mitigation Program (NTHMP)
- NOAA National Weather Service (NWS)
- NOAA National Ocean Service (NOS)
- NOAA Office of Oceanic and Atmospheric Research (OAR)
- National Meteorological and Hydrographic Services worldwide

Providers of water level data are: NOS/Center for Operational Oceanographic Products and Services (CO-OPS) for coastal tide gauge data, NWS/National Data Buoy Center (NDBC) for DART® data, NWS/Tsunami Warning Centers (TWCs) for tide gauge data from regional networks, and OAR/PMEL for bottom pressure and coastal tide gauge data. All ingested records are quality controlled, processed and provided to the public at <https://neds.noaa.gov/hazard/tsu.shtml>. The contribution of our partners is greatly appreciated.



Tsunami Online Event Summaries

- Authoritative Event reports for select events:
 - Tsunami source & impact
 - Latest confirmed casualties
 - Past events in same region
 - Field surveys & photographs
 - Source documents
- DART & Tide Gauge data
- Tsunami-Travel-Time maps

MARCH 11, 2011 JAPAN EARTHQUAKE AND TSUNAMI
 Updated: March 9, 2012 at 20:00 UTC, 02:00 pm MDT

The 11 March 2011 magnitude 9.0 Honshu, Japan earthquake (38.297 N, 142.373 E, depth 29 km) generated a tsunami that was observed all over the Pacific region and caused tremendous devastation locally. The National Police Agency of Japan reports that as of March 8, 2012, there are 15,854 deaths and 3,203 missing in Japan. The tsunami also caused over \$200 billion damage in Japan and resulted in a nuclear accident with explosions and leaks in three reactors at the Fukushima I (Daiichi) Nuclear Power station. The tsunami also caused damage over 16,000 km away at Isla Chiloe, Chile; \$6 million in losses to the fishing industry in Tongoy, Chile; \$30 million damage in Hawaii; and \$70 million damage in California. This was the first time observational evidence from satellites linked a tsunami to ice-shelf calving in Antarctica.

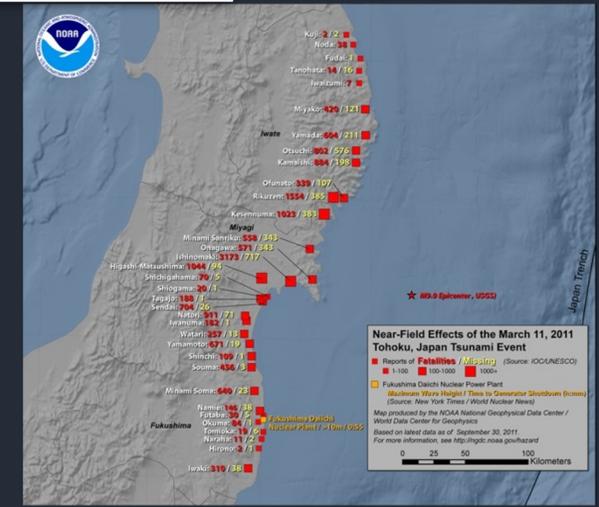
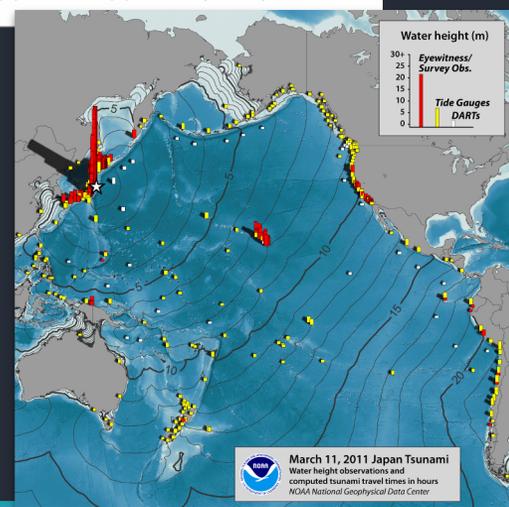
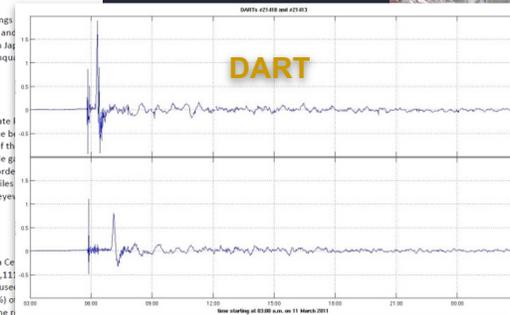
This is the fourth largest earthquake in the world and the largest in Japan since instrumental recordings. The earthquake generated the deadliest tsunami since the 2004 magnitude 9.1 Sumatra earthquake and nearly 230,000 deaths and \$10 billion in damage. This is the most devastating earthquake to occur in Japan since the 1923 Great Kantō earthquake which was responsible for over 200 deaths.

MARCH 11, 2011 EYEWITNESS AND INSTRUMENTAL RECORDINGS

Field survey results indicate the highest runup height was 38.9 meters (tide removed) in Iwate (39.533757 N, 142.046279 E) (<http://www.coastal.jp/sunami2011/>). Runup is the difference between elevation of maximum tsunami penetration (inundation line) and the sea level at the time of the gauge recordings in Japan range from 1 to 9 meters. Two meter waves were observed at tide gauges in South America, Hawaii, and the west coast of the United States. The highest wave ever recorded at a bottom sensor was measured at 1.8 meters by DART* station 21418 located 450 nautical miles from Japan (see display on p. 4). NGDC will continue to update the historic tsunami database as eye-witness reports are received.

HISTORICAL EARTHQUAKES AND TSUNAMIS IN JAPAN

At the time of this event (March 3, 2011), according to the NOAA National Geophysical Data Center Service for Geophysics / (<http://ngdc.noaa.gov/hazard/>) Global Historical Event databases, 2,111 (validity ≥ 1) had occurred in the world since 2000 B.C., and 281 (13%) of these tsunamis cause Japanese region, 304 tsunamis (validity ≥ 1) had been observed since 684 A.D., and 78 (26%) caused deaths. The majority of Japanese tsunamis were generated by earthquakes (87%), the rest from volcanic eruptions (5%) and unknown causes (8%). The most fatal Japanese earthquakes and tsunamis are listed below:



Digital Elevation Model Development

NOAA develops and uses digital elevation models (DEMs) to support a variety of mission requirements including coastal flood forecasts and warnings due to tsunamis, hurricanes, and storm surge, marine habitat research, and sea level change studies.

In Support of:

- U.S. National Tsunami Hazard Mitigation Program
- COASTAL Act
- United Nations Development Programme (UNDP)
- Office of U.S. Foreign Disaster Assistance (OFDA), United States Agency for International Development (USAID).

In Coordination with:

- NOAA Pacific Marine Environmental Lab
- NOAA Caribbean Tsunami Warning Program

The DEM team at NCEI have developed custom scripts that make use of free open-source software such as GDAL, MB-System, GMT, VDatum, etc.

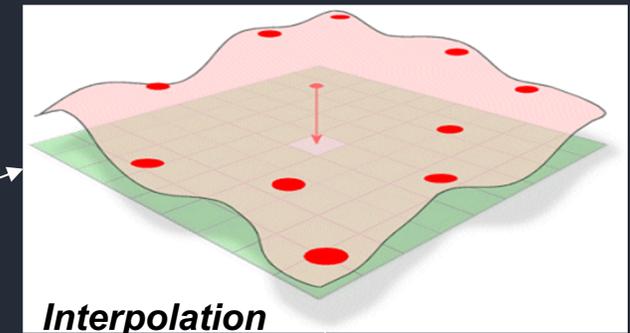
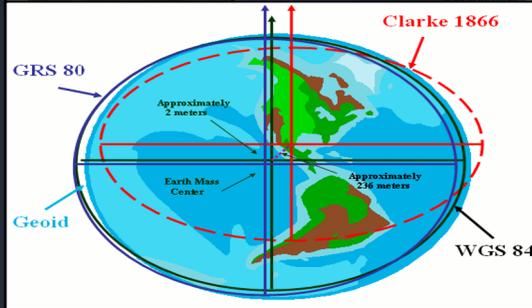
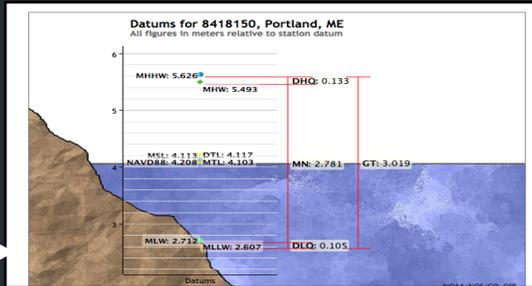
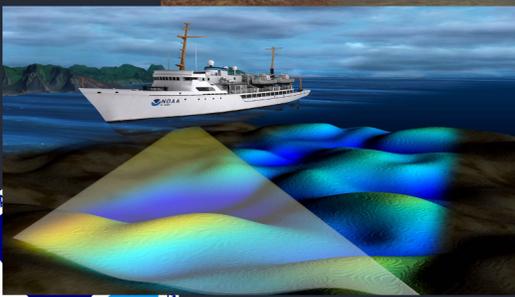
U.S. DEMs integrate bathymetry and topography seamlessly and are tiled to enable targeted, rapid updates as new data become available.

<https://coast.noaa.gov/dataviewer/>



What is a Digital Elevation Model?

- Gridded representation of the Earth's surface
- *Integrated topography and bathymetry*
- *One Continuous surface*



Input Data (Points)

Processing

Output Data (Grid)

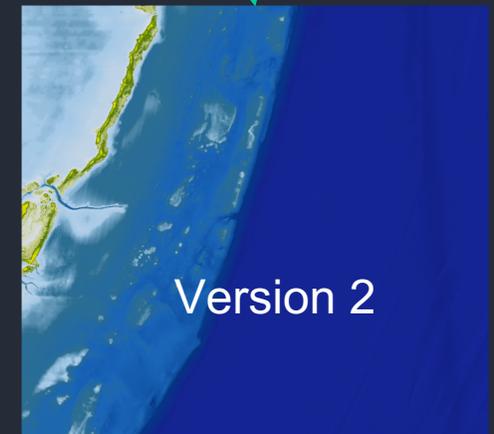
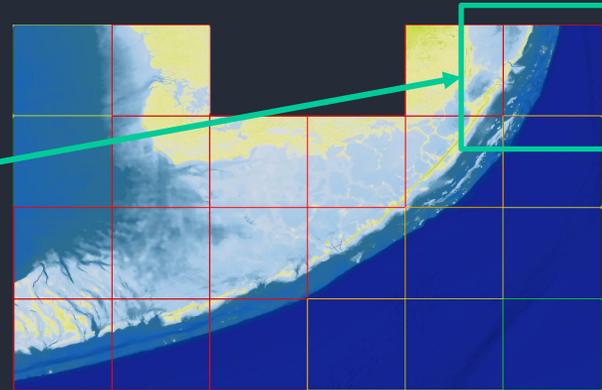
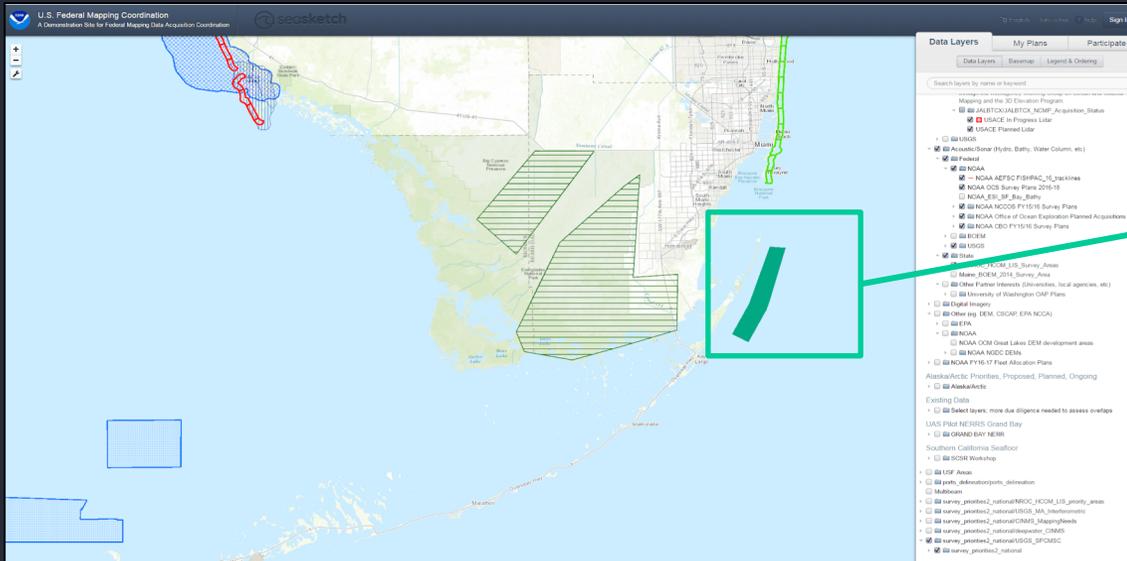


NTHMP DEM priorities

- New data released
- Areas of interest
- Date of last DEM
- News of upcoming data collections



Tiled DEM updates



- Use federal planning web maps to identify and prioritize DEM update areas
- Targeted update reduces lag between source data release and integration into DEM
- More up-to-date DEMs



Spatial Metadata

- Future data products to enhance value of DEMs (*In Progress*)
 - **Spatial Metadata**
 - **Vertical Uncertainty**
- **Spatial Metadata** provides users with information on input elevation data used in the DEM development
- Important information includes:
 - Collection agency
 - Date of the data collection
 - Instrumentation (lidar, sonar, satellite, etc.)
- **Vertical Uncertainty** provides users with quantitative estimate of quality of the DEM values
- DEM quality can vary across space:
 - Integration of different data (e.g., old vs. new technologies)
 - Terrain (e.g., flat or sloped)
 - Interpolation (estimating elevations in areas of no data)

Identify

Identify from: <Top-most layer>

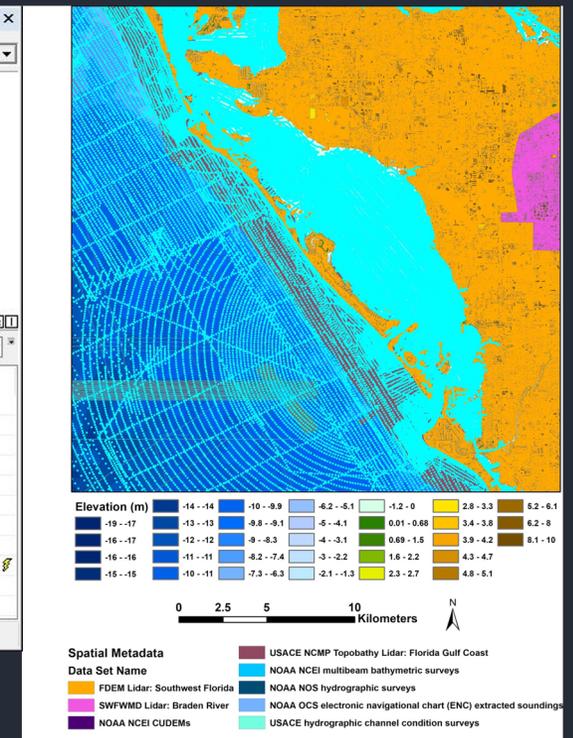
Spatial Metadata

- USACE hydrographic channel condition surveys
- NOAA NCEI multibeam bathymetric surveys
- NOAA NOS hydrographic surveys
- NOAA OCS electronic navigational chart (ENC) extracted soundings
- USACE NCMP Topobathy Lidar: Florida Gulf Coast
- NOAA NCEI CUDEMs
- FDEM Lidar: Southwest Florida
- SWFWMD Lidar: Braden River

Location: -82.622233 27.378778 Decimal Degrees

Field	Value
Agency	NOAA NOS
Date	1857 - 2019
FID	2
HDatum	NAD83
Name	NOAA NOS hydrographic surveys
Resolution	< 10 meters to several kilometers
Shape	Polygon
Type	XYZ
URL	https://maps.ngdc.noaa.gov/viewers/bathymetry/
VDatum	Mean lower low water (MLLW)

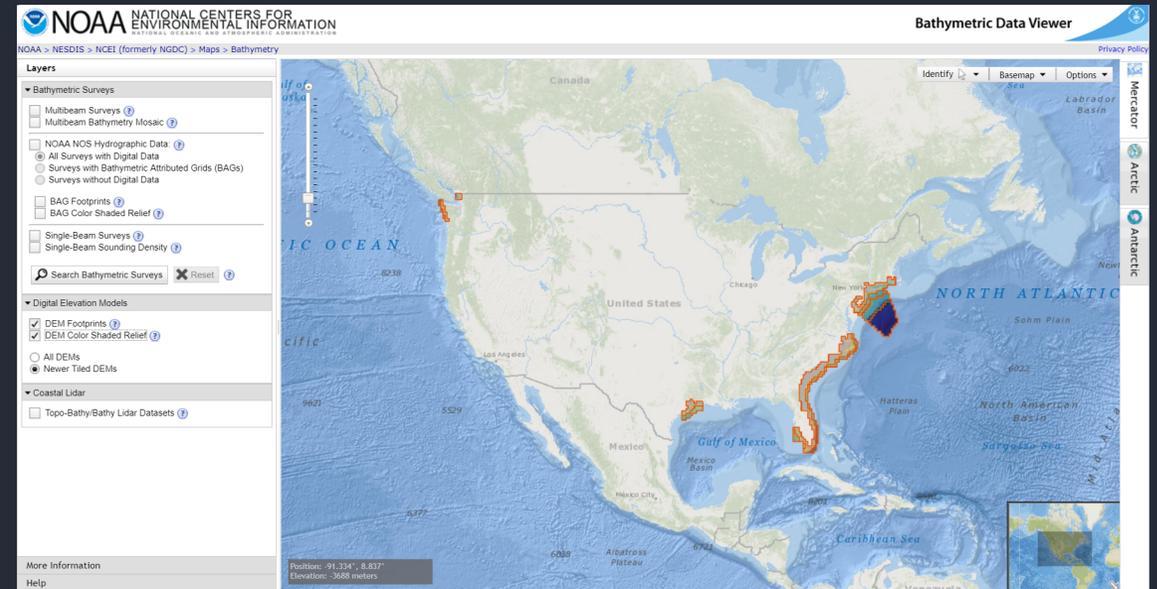
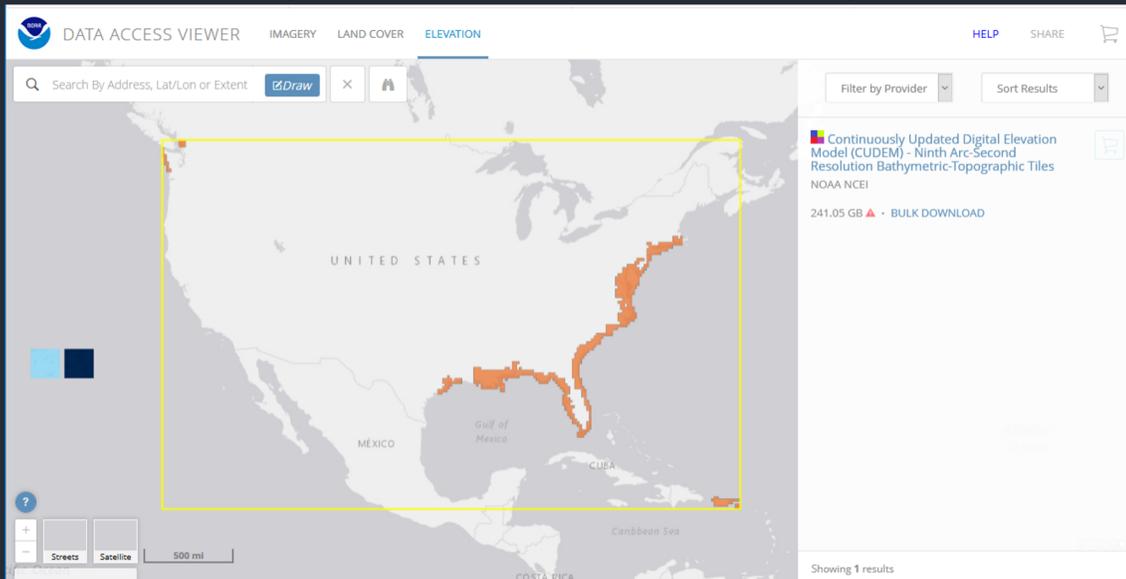
Identified 9 features



DEM Access



- Most recent topo-bathy and bathy DEMs available via Digital Coast
- Discoverable via NCEI Bathymetry Viewer



THANK YOU!



NOAA
National Centers for
Environmental
Information (NCEI)

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Questions & Comments?

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Email Haz.Info@noaa.gov

General inquiries on DEMs. Email DEM.Info@noaa.gov