National Tsunami Warning Center

Monitoring and Application of Sea Level Data

NTWC
910 S. Felton St.
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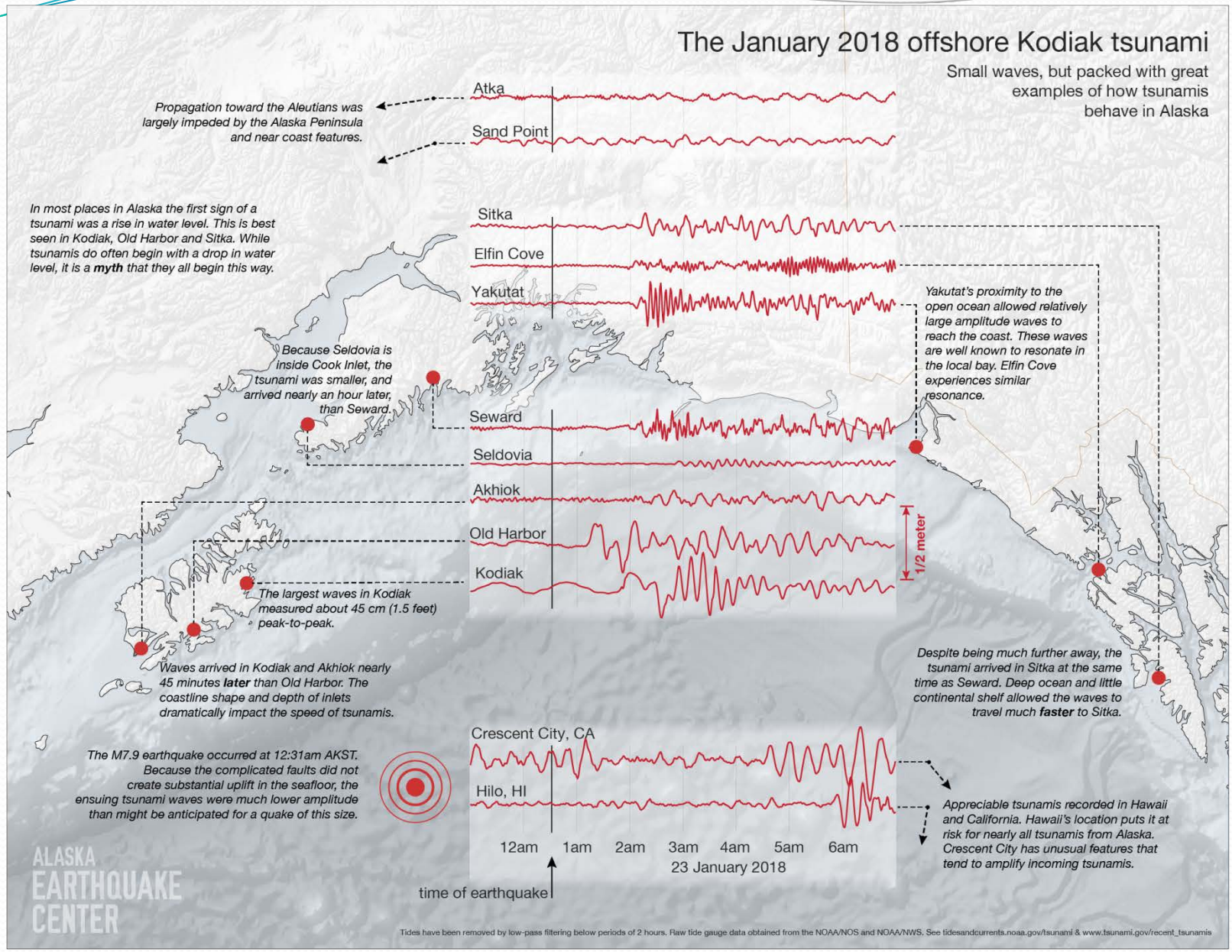
99645

When an earthquake occurs that can generate a tsunami

- National Weather Service, Tsunami Warning System, has procedures to issue a Tsunami Warning based solely on a large seismic event
- Immediately following large earthquake events, the tsunami threat is reevaluated by monitoring traditional tide gauge stations, DART buoys, and NWS Tsunami Gauge stations
- For the purpose of expedient cancellation of a Tsunami Warning, a dense network of sea level stations is needed for timely confirmation of tsunami hazard status


The January 2018 offshore Kodiak tsunami
Small waves, but packed with great examples of how tsunamis behave in Alaska
Propagation toward the Aleutians was largely impeded by the Alaska Peninsula and near coast features.
Atka
Sand Point
In most places in Alaska the first sign of a tsunami was a rise in water level. This is best seen in Kodiak, Old Harbor and Sitka. While tsunamis do often begin with a drop in water level, it is a myth that they all begin this way.
Sitka
Elfin Cove
Yakutat
Yakutat's proximity to the open ocean allowed relatively large amplitude waves to reach the coast. These waves are well known to resonate in the local bay. Elfin Cove experiences similar resonance.
Because Seldovia is inside Cook Inlet, the tsunami was smaller, and arrived nearly an hour later, than Seward.
Seward
Seldovia
Akhiok
Old Harbor
Kodiak
1/2 meter
The largest waves in Kodiak measured about 45 cm (1.5 feet) peak-to-peak.
Waves arrived in Kodiak and Akhiok nearly 45 minutes later than Old Harbor. The coastline shape and depth of inlets dramatically impact the speed of tsunamis.
Despite being much further away, the tsunami arrived in Sitka at the same time as Seward. Deep ocean and little continental shelf allowed the waves to travel much faster to Sitka.
The M7.9 earthquake occurred at 12:31am AKST. Because the complicated faults did not create substantial uplift in the seafloor, the ensuing tsunami waves were much lower amplitude than might be anticipated for a quake of this size.
Crescent City, CA
Hilo, HI
Appreciable tsunamis recorded in Hawaii and California. Hawaii's location puts it at risk for nearly all tsunamis from Alaska. Crescent City has unusual features that tend to amplify incoming tsunamis.
12am 1am 2am 3am 4am 5am 6am
23 January 2018
time of earthquake
ALASKA EARTHQUAKE CENTER
Tides have been removed by low-pass filtering below periods of 2 hours. Raw tide gauge data obtained from the NOAA/NOS and NOAA/NWS. See tidesandcurrents.noaa.gov/tsunami & www.tsunami.gov/recent_tsunamis

When an earthquake occurs that can generate a tsunami

- The travel time of a tsunami wave from the earthquake source is determined for coastal locations
- The closest sea level station may not be operational because large earthquakes can disrupt communication to local gauging stations
- Observed wave heights are used to scale tsunami forecast models. For the water level data to be utilized in TWS operations there must be minimal data latency and a rapid (15-sec) sample rate
- Several Alaska shore stations and DART stations have a close proximity to tsunami sources associated with the Pacific tectonic plate, and may be within ½ hour of wave detection

When an earthquake occurs that can generate a tsunami

- A sea level station within ½ hour of travel time enables rapid cancellation of a Tsunami Warning that is impacting Warned communities
- For many Alaskan earthquakes, an outage at the nearest sea level station may force a wait for the *potential* tsunami to travel for more than 1 additional hour to the next station
- Informed Operational decisions are enhanced by minimal data latency
- Some tide stations only encounter distorted tsunami waves due to reduced ocean exposure and increased harbor reflections which affect wave arrival times and amplitudes

Before an earthquake occurs the Alaska Tsunami Forecast Model (ATFM) has been prepared

- 7 million cells
- Times 20,000 time steps
- Times ~ 10 floating point operations per cell per time step
- Works out to 1.5×10^{12} flops per model run
- Anticipates fine observations for fine scaling
- Modeling improvements and hardware improvements are ongoing
- New model runs are an ongoing development

National Weather Service Tsunami Gauge stations

- Sources of failures for electronic systems at oceanfront environments are numerous and cause outage gaps
- Many stations monitored by NTWC cost thousands of dollars for transportation which extends outages
- A station intended for tidal measurement are not as durable as a station intended for tsunami measurement
- NWS tsunami forecast locations are not geocoordinated with tide stations
- The water level observations are used to confirm and revise the forecast
- The tide stations are not always located at the open ocean coastline, where the maximum tsunami threat exists, and instead may be in a wave sheltered harbor. Open ocean exposed stations are preferred.

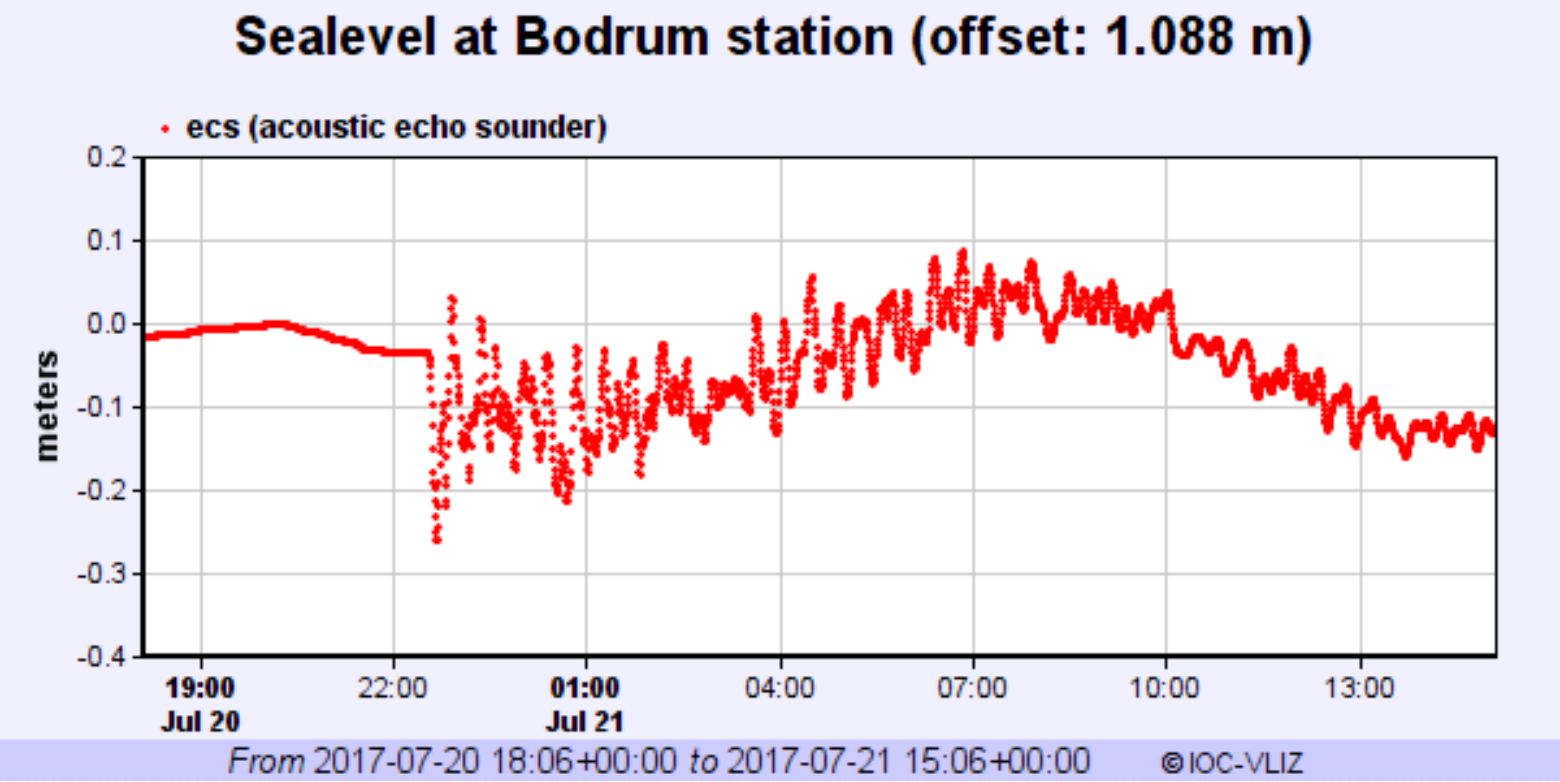
National Weather Service Tsunami Gauge stations

- Alpha Tsunami Gauge stations operate over 11 years between failures, and require a strong infrastructure
- AT Tsunami Gauge stations install in 3 hours on undeveloped shores, and are deployable in a few days, with an operational expectation of 2 years
- No vertical reference for relative measurements , which are unaffected by vertical displacement of a local earthquake
- The objective of an NWS Tsunami Gauge; to measure the peak of a tsunami and transmit the value, is supported by 15 second scan and telemetry rate
- Stations are sited in close proximity to open ocean, and are not behind jetties, breakwaters, or sources of flotsam.

Considerations for sea level data used at NTWC

- Quality of exposure to open ocean wave
- Sample rate
- Transmission interval
- Survivability of station
- Availability of data

Bodrum, Turkey 7/20/17 6.7 earthquake



Datum referenced absolute measurements became non-referenced relative measurements after vertical displacement