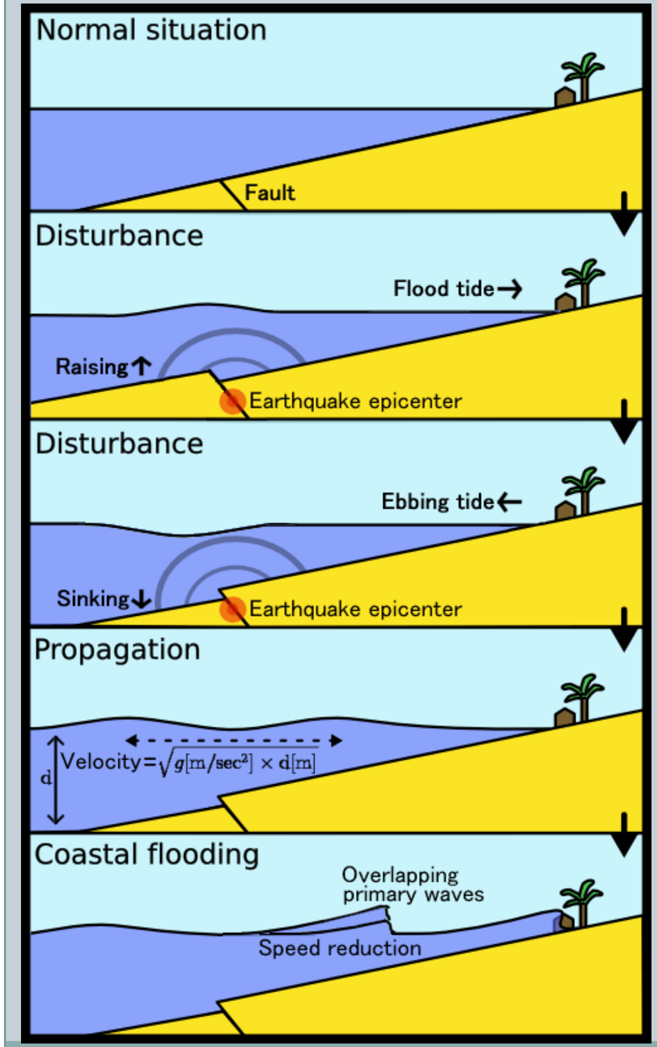
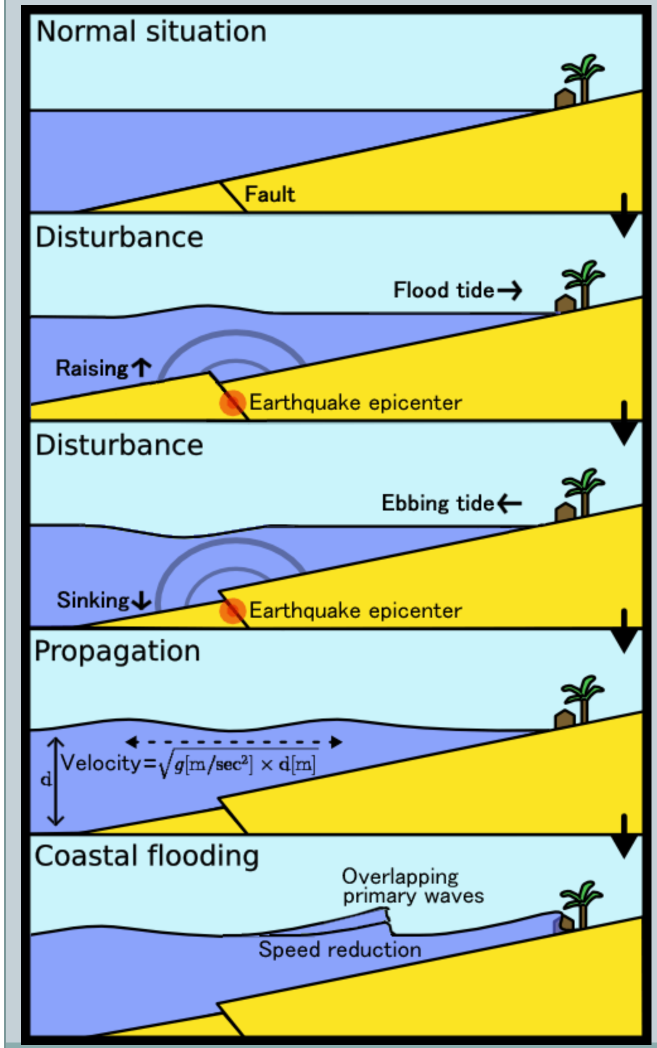
Computers Watching Tsunamis

DEEP-OCEAN ASSESSMENT AND REPORTING (DART II)

Origins of Tsunamis



Origins of Tsunamis



Energy density *I(r)* in terms of energy, *E*, and distance, *r*:

$$I(r) = \frac{E}{r^n}$$

n=2 for body waves
n=1 for surface waves

Origins of Tsunamis

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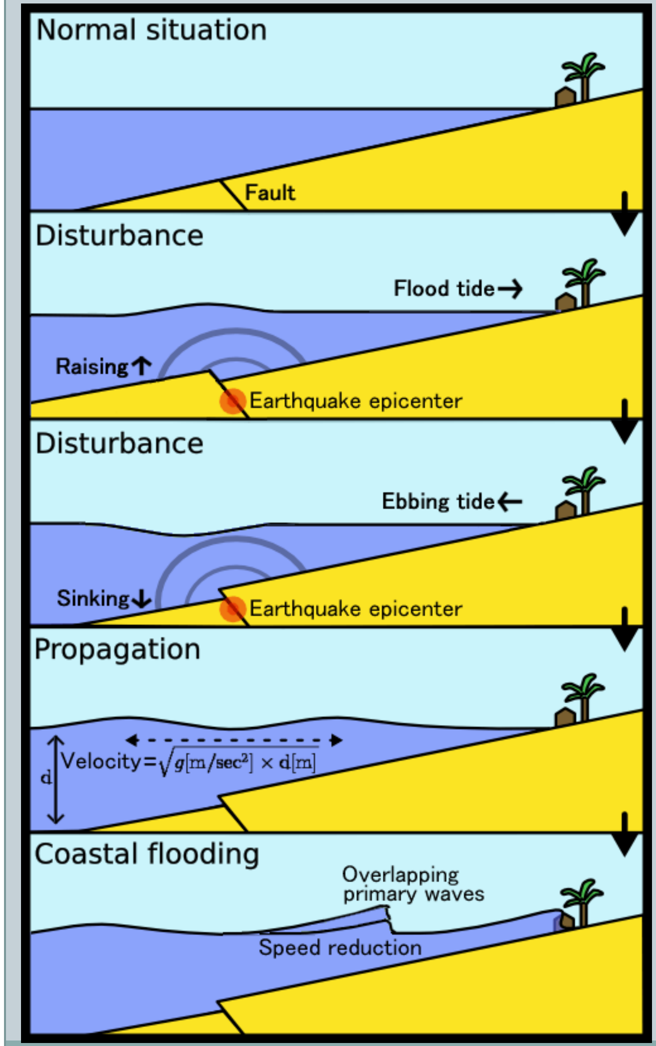

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Tip:

It is better to meet a tsunami diving than snorkeling

Impact of Tsunamis

- Without a timely warning, the life toll can be devastating
- Evacuation may take hours

Impact of Tsunamis

And even with proper warning, there is only so much you can do….

Challenges in Predicting Tsunamis

- Timeliness
- Accuracy
- Physical

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Timeliness

- There is usually less than 24 hours between an earthquake event and a tsunami event in a populated coastal community

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Accuracy

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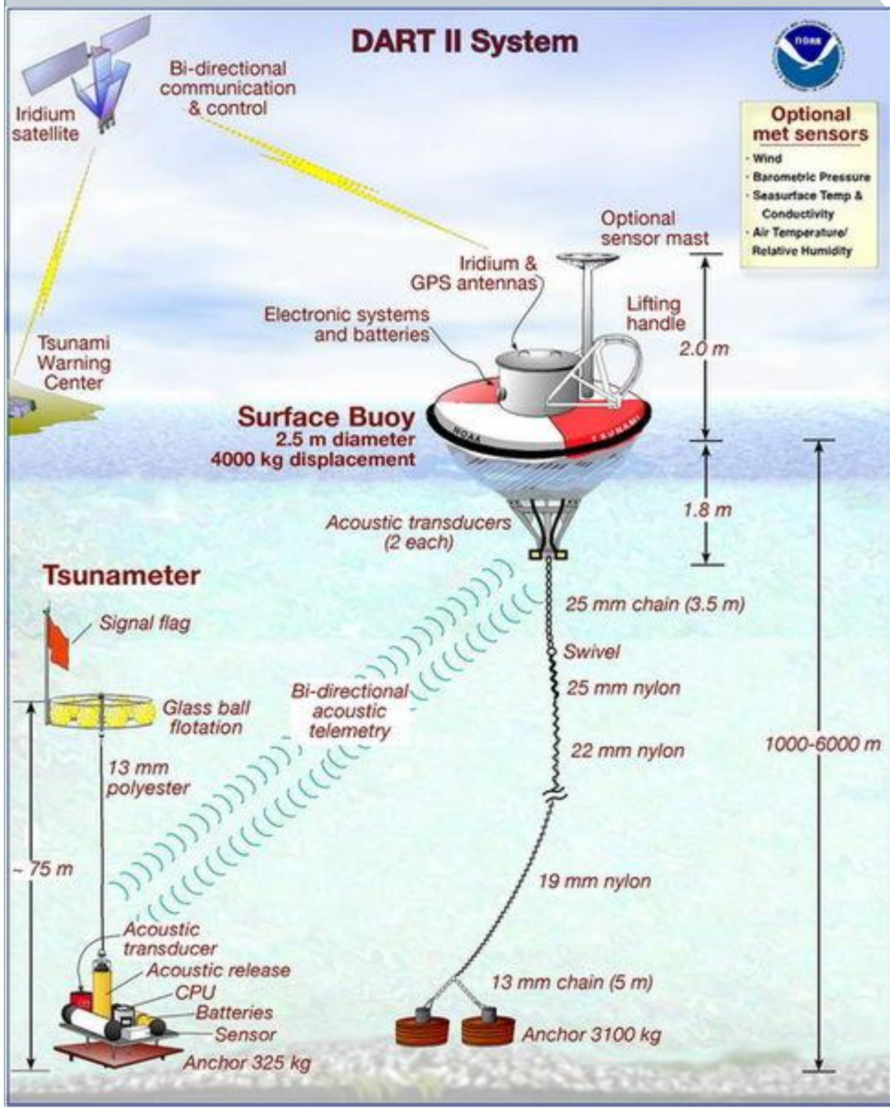
Physical

- Ocean is vast
- Inhospitable and hard to access environment

The DART System



A series of ocean floor sensors and buoys

Data inversion technique

Satellite communication

An automated comprehensive tsunami warning system

Tested well in real-time conditions

Main difference between DART I and DART II is a two way communication capability

Embedded System Design Considerations

- Real-time deadline
- Harsh environment
- Self sufficiency
- Size and Energy

Embedded System Design Considerations

Real-time deadline

- Maximum 10 minute delay from event record to data received at the station

Harsh environment

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Self sufficiency

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Size and Energy

- Must survive on battery power for a long time

Functional Protocol

MOST (Method of Splitting Tsunamis)

Measurements are pressure and temperature

Data from DART II may be requested by the user

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Use a pre-computed database of deep ocean model simulations

Real-time data from the tsunami-meter is inverted based on the model

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The underwater tsunameter calculates water column heights and transmits to the buoy

The buoy sends data to a satellite network

Data is received in an on-shore facility and a forecast is made

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- DART II is in power-saving Listen mode
- Can receive an initiation signal from a station 7/15 min

Operational Requirements

Measurement
- amplitudes

Accuracy
- < 0.5 cm
  - *water column height from P, T measurement*

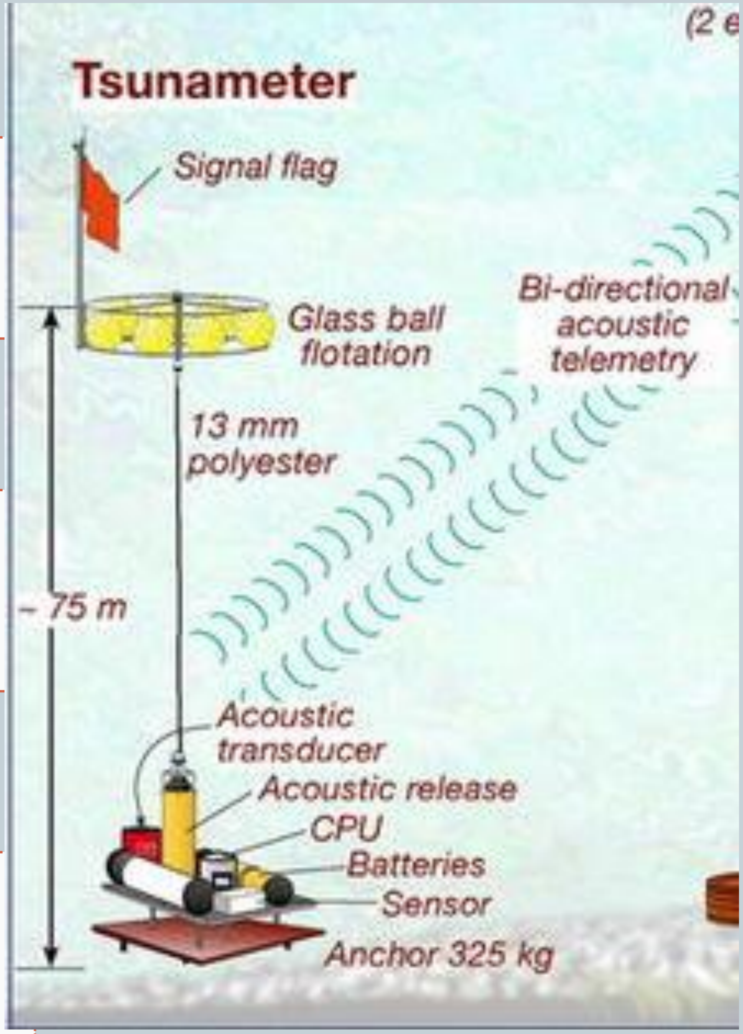
Sampling
- < 1 min

Processing
- < 2 min

Delivery
- < 5 min

Sensor Assembly

- Sensors
- Reciprocal counter
- Computer



Sensor Assembly

Sensors

- Measures pressure, temperature, and tilt

Reciprocal counter

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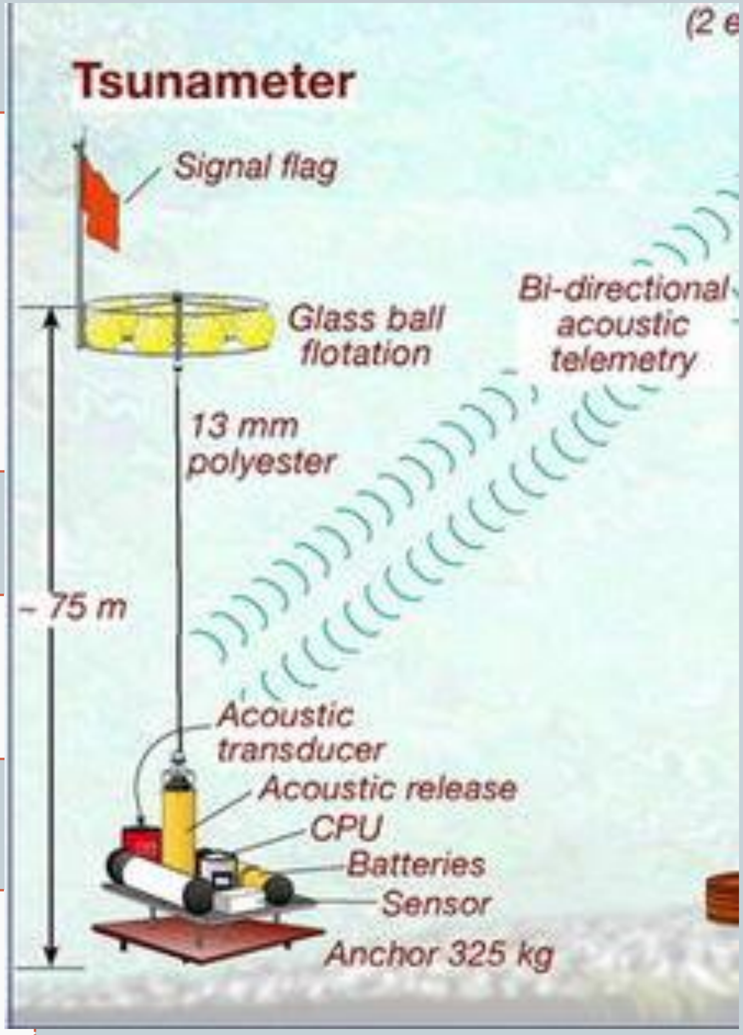

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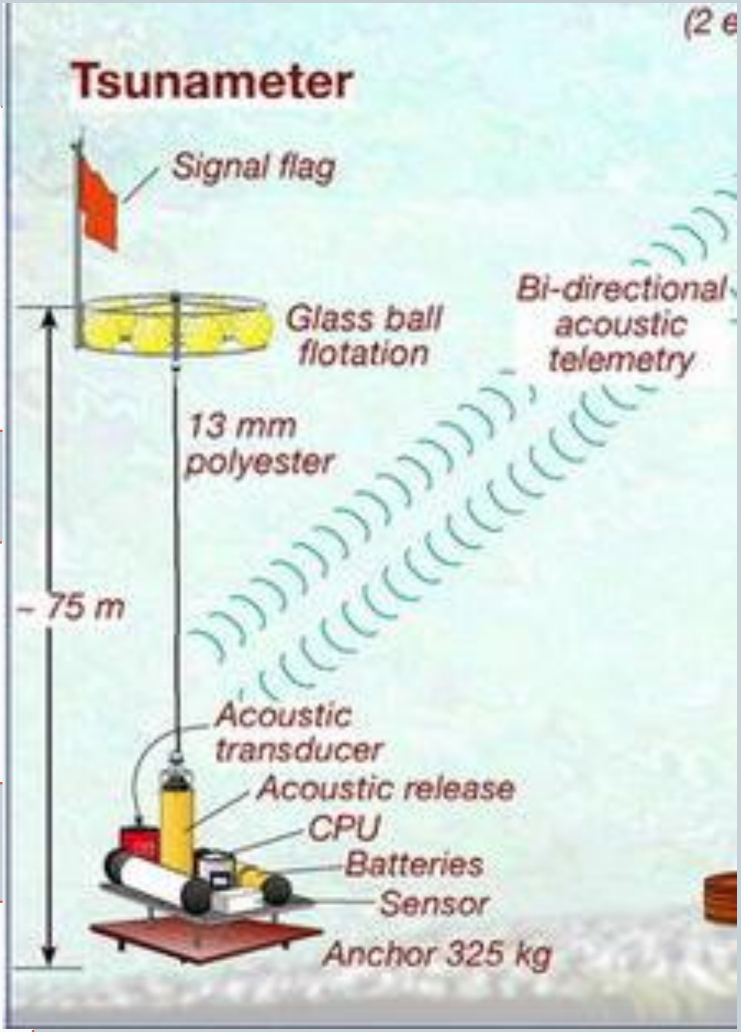

Sensor Assembly

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Reciprocal counter

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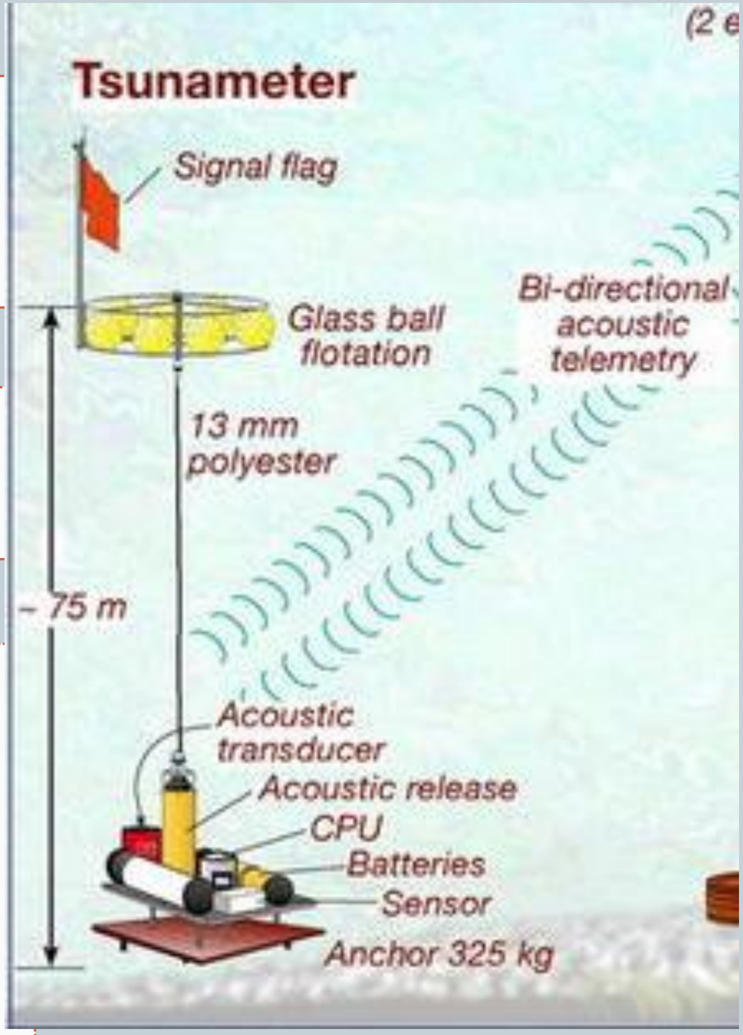
Computer

- Motorola 68332
- 512B RAM
- Communications, detection algorithm, store and retrieve, mode-switching



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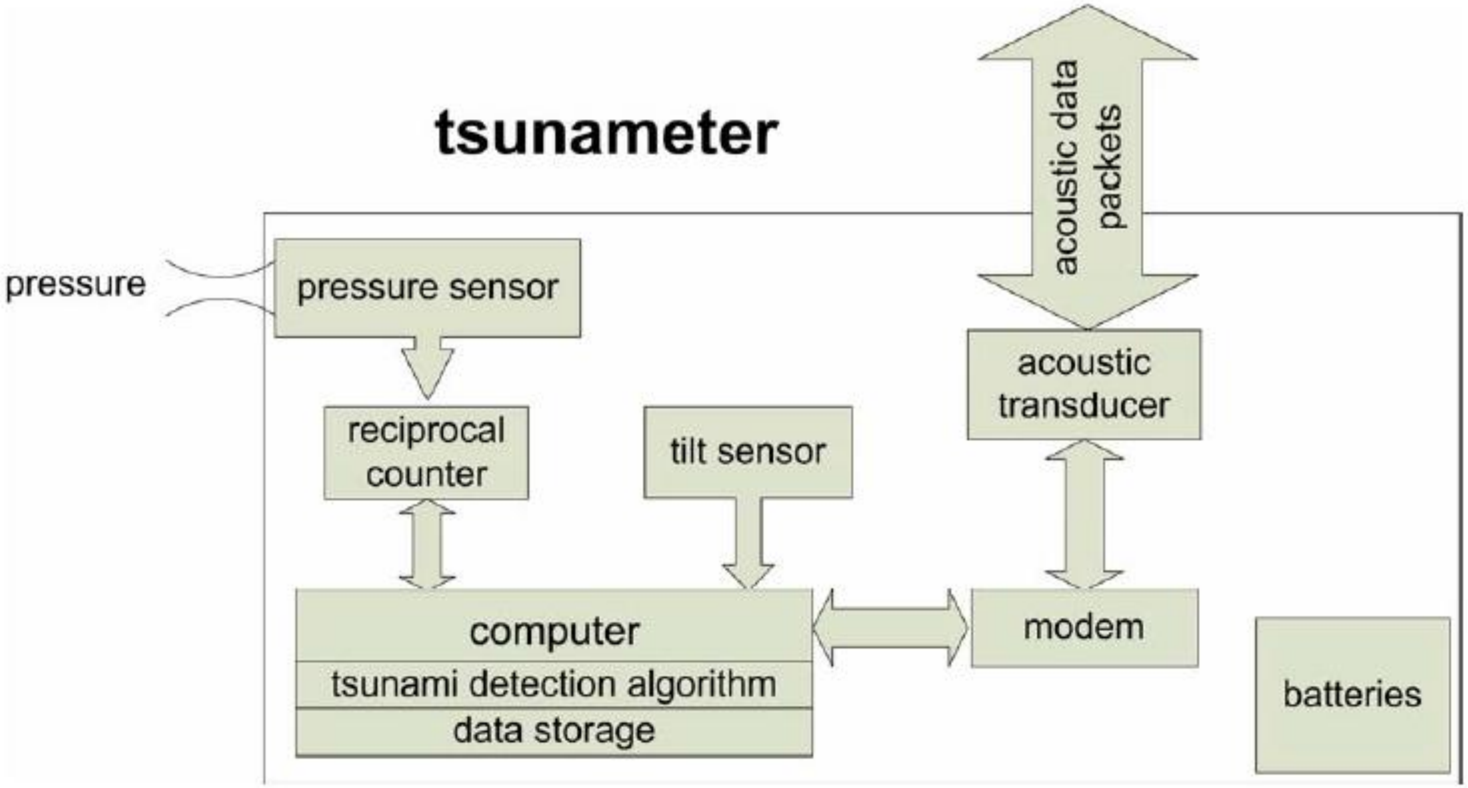
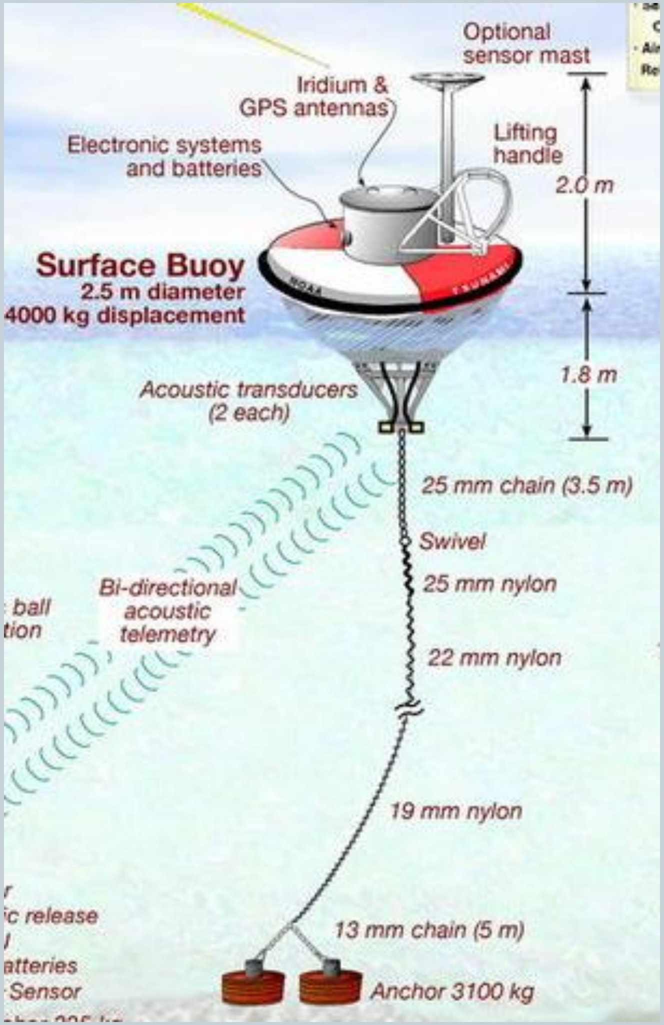


Fig. 6: Block diagram of DART II Tsunameter.

Buoy Assembly

- Downward and upward transducers
- Mooring
- Iridium Satellite Network
- GPS



Buoy Assembly

Downward and upward transducers

- Receive data from tsunameter
- Send & receive data from satellite

Mooring

Iridium Satellite Network

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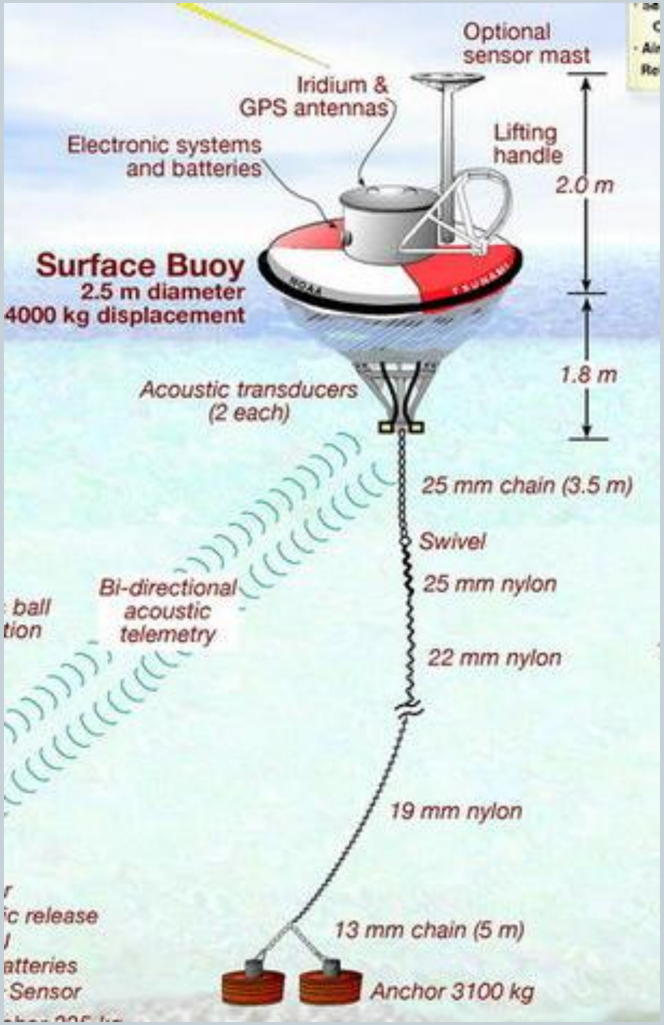

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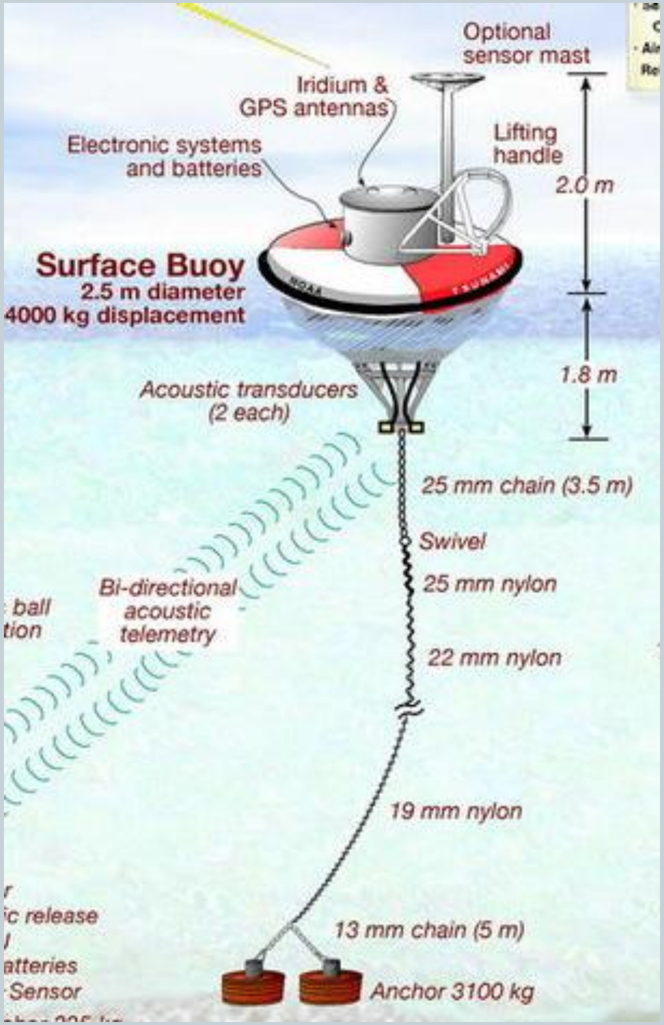

Buoy Assembly

Downward and upward transducers

- Receive data from tsunameter
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Mooring

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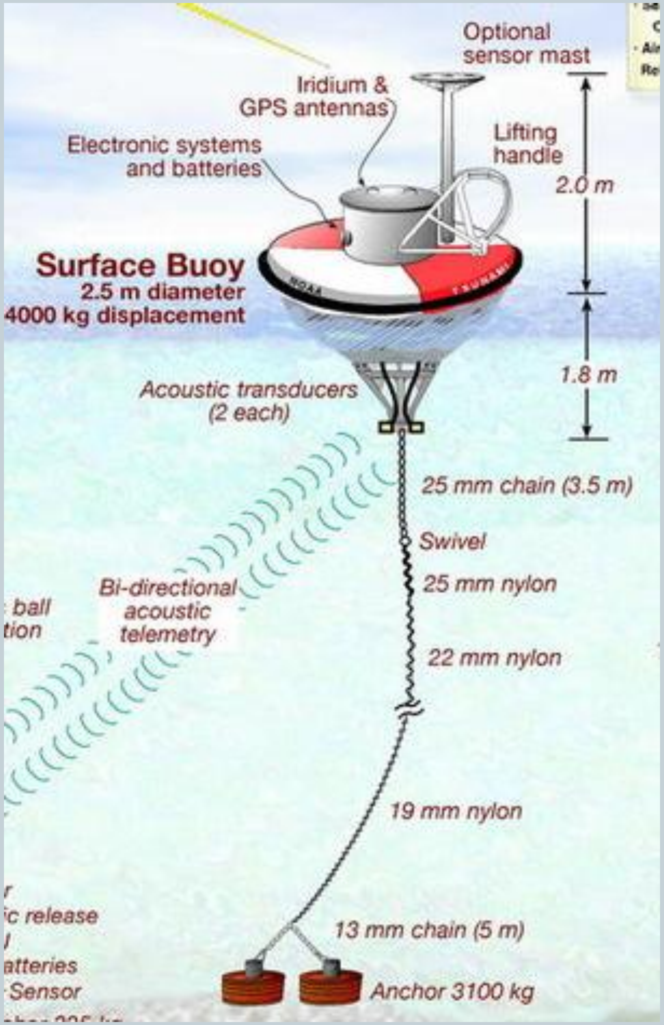
Iridium Satellite Network

- 2400 baud
- 30 sec transmission time

GPS



Energy Considerations

Two Modes of Operation:

- Standard Mode (idle)
- Event Mode

Batteries

Energy Considerations

Two Modes of Operation:

- Standard Mode (idle)
  - Water temperature & pressure measured every 15 min
  - Reports every 6 hours
  - Iridium transceivers off when not in use
  - Listen mode is 20% duty cycle
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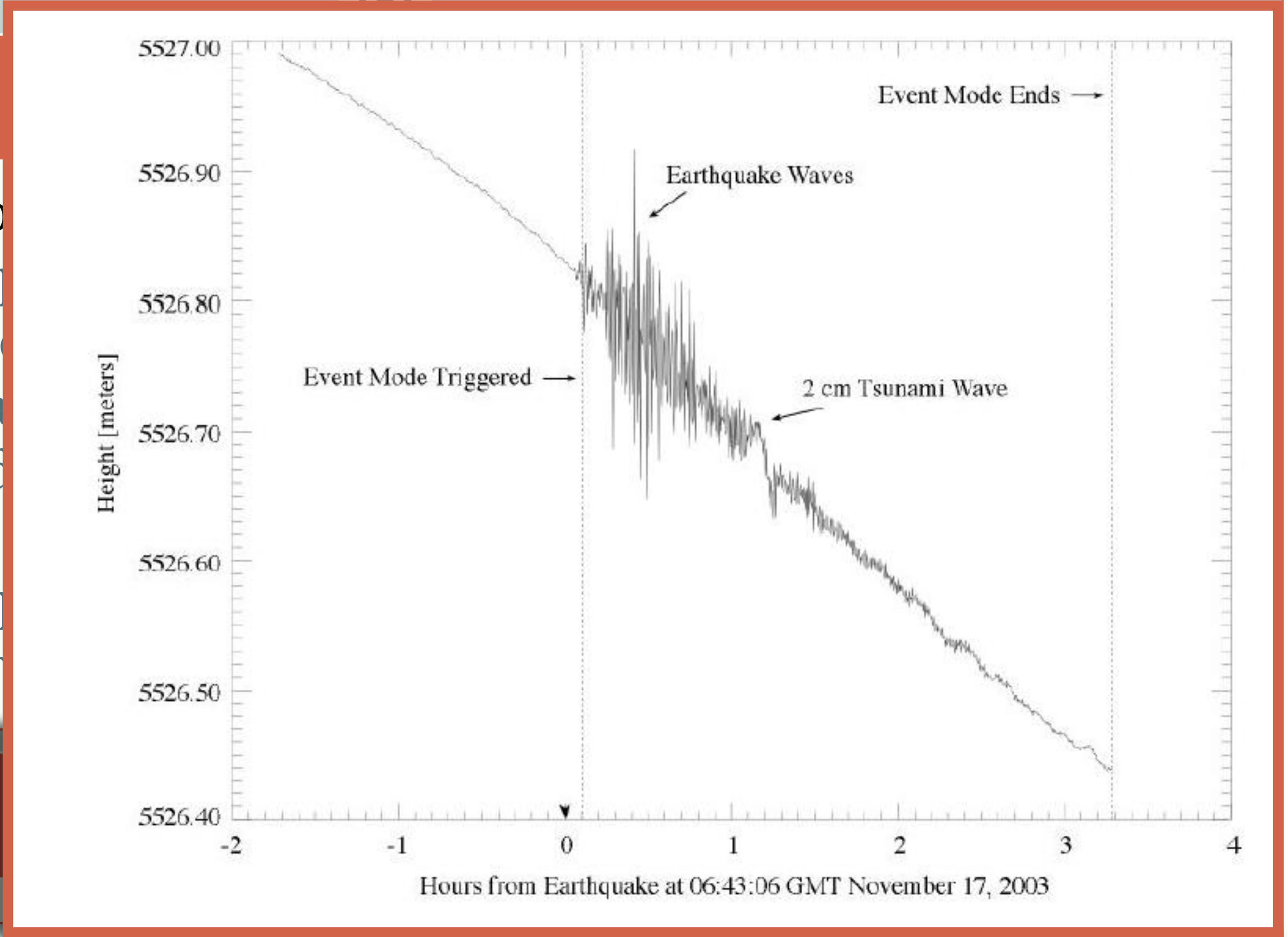

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Batteries

- Sensor – 4 years lifetime
- Buoy – 2 years lifetime

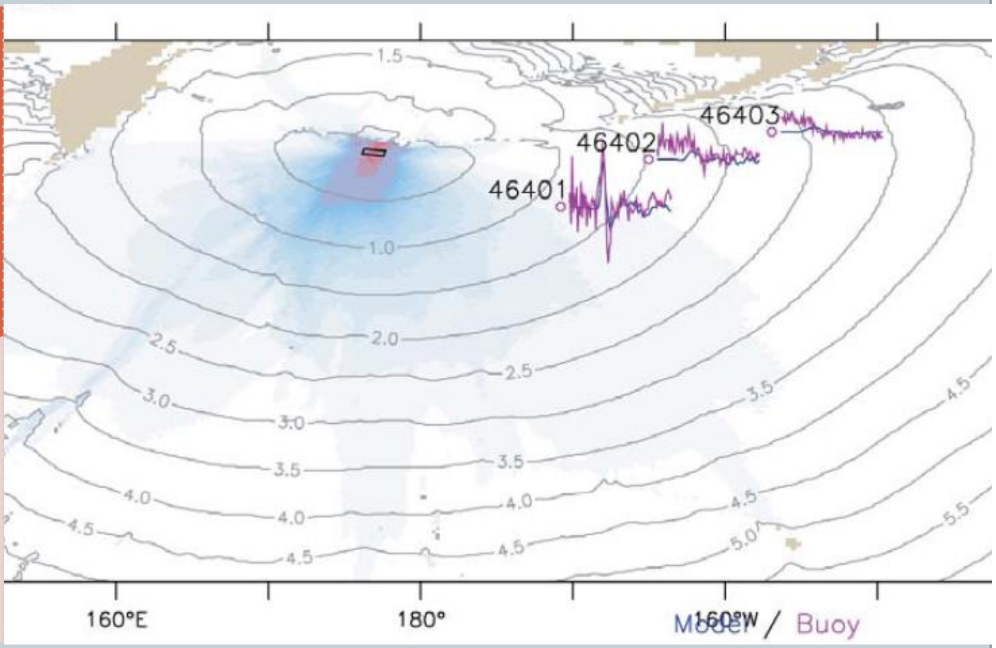
Environmental Factors

- Defense against fish eating the mooring line
  - Use wires at the depths where fish are encountered
- Long battery life
  - Aggressive power-saving modes
  - Minimizes the need for human intervention
- Protection around the pressure sensor
- Computer redundancy in the buoy

2003 Test Case

Large earthquake generates a tsunami

- Detected by 3 tsunameters



2003 Test Case

Large earthquake generates a tsunami

- Detected by 3 tsunameters

MOST model estimated 7.8 magnitude of earthquake

- Corroborated later by USGS

2003 Test Case

Off-shore wave heights predicted for Hilo, HI

- It is determined that a tsunami will not occur
- Hilo tide gage measurements in perfect agreement with forecast

First "blind" study

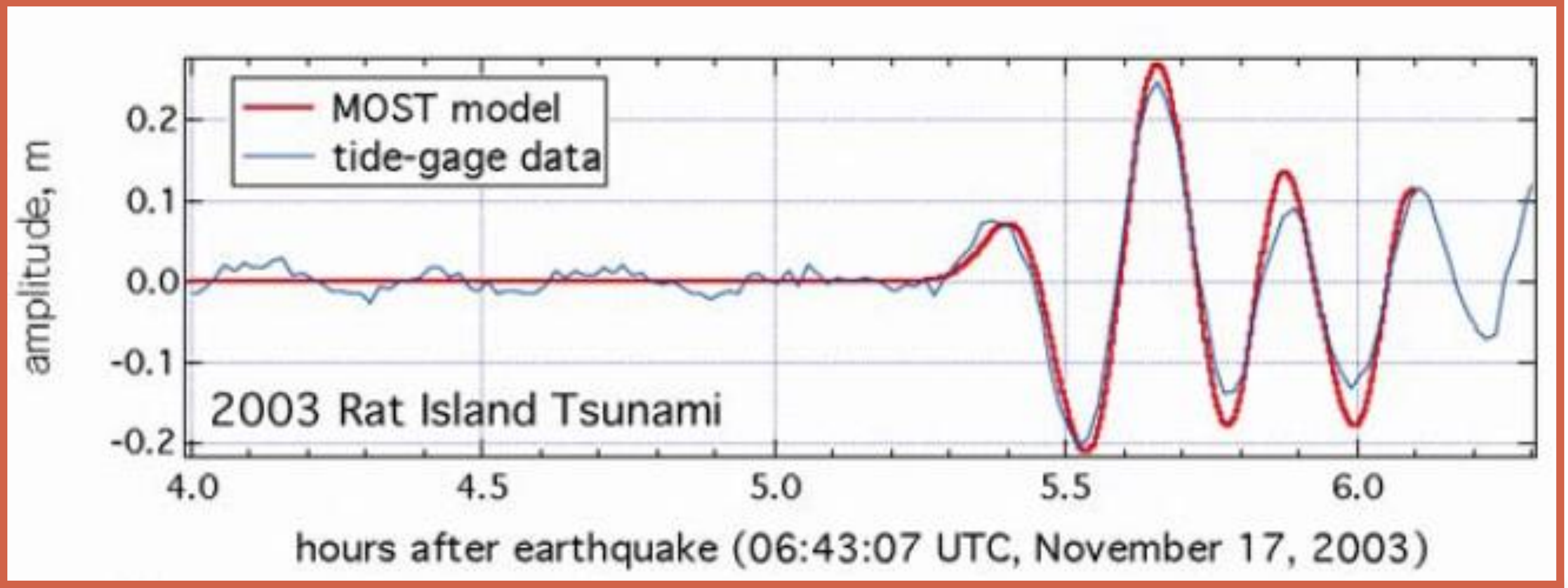
- Real-time forecast
- Proof of concept

2003 Test Case

Off-shore wave heights predicted for Hilo, HI

- It th n
- H m p w

First "blind" study

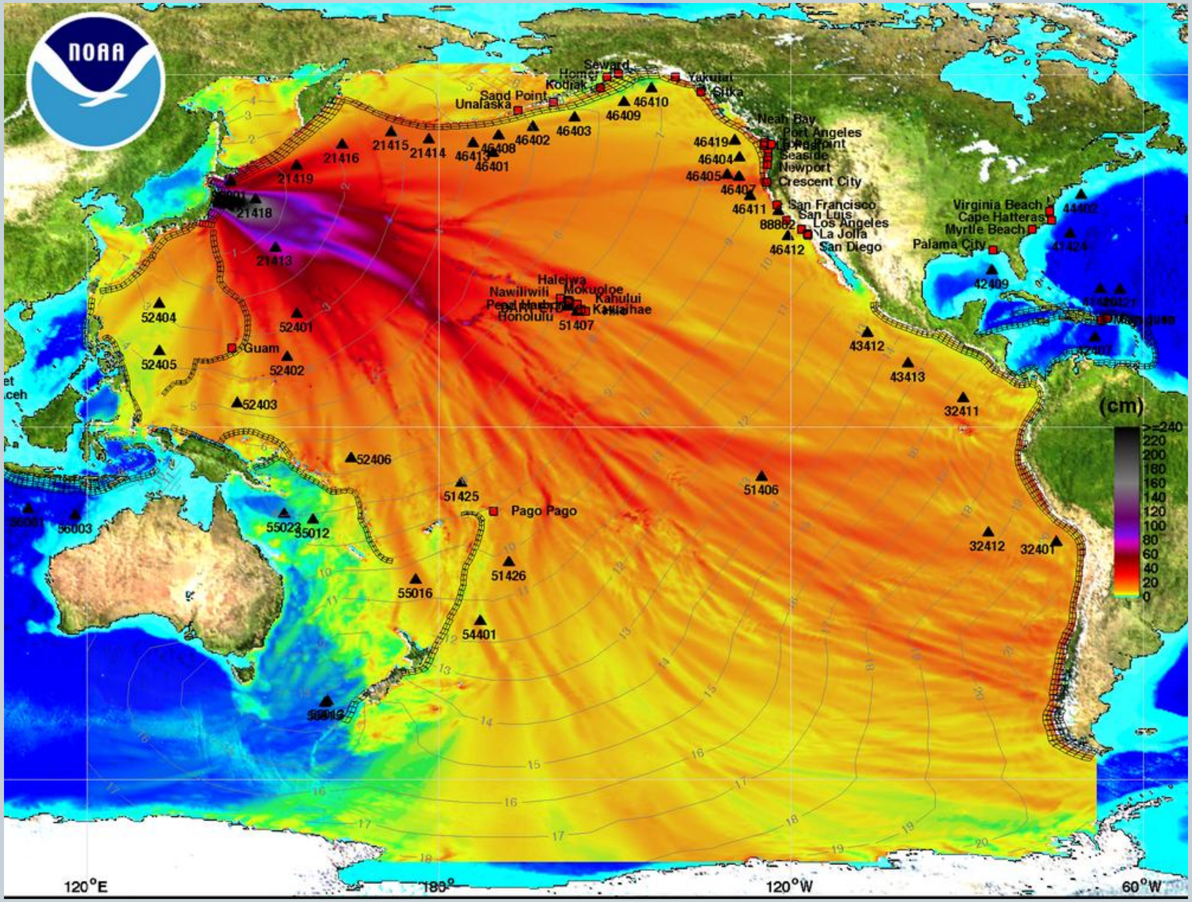


DART Extension

- Funded since 1996
- After the Indian Ocean Tsunami in 2006, 39 units were added
- More units are added on regular basis
- NOAA/PMEL continues to refine detection algorithms, MOST model, communications control

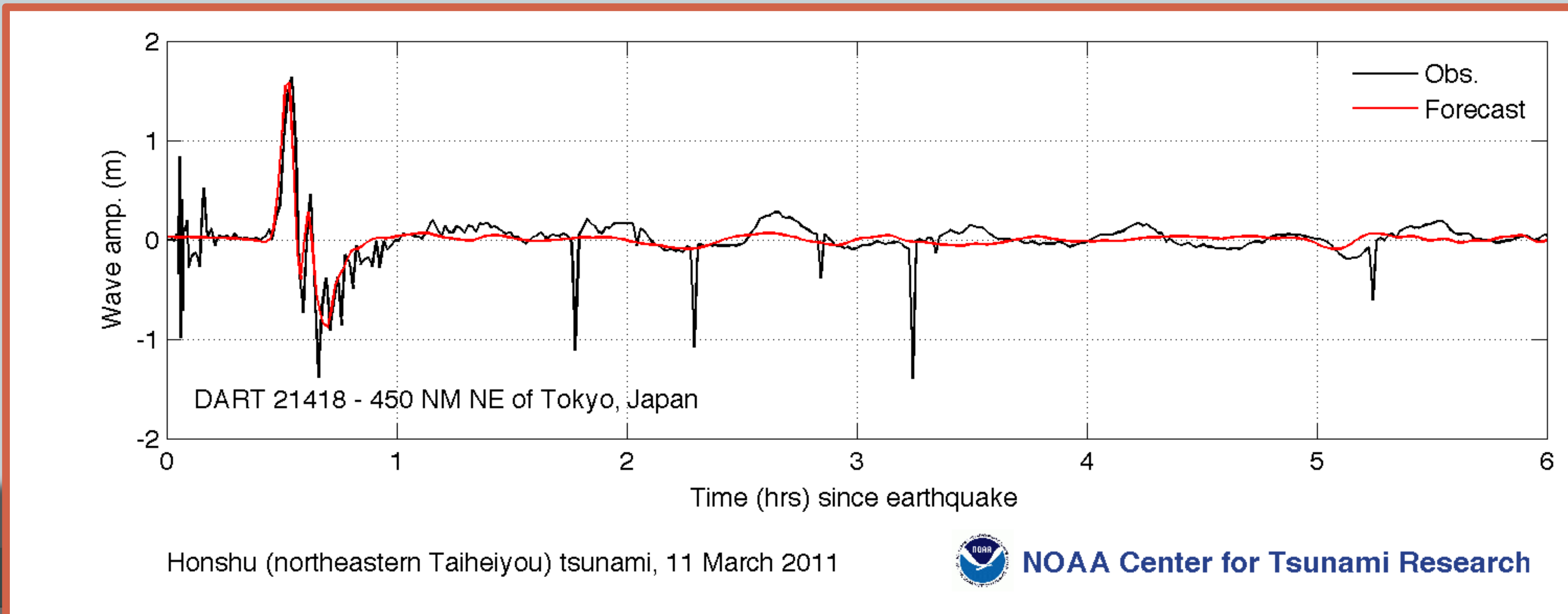
Recent News: 2011 Japan

MOST model of wave heights of the 2011 tsunami in Japan



Recent News: 2011 Japan

- DART II water column height for Tokyo
- Tsunami hit ~30 min after the quake
  - No hope for evacuation
- Forecast was spot on

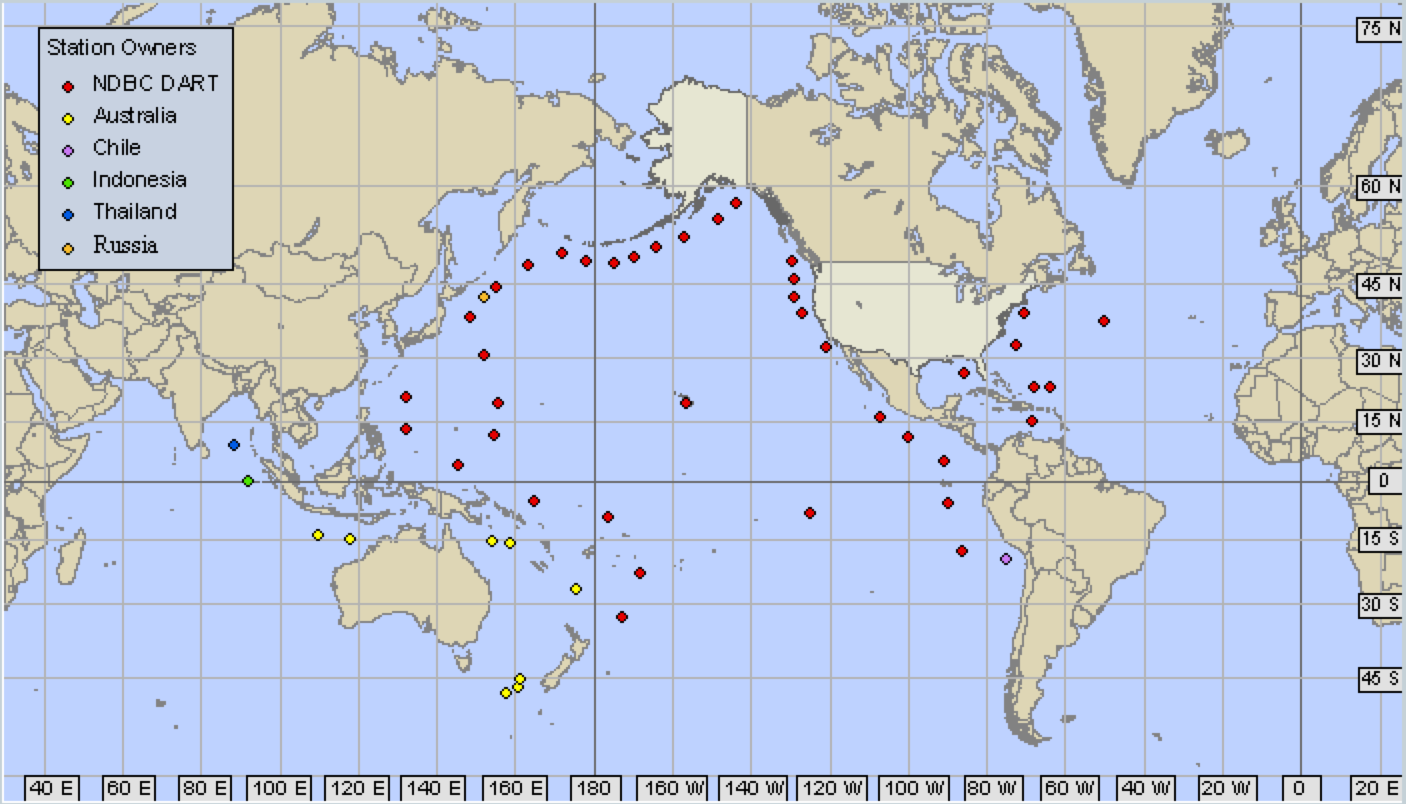


References

C. Meinig, S. E. Stalin, A. I. Nakamura, F. Gonzalez, and H. B. Milburn; “Technology Developments in Real-Time Tsunami Measuring, Monitoring and Forecasting”, In Oceans 2005 MTS/IEEE, 19–23 September 2005, Washington, D.C.

www.pmel.noaa.gov

Where are they now?



http://www.ndbc.noaa.gov/dart.shtml