UNESCO/IOC – NOAA ITIC Training Program - International (ITP-Intl)
TSUNAMI WARNING AND EMERGENCY RESPONSE
9-12 January 2023, Rarotonga, Cook Islands

Sea Level Monitoring
Instruments, Limitations, and Challenges

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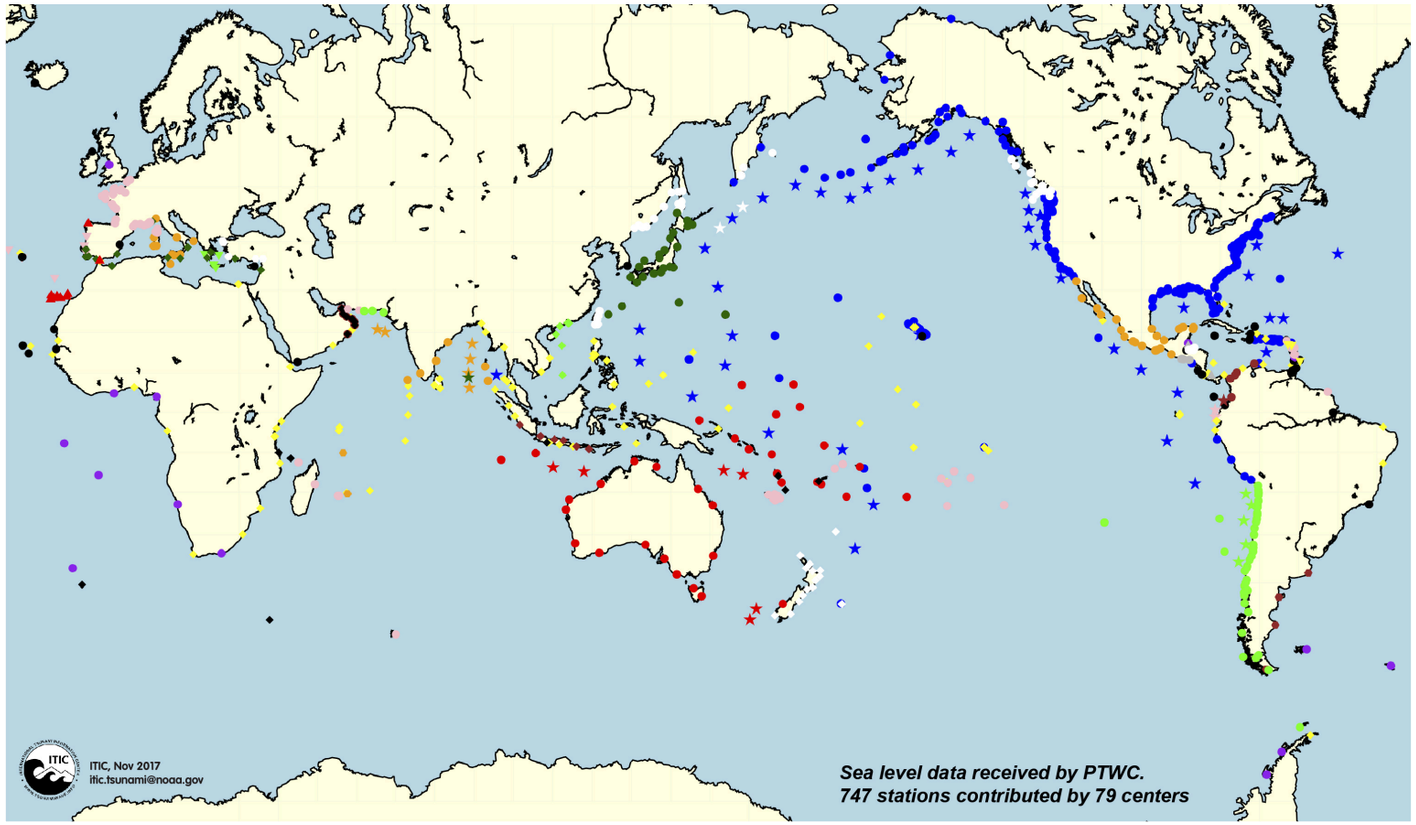
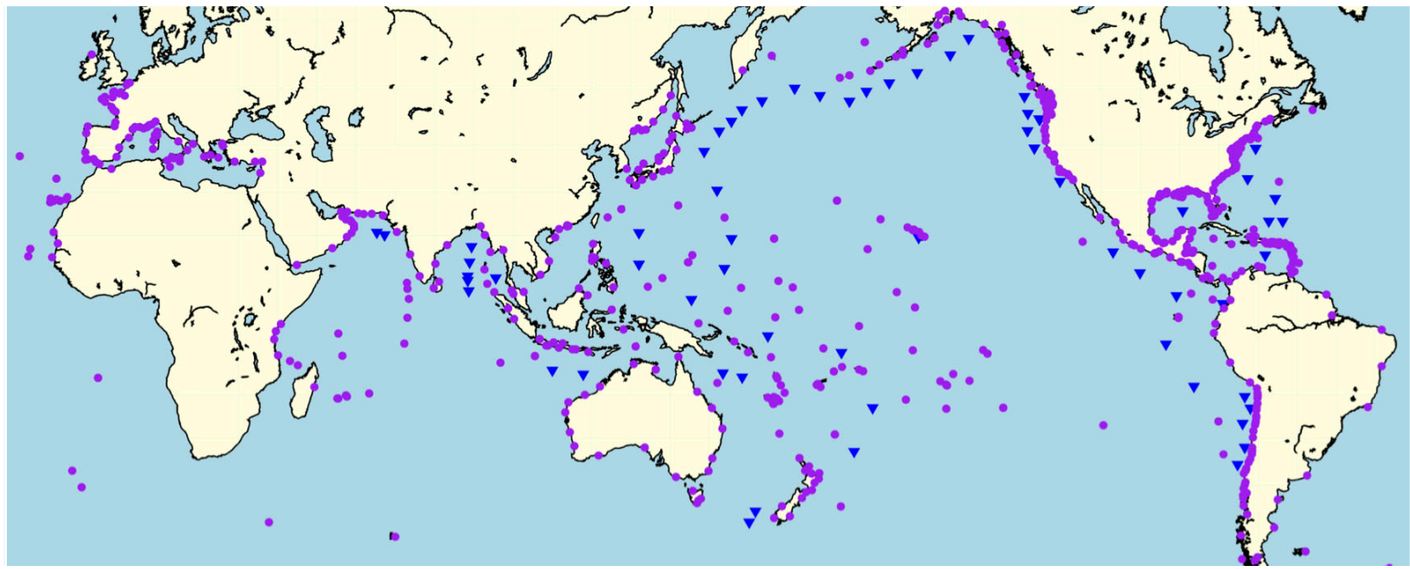
PTWC Global Sea Level Network

All Stations by Owner



All Stations



Why Sea Level Gauges are Needed

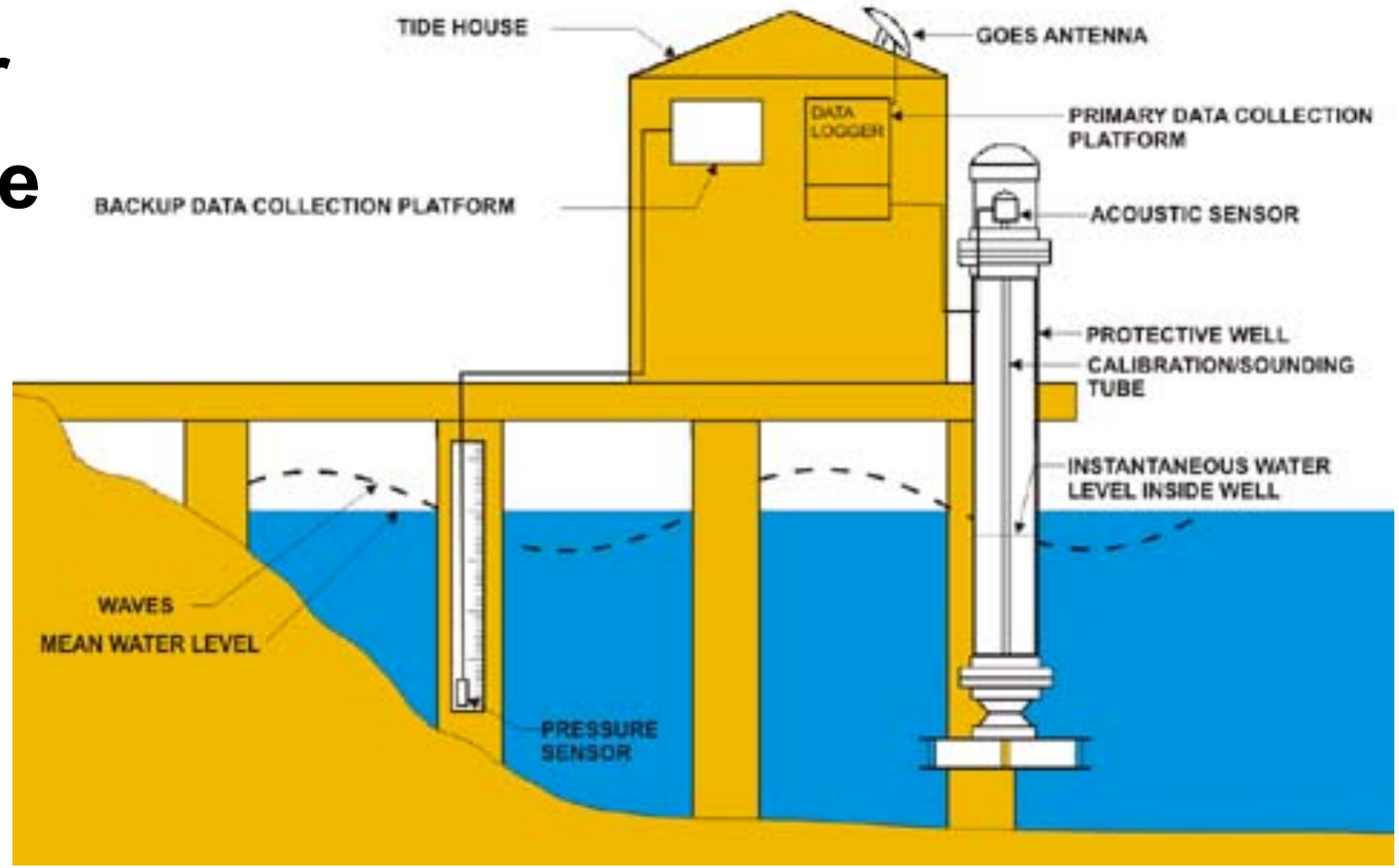
- **To verify if a tsunami exists or not**
- **To measure tsunami size for decision-making**
  - Compare with historical data
  - Constrain forecast model
- **To aid in response**
  - How bad was it?
  - Is it safe to go in/return?

Two Basic Types of Sea Level Gauges

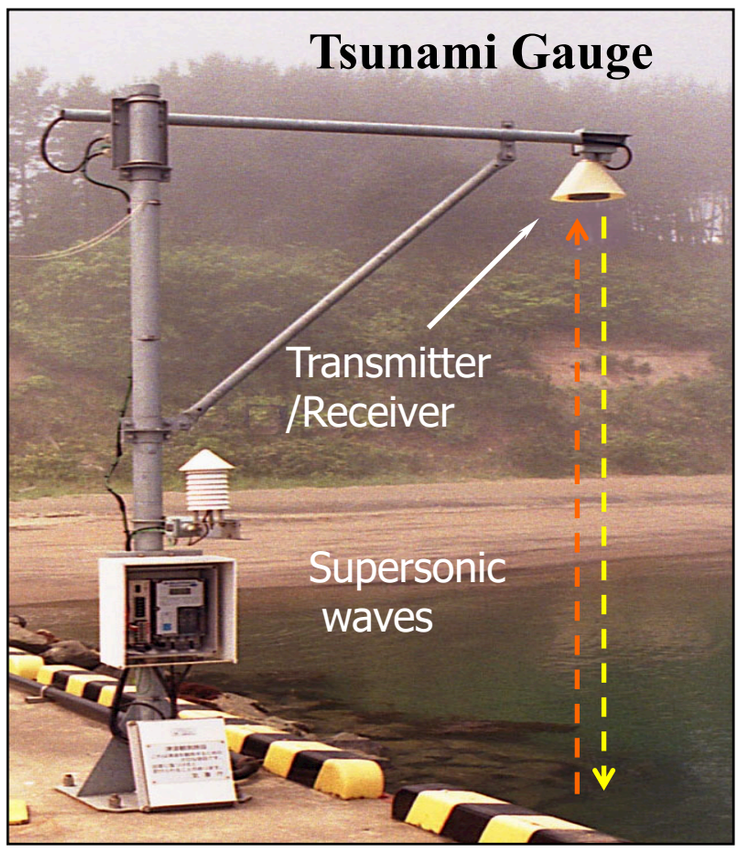
- **Coastal**
  - Good for comparison with historic events
  - Observation at coast used to authoritatively cancel warning
  - Heights sensitive to local effects (coastal shape, bathymetry, etc)
- **Deep Ocean**
  - Best for constraining forecast models. Heights not affected by local effects –'pure' tsunami signal
  - Observations in deep water. Not likely to be destroyed by wave
  - Forecast models are required to interpret deep-ocean observations

Typical Coastal Gauge

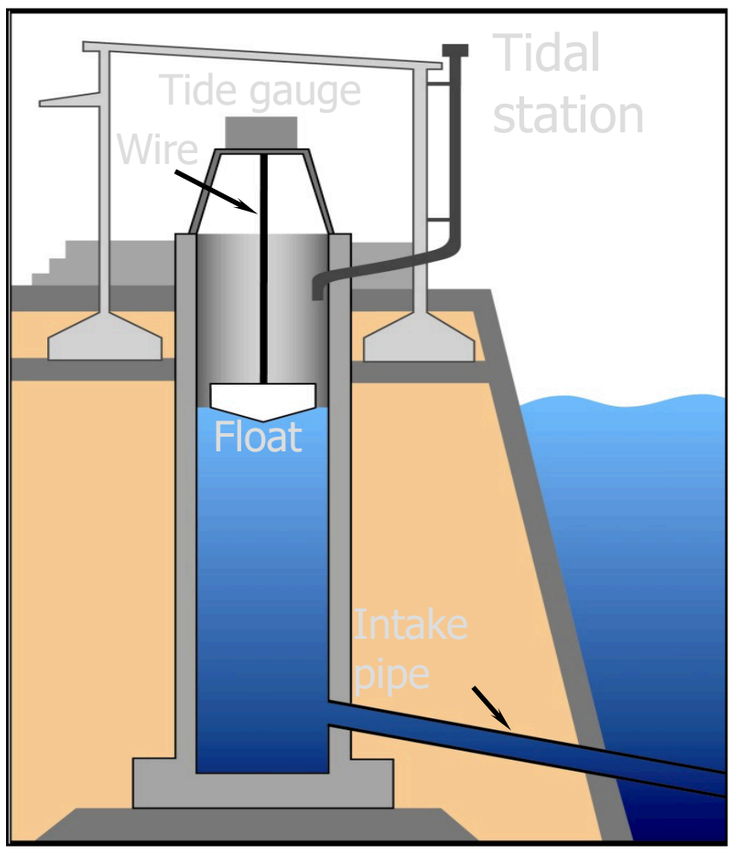
- Mechanical level
- Acoustic sensor
- Pressure sensor
- Radar/Microwave



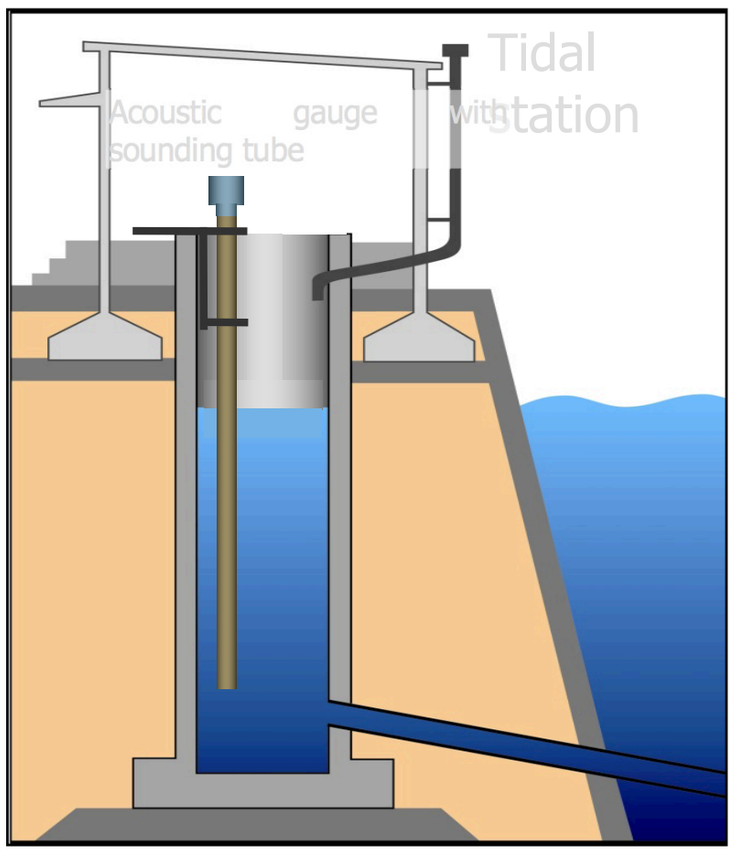
Sea Level Observation equipment – Japan - JMA



Microwave/Radar in the Open Air



Float gauge in the Stilling Well



Acoustic gauge with Sounding Tube

Instruments

Fuess type gauge

Microwave/
Radar
gauge

Pressure sensor

Examples of Caribbean Stations

Wet sensor (run-up detector)

It does not measure sea level, only detects if it submerged in water.
When it does, a flooding signal is transmitted to PTWC via cell modem.

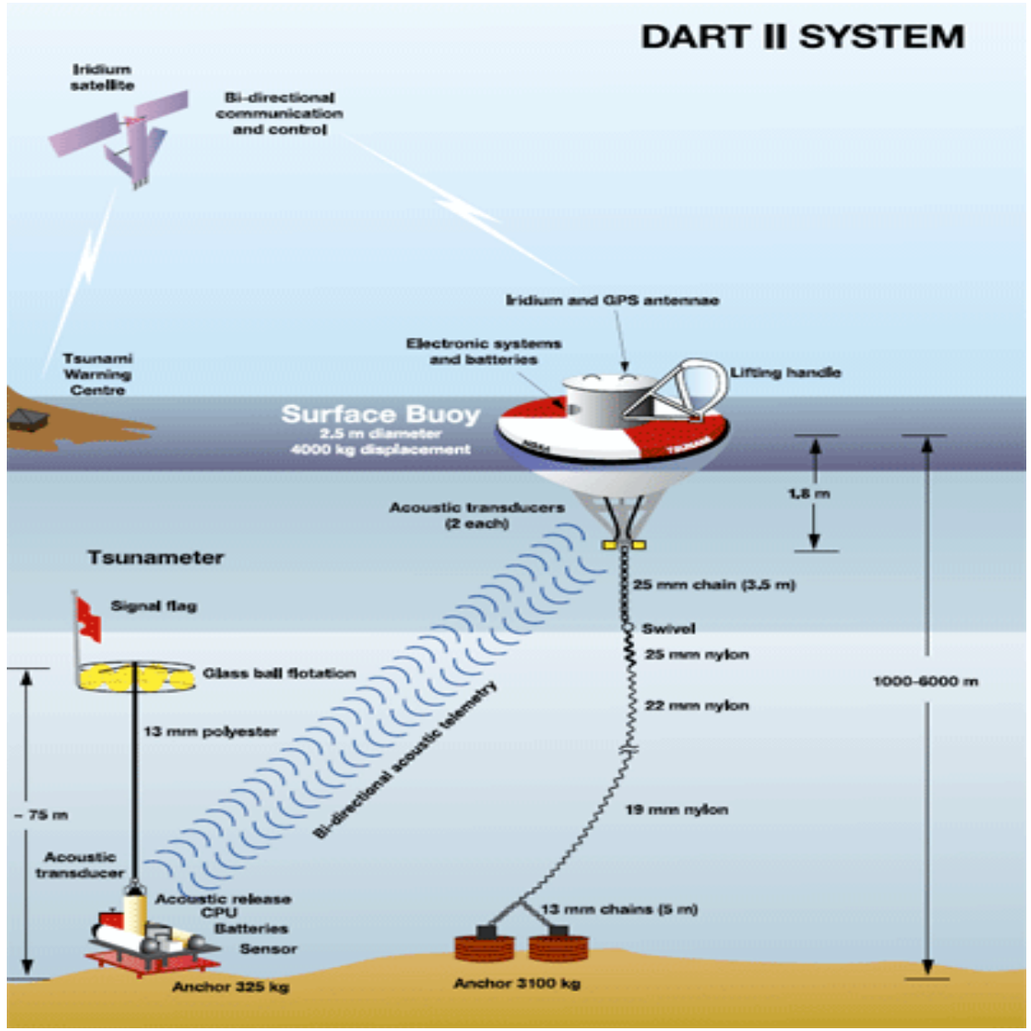
Run-up detector in Milolii, Hawaii Island

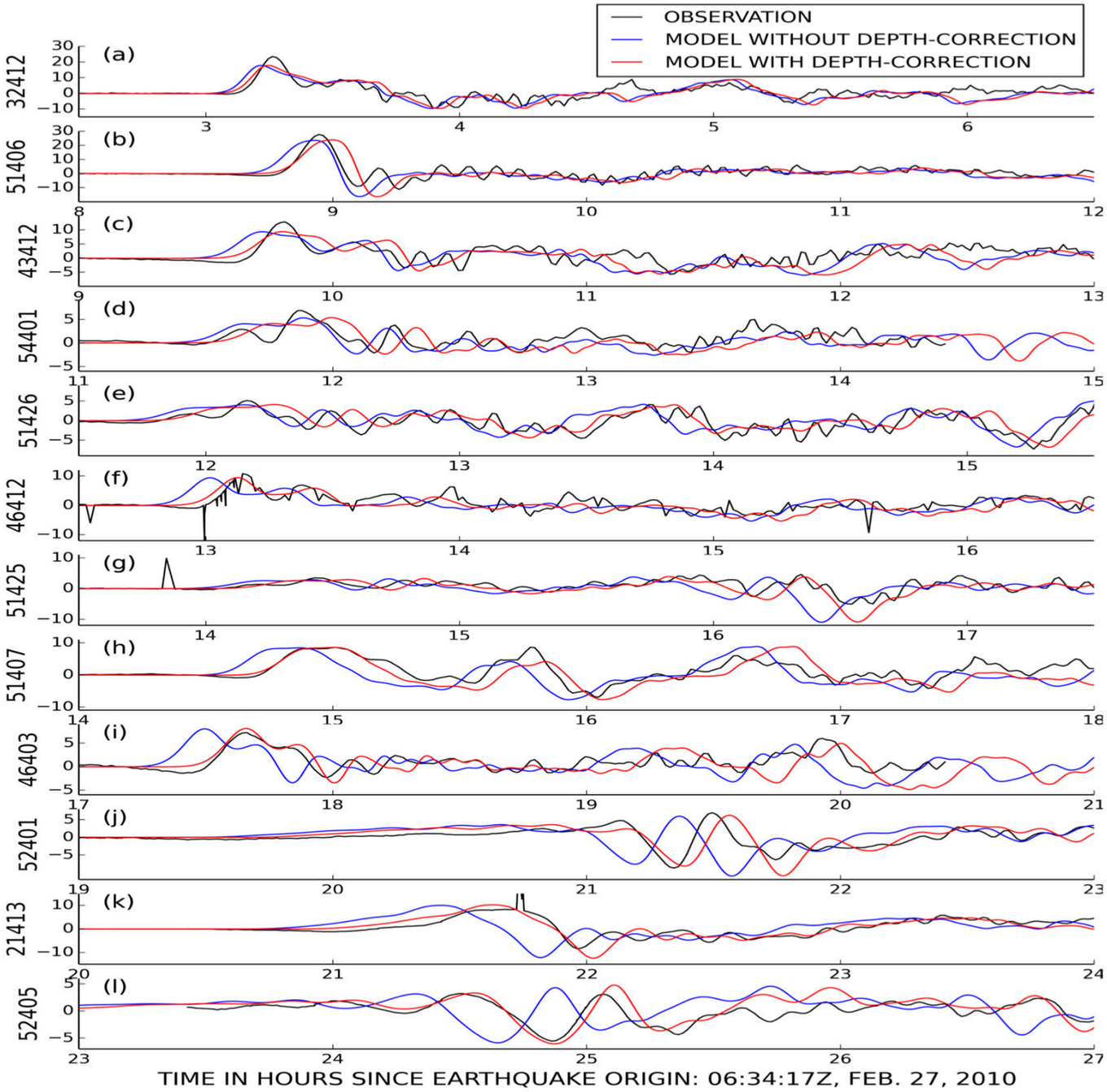
Wet sensors on Hawaii Island

Communications tests are done about once day.

Deep-Ocean Gauge

The tsunami signal is detected by a pressure sensor on the ocean floor. That signal is relayed by acoustic telemetry to the buoy. The buoy in turn transmits the signal via satellite back to the warning centers.





Chile tsunami
February 27, 2010
DARTs records

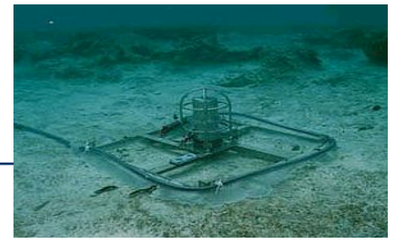
In case of big Tsunami, instrument stops working

Sea Level Gauge Data Streams

- **Sampling intervals**
  - 15s — Optimal For TWS
  - **1 minute** — Good For TWS
  - 2 minute — OK For TWS
  - 6 minute — Can be Used
  - 15 minute — Not useful for TWS
- **Transmission intervals**
  - Real-time — Optimal
  - 3-6 minute — Very Good
  - 15 minute — Good
  - 1 hour — Poor
  - 3 hours — Not useful

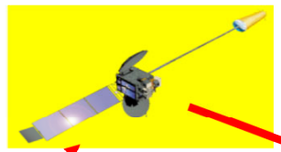
Concept of the Tidal Data Collection System using the Geostationary Satellite of USA

Acoustic gauge



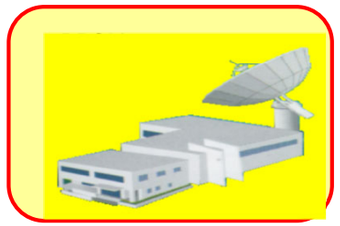
Pressure sensor

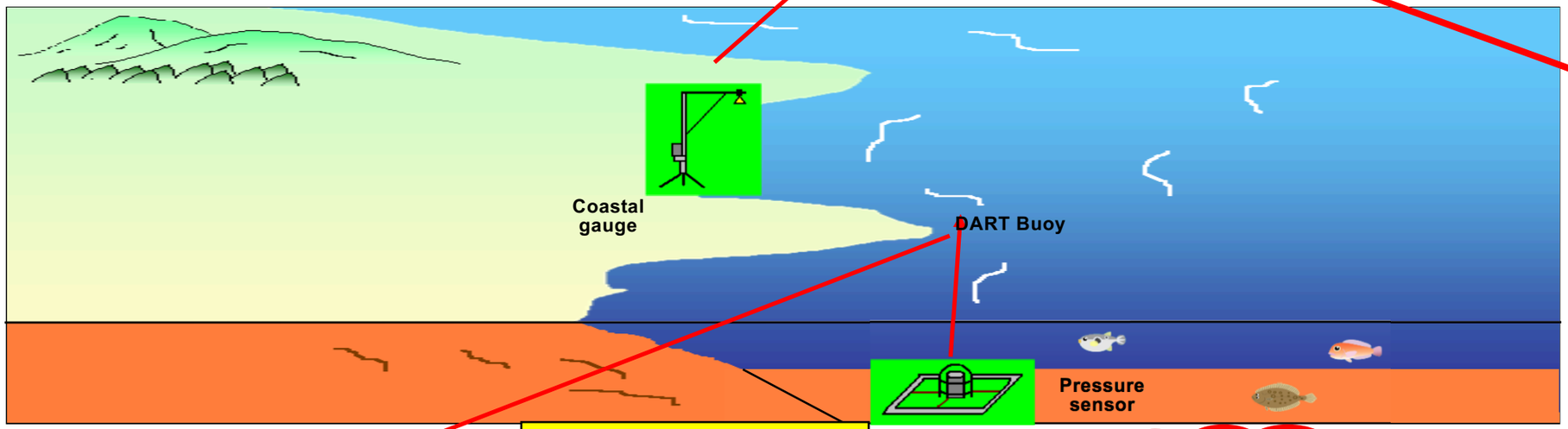
Transmission of Data
- Transmission Interval:
  5 min., 6 min, 15 min or 1 hour.
- Transmission Period:
  Within 1 min



GOES

Acquisition of Tidal Data
1.6 GHz band





NOAA NESDIS – Wallops Island

IRIDIUM

NOAA Data Buoy Center

IOC Sea Level Monitoring Facility

Met Services

GTS)

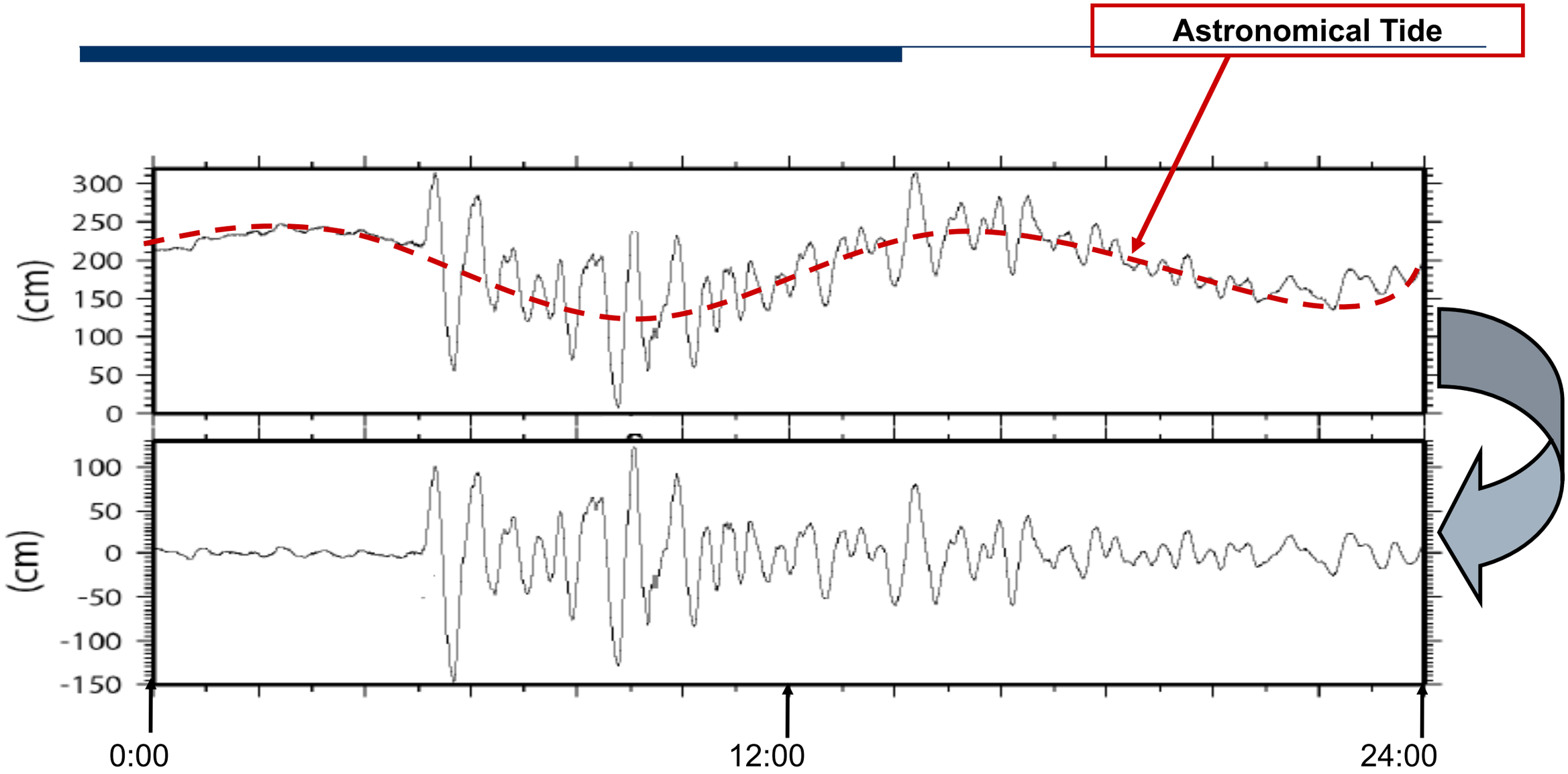
US NTWC

PTWC

TCP/IP

NOAA PORT

Removal of Astronomical Tide Signal



PTWC does tide prediction using harmonic analysis of 1-2 years of data

Harmonic analysis:

Representation of tidal signals as a superposition of sine and cosine functions:

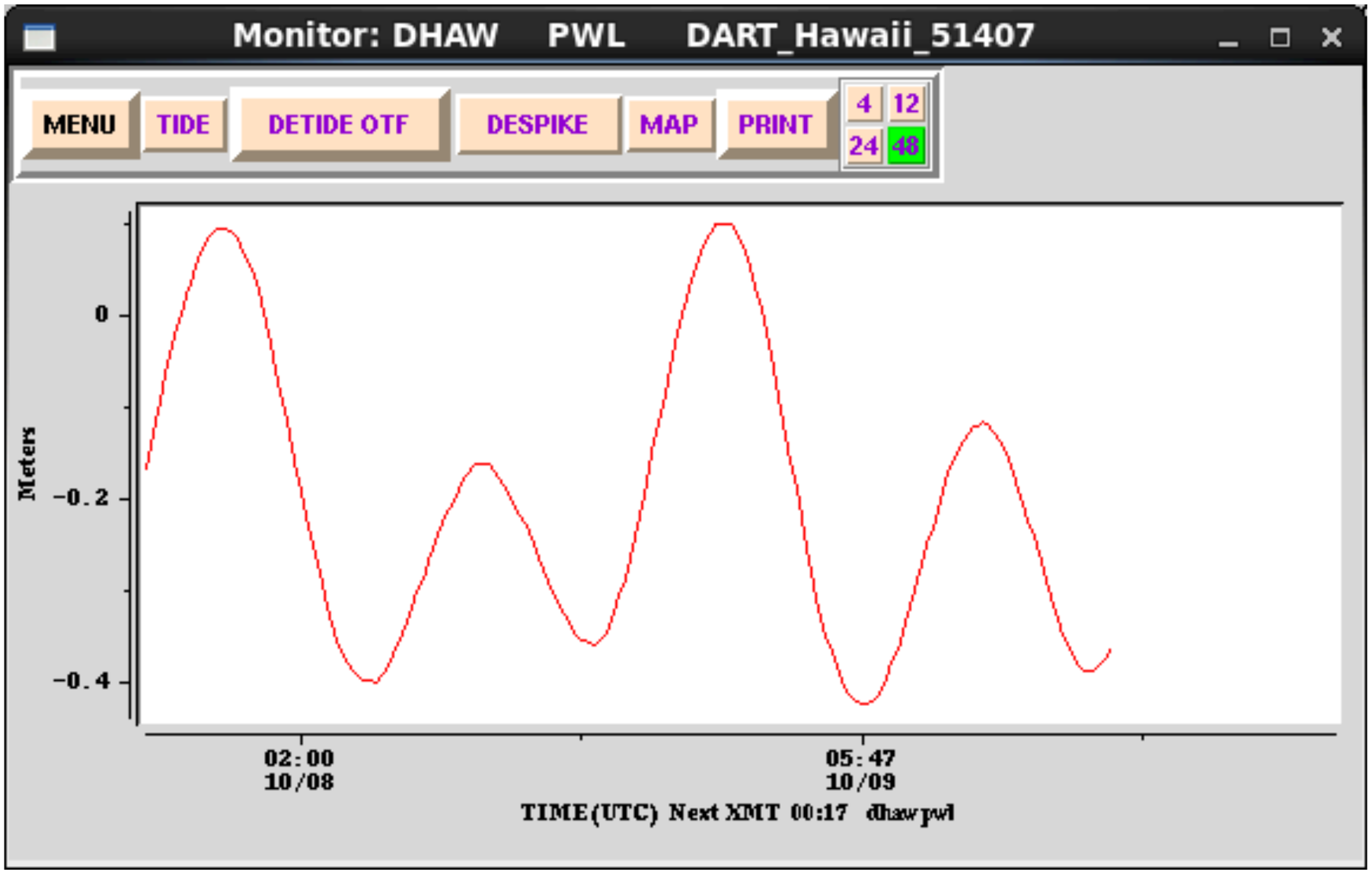
$$\text{tide(t)} = \sum a_i \cos(\omega_i t) + \mathrm{b_i} \sin(\omega_i \mathrm{t})$$

ω_is are called harmonic constituents.
ω_i, a_i, b_i are solved by least-square fit to the observations.

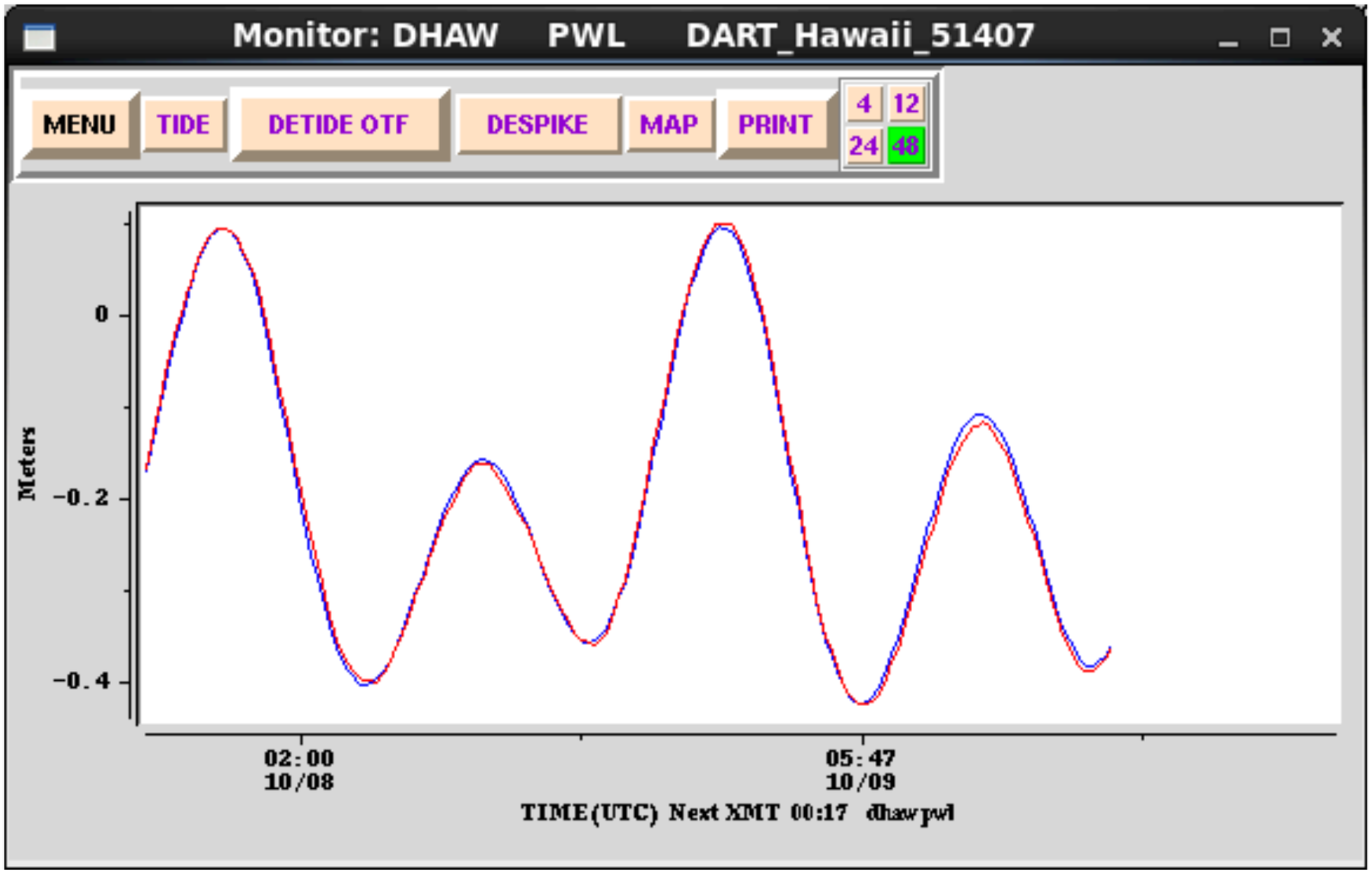
Analysis from using 1-2 years of data can predict the tides for Least one year or longer. Some times, the coefficients are good for 5-6 years.

People who are in the tide prediction business might use 5-10 years of data for tide prediction.

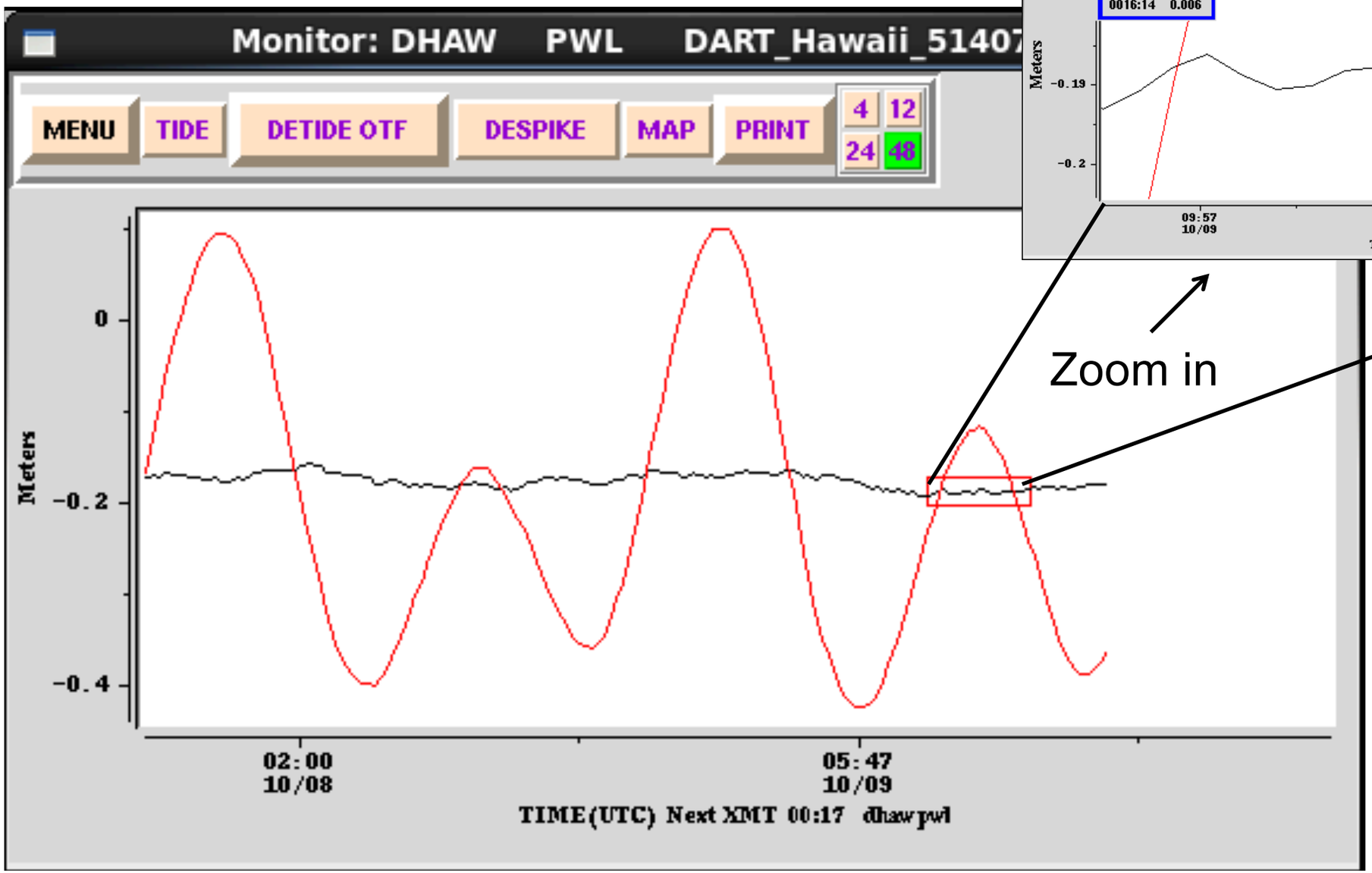
Raw data


Monitor: DHAW PWL DART_Hawaii_51407
MENU
TIDE
DETIDE OTF
DESPIKE
MAP
PRINT
4
12
24
48
0
-0.2
-0.4
Meters
02:00
10/08
05:47
10/09
TIME(UTC) Next XMT 00:17 dhawpwl

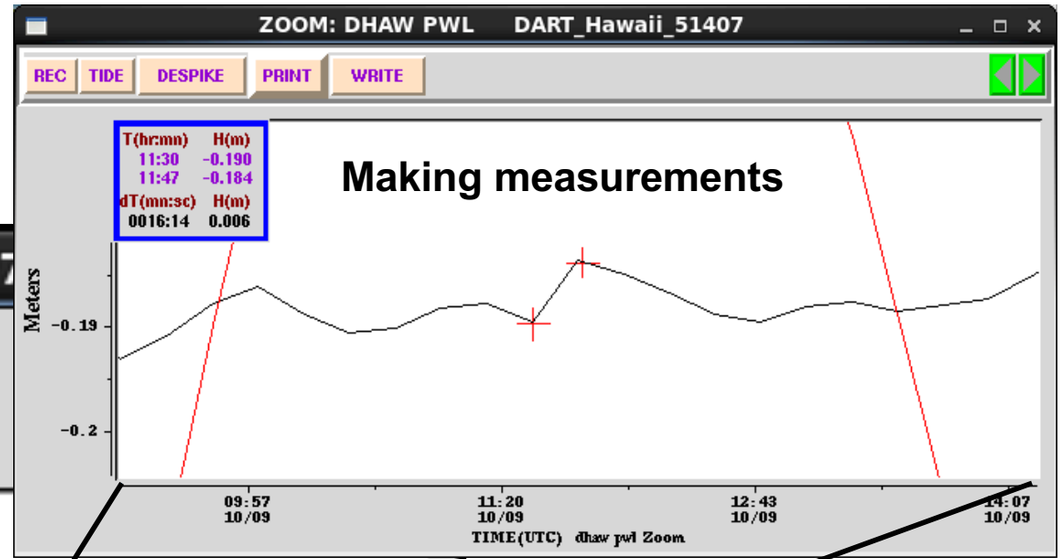
Raw data (red) with predicted tide (blue)



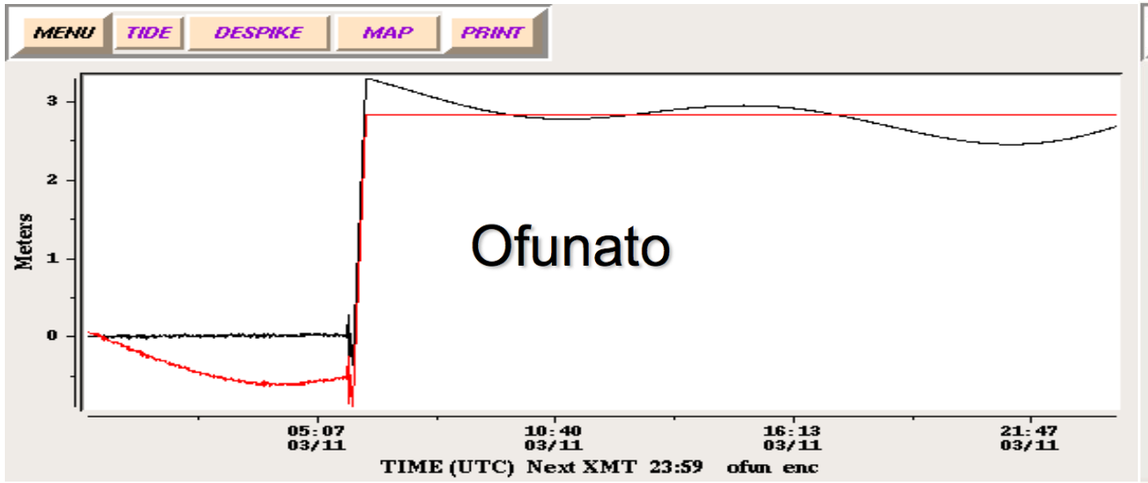
Raw data and detided data=raw–predicted

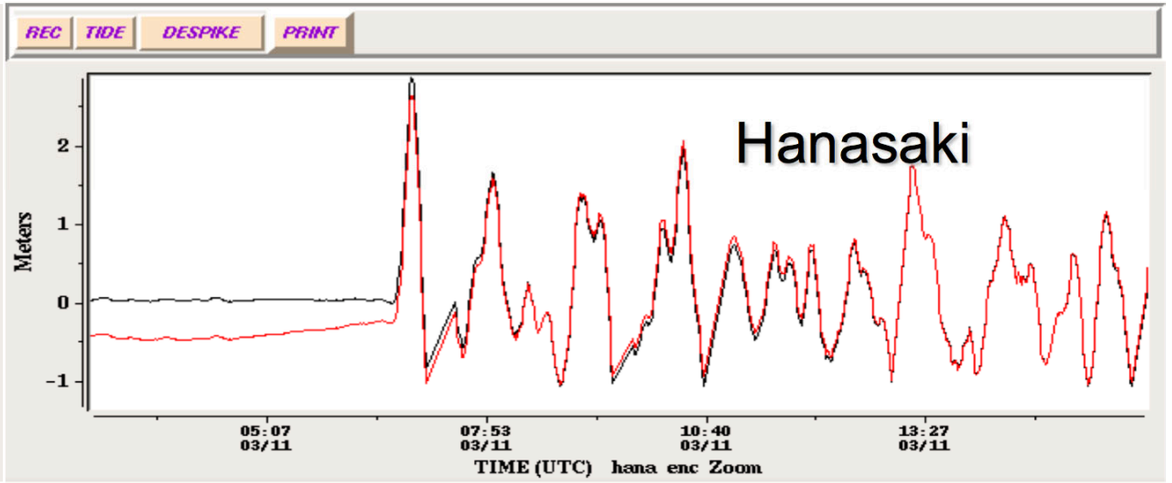


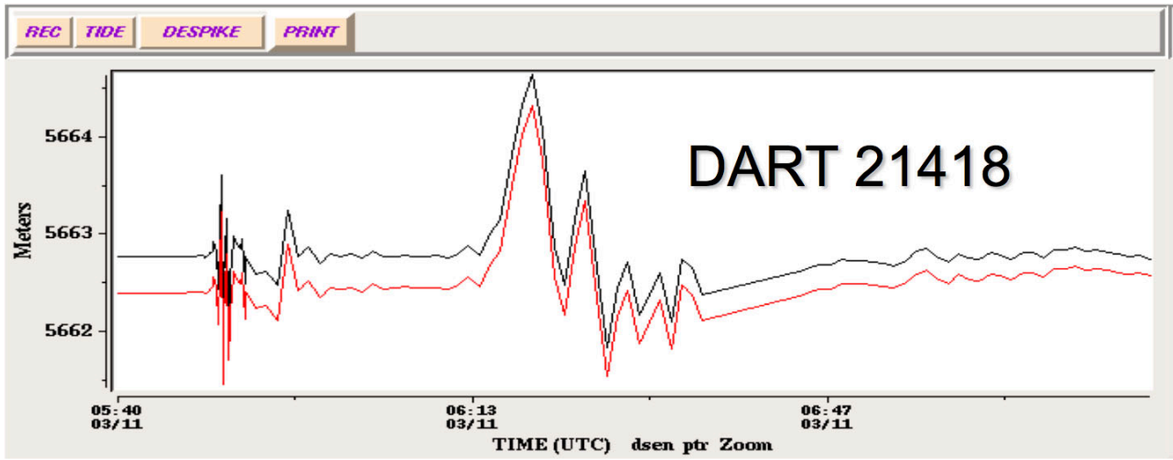
Zoom in

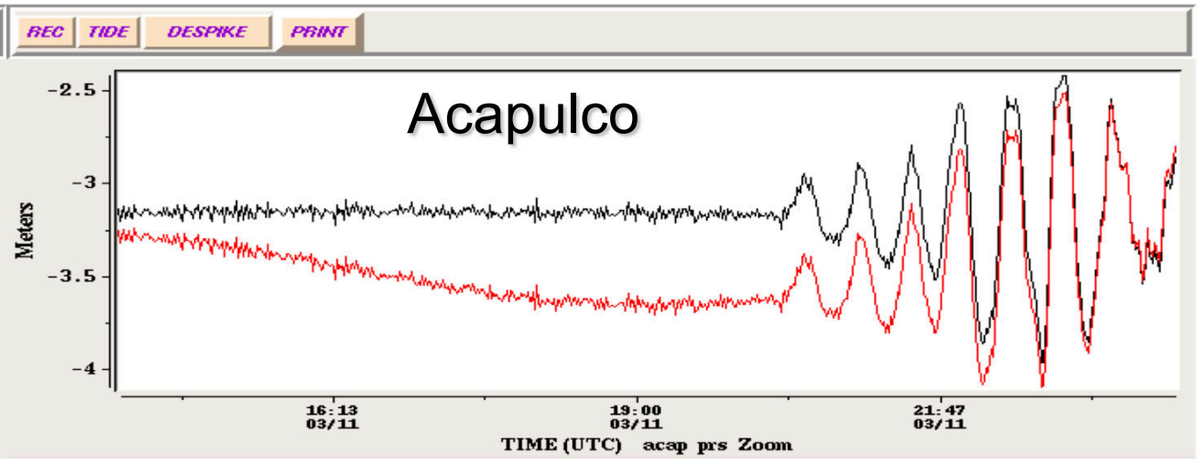


Tohoku Tsunami Marigrams









PTWC Reporting of Observed Tsunamis

- **Time of measurement**
- **Maximum Wave Amplitude – above normal sea level and time of measurement**

TEST... TSUNAMI OBSERVATIONS ...TEST

* THIS IS A TEST MESSAGE. THE FOLLOWING ARE TSUNAMI WAVE OBSERVATIONS FROM COASTAL AND/OR DEEP-OCEAN SEA LEVEL GAUGES AT THE INDICATED LOCATIONS. THE MAXIMUM TSUNAMI HEIGHT IS MEASURED WITH RESPECT TO THE NORMAL TIDE LEVEL.

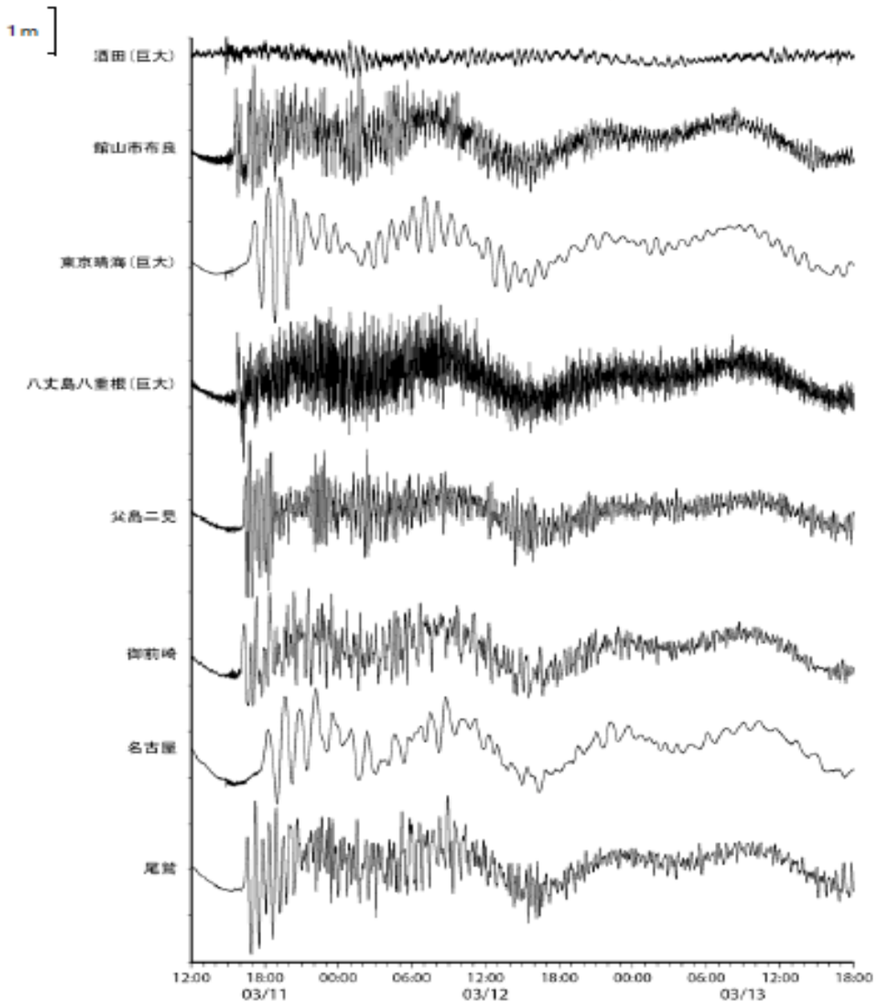
GAUGE LOCATION	GAUGE COORDINATES LAT	LON	TIME OF MEASURE (UTC)	MAXIMUM TSUNAMI HEIGHT	WAVE PERIOD (MIN)
CONSTITUCION CL	35.4S	72.5W	0505	6.42M/ 21 FT	16
TALCAHUANO CL	36.7S	73.1W	0505	4.38M/ 14 FT	16

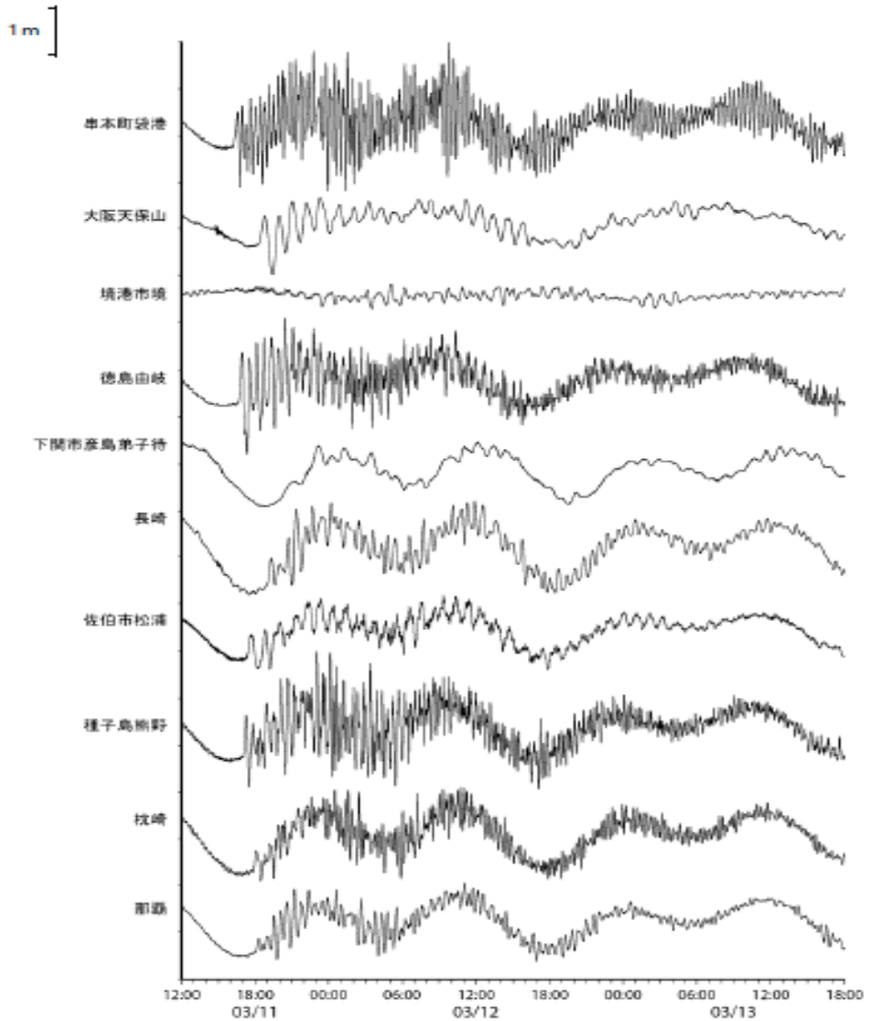
Limitations of Sea Level Data Analysis

- **Type of Sea Level Measurements**
  - Coastal Gauge
    - Most common
    - Signal highly modified by coastal effects
      well protected/resonant harbors tend to dampen/amplify tsunamis, thus readings might not be representative of tsunami hazards for the coastlines more/less exposed to the open ocean.
    - May be destroyed by large tsunami or clipped (wave higher than the housing, large draw down such that ocean bottom is exposed).
  - Deep Ocean Gauge
    Less common, costly to deploy and maintain, only ~70% deployed are reporting data at any given time, might also have funding issues.
  - Wet Sensors: on land, less expensive, only indicate if flooding has occurred

Challenges in warning cancellation

March 11, 2011 - 2 days tsunami records (Western Japan)





Thank You

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