TSUNAMI DETECTION ALGORITHM

“NEAREST” Meeting

Lisbon 17-18 May 2007

- 1. Comparison between

Filtered sea level data

and

Newton linear prediction on sea level data

2. Band Pass Filtering

within the tsunami frequency band (2-120 min.)

predicts the sea level value h_PRED(t) at time t

↓

At time $(t + s_r)$ reads the pressure measurement and converts to equivalent sea level height h_MEAS($t+s_r$)

↓

Tides and Spikes Removing + Low (Band) Pass Filter

We obtain the filtered data h_FILT(t) at time t

↓

| h_PRED(t) – h_FILT(t) | > TRESHOLD

↓ TRUE

TSUNAMI DETECTED !

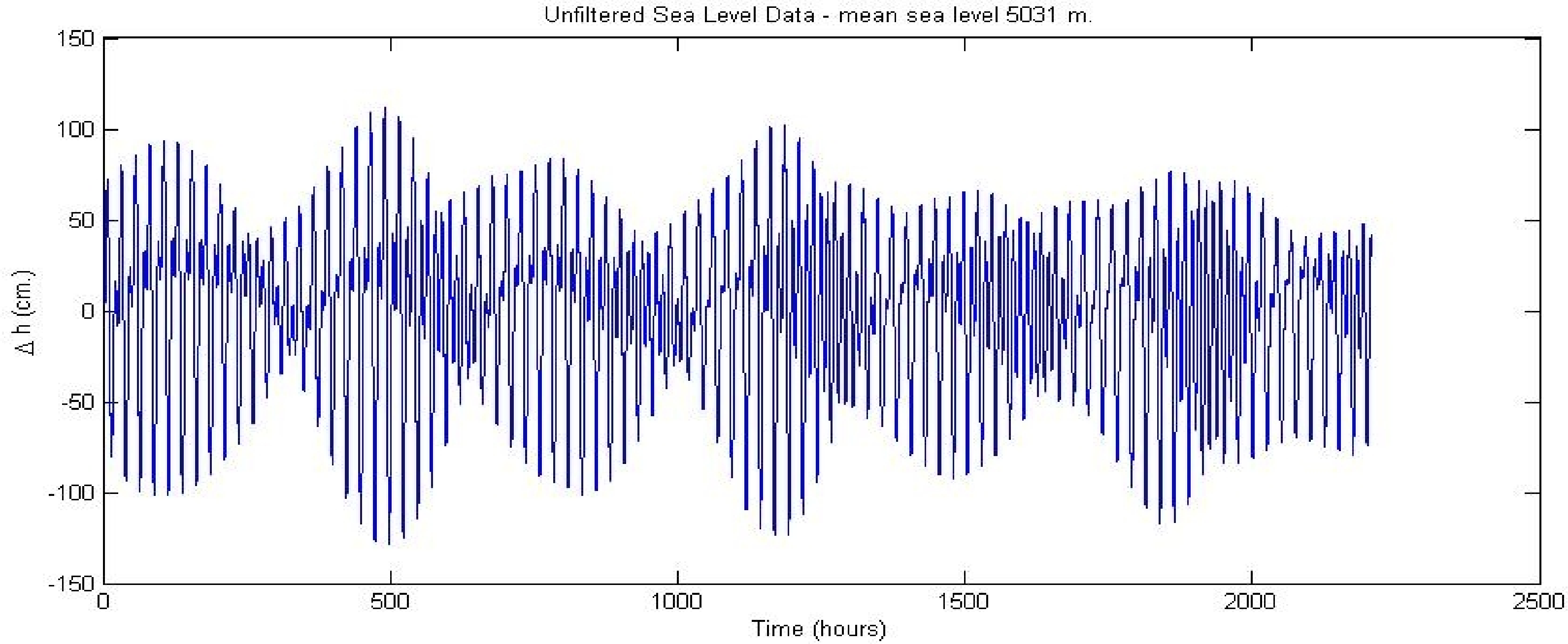
In the following examples we use

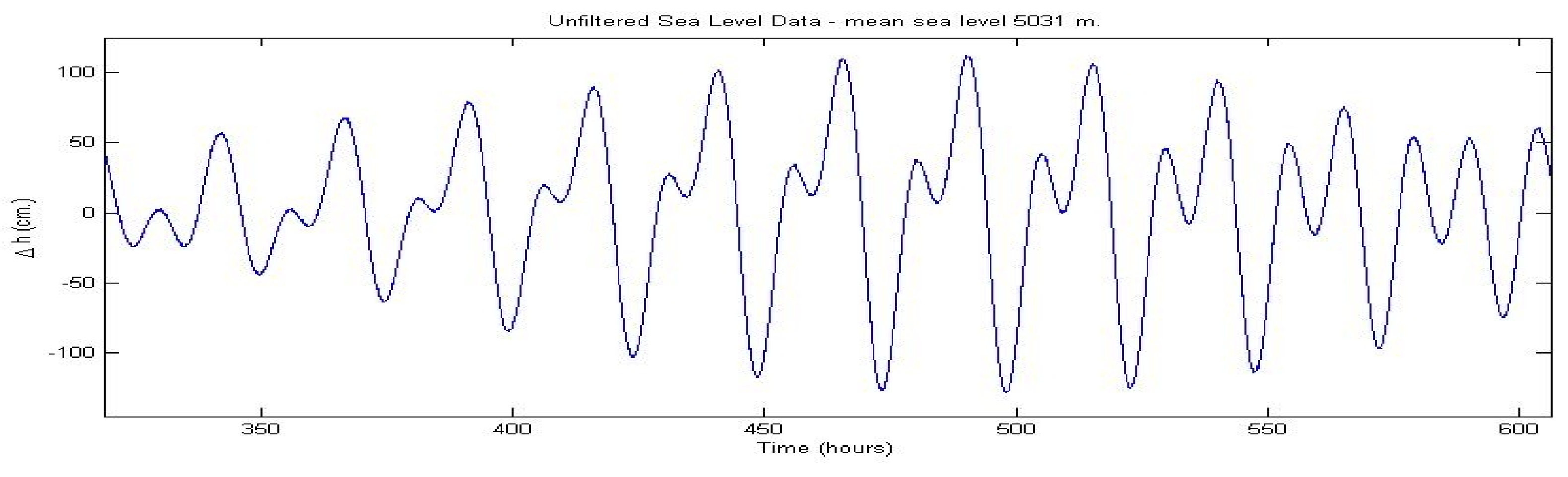
real bottom pressure recorder DART time series

Name	Starting	Lat.	Lon.	Location
d165_2001-ed.dat	June 1st 2001	50.4406	-165.0389	South of Dutch Harbor, AK
d125_2002-ed.dat	September 2nd 2002	-8.4887	-125.014	Equatorial Pacific Ocean

With synthetic Tsunamis superimposed

Example 1: d165_2001-ed.dat (noisy data)





DART Algorithm:

comparison between

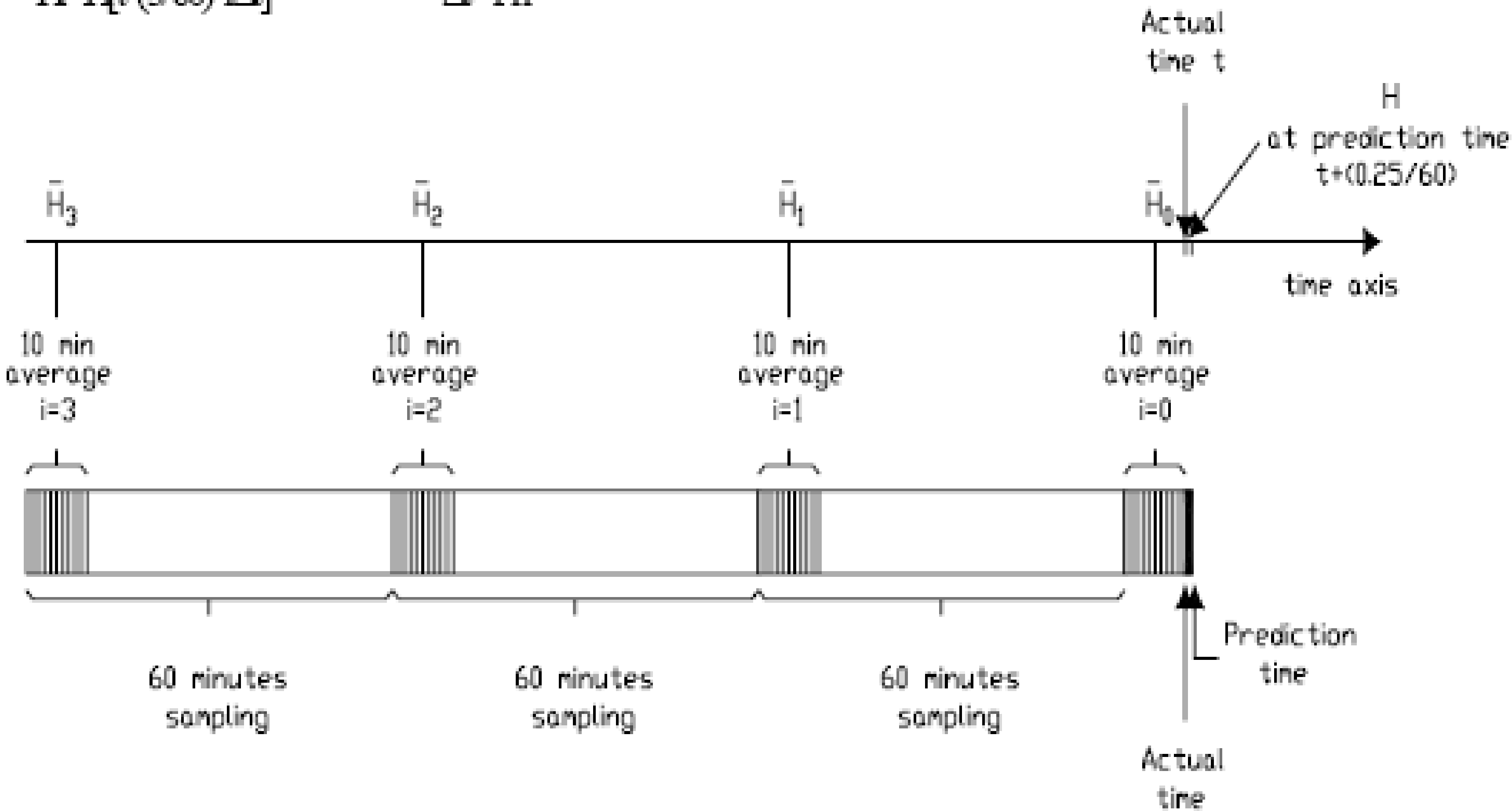
Measured sea level data

and

Newton Linear Prediction

When the difference exceeds a prescribed treshold we have a tsunami detection

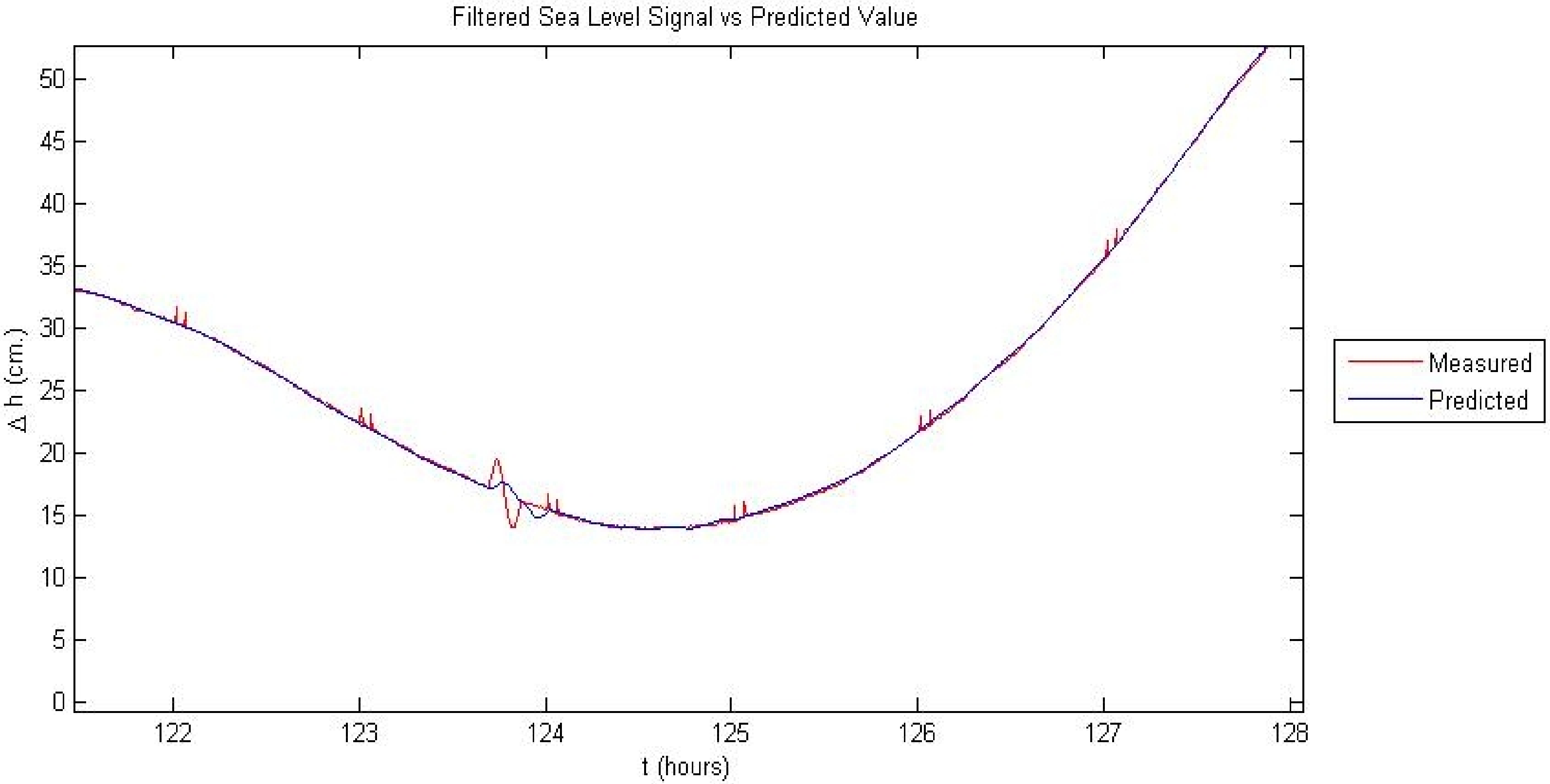
$$\bar{H}_i = \bar{H}[t-(5/60)-i\Delta t] \implies \Delta t = 1\,h$$



Newton Linear Prediction:

Syntethic 10 min. period Tsunami waves inserted

(2.5 cm. Tsunami Amplitude)



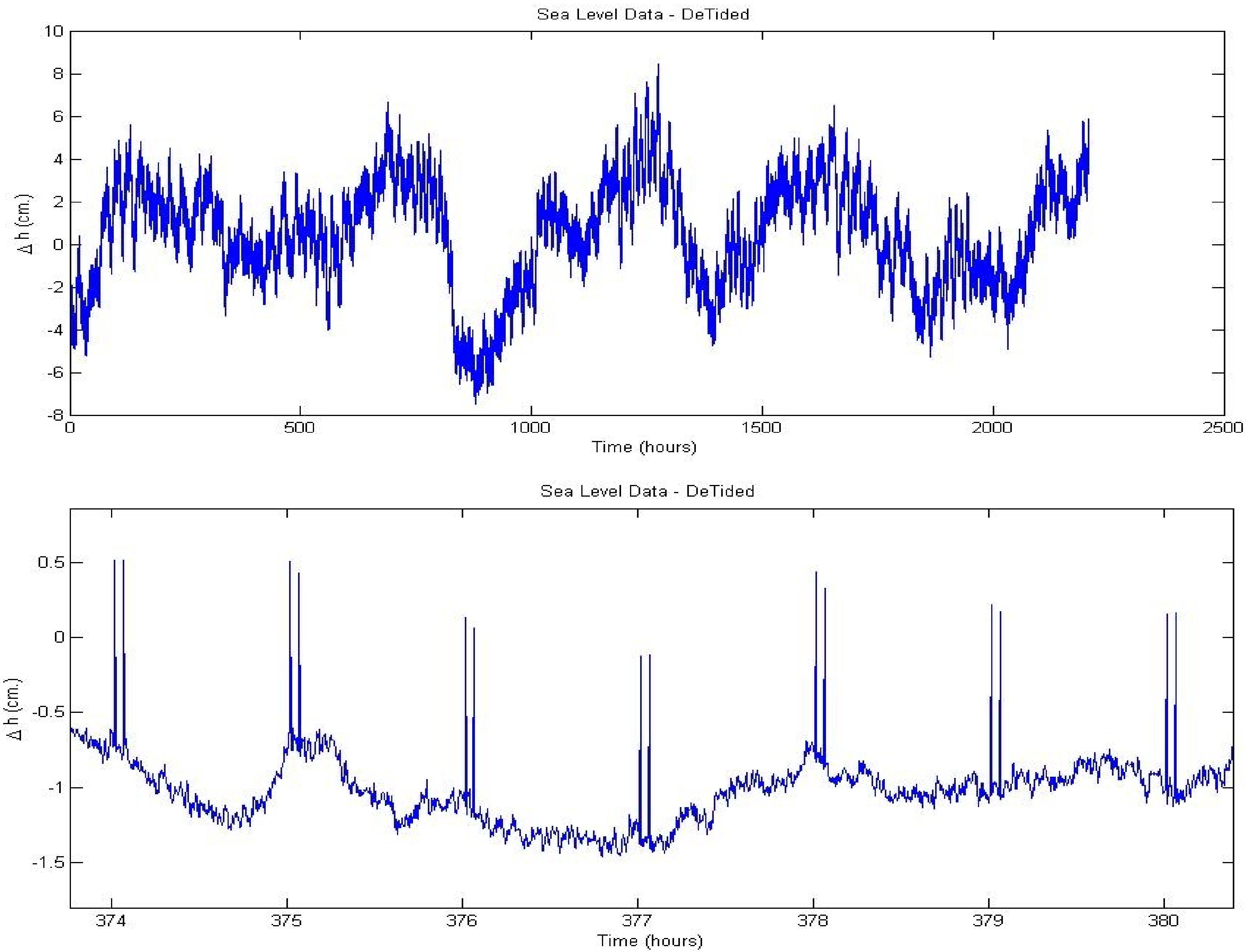
Tides Removing:

Harmonic Least Squares Analysis

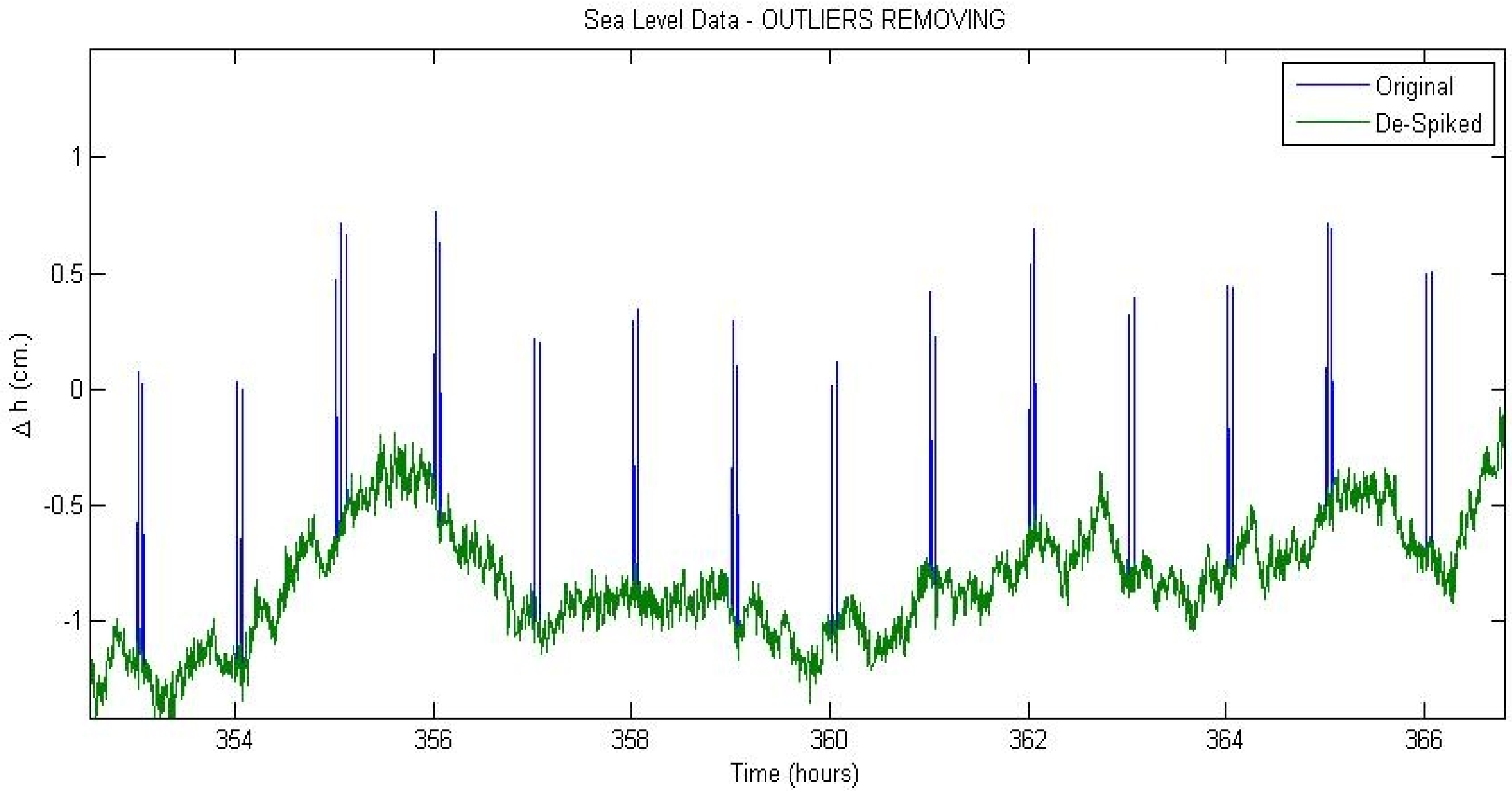
using 37 tide components

note: at least 3 months of sea level data are necessary !

Tides Removing



Spikes Removing



1. MODIFIED DART Algorithm:

Comparison between

De-Tided, De-Spiked, Low Pass Filtered Sea Level Data

and

Newton Linear Prediction

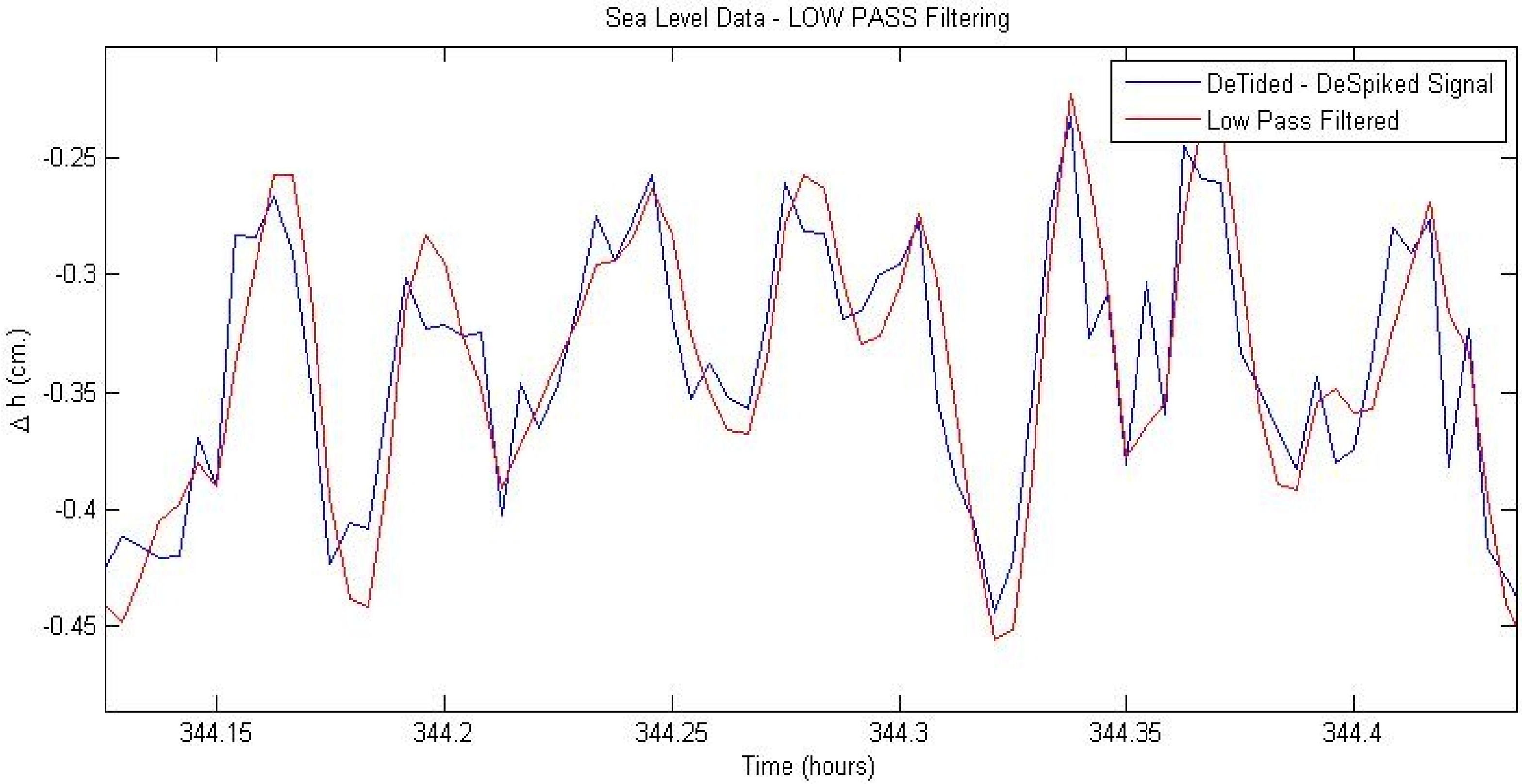
When the difference exceeds a prescribed treshold we have a tsunami detection

Low Pass Filtering

Windowing: Hann

Band Pass Period: T > 120 sec.

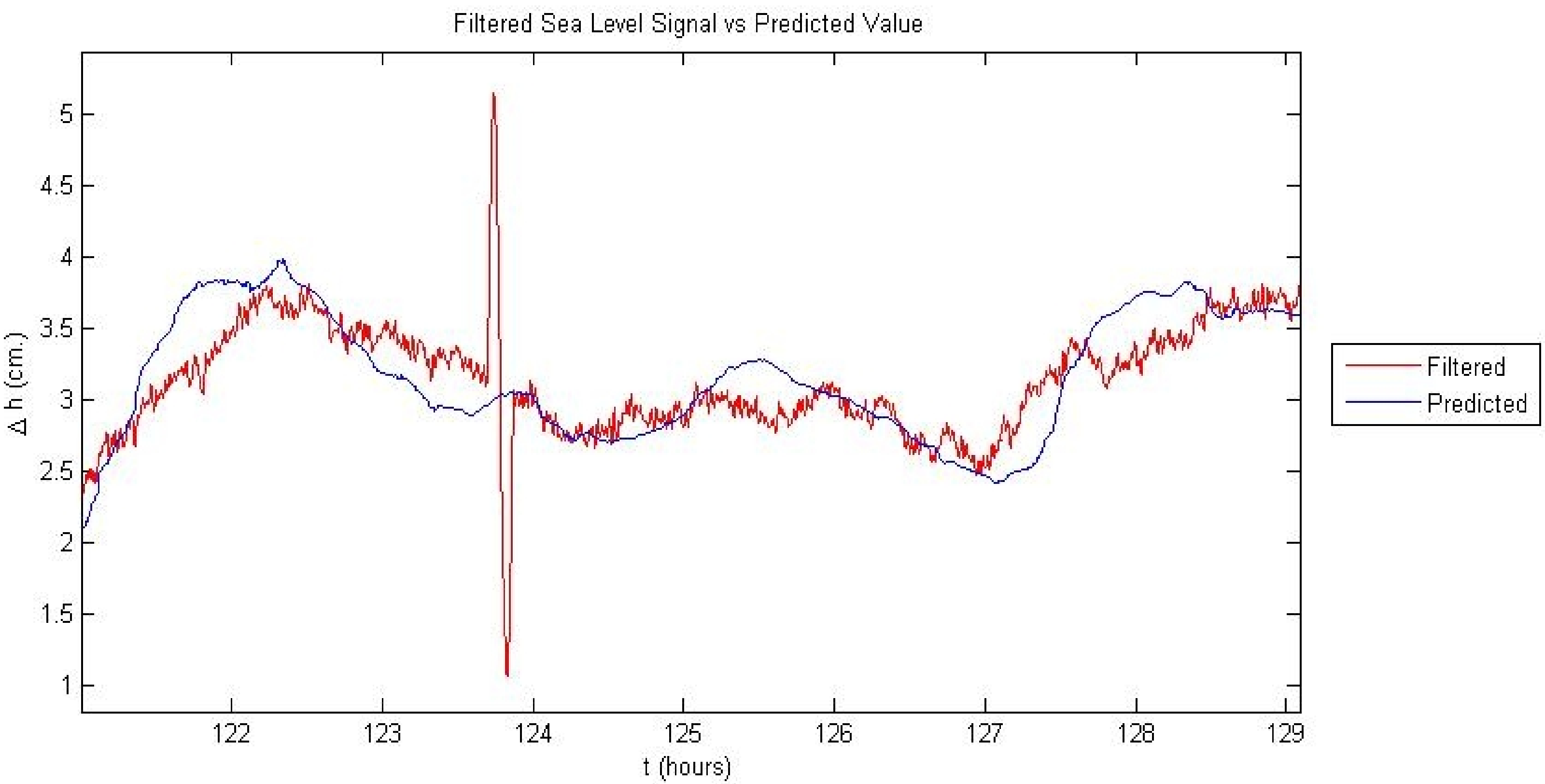
Points: 2048



Newton Linear Prediction:

Syntethic 10 min. period Tsunami waves inserted

(2 cm. Tsunami Amplitude)



2. BAND PASS FILTERING Algorithm:

When the

De-Tided, De-Spiked, Band Pass Filtered Sea Level Data

exceeds a prescribed treshold

we have a tsunami detection

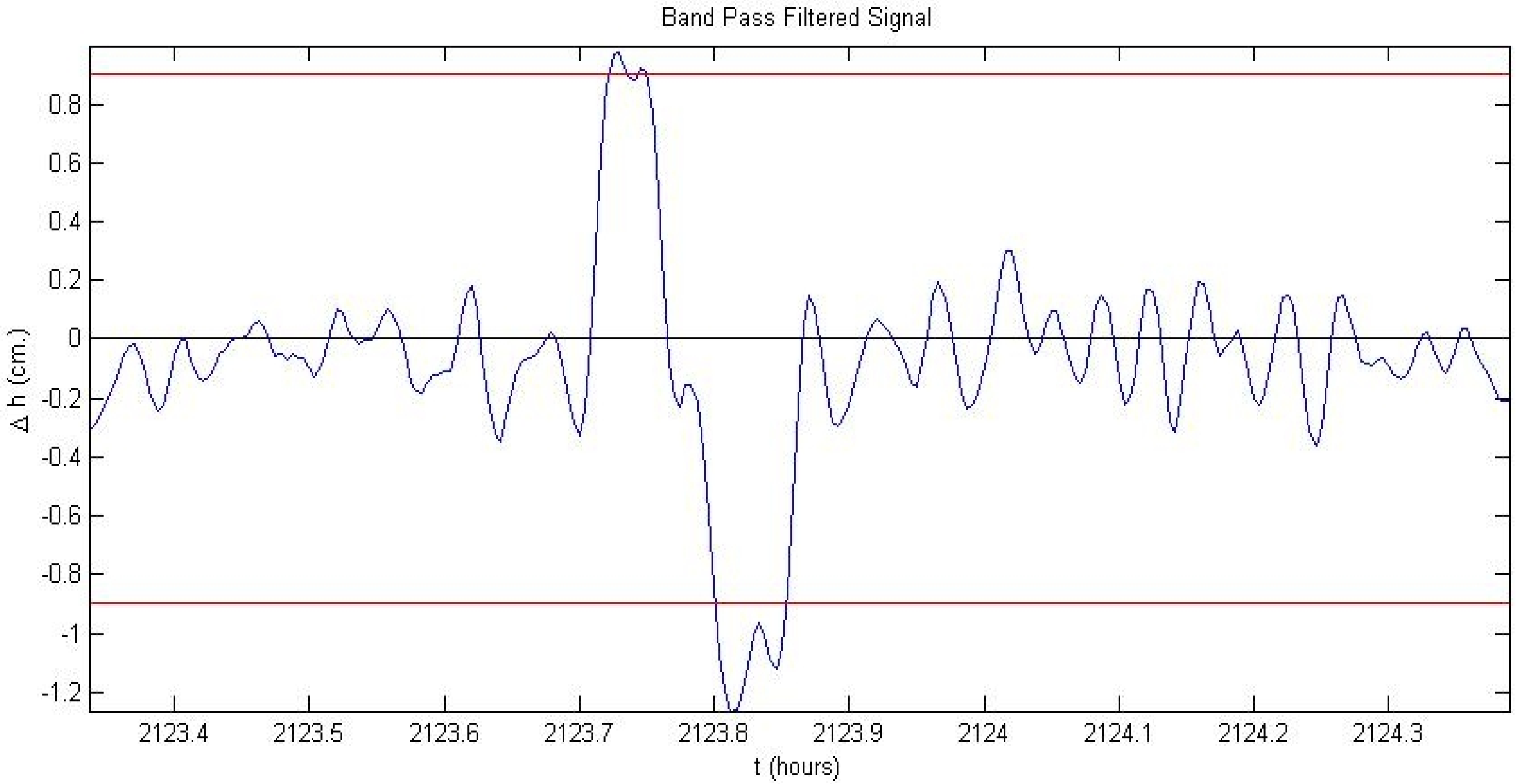
Band Pass Filtering

Windowing: Hann

Band Pass Period: 120 sec. < T < 80 min; Points: 4000

Syntethic 10 min. period Tsunami waves inserted

(1 cm. Tsunami Amplitude vs 0.9 cm. Treshold)



Example 2: d125_2002-ed.dat

LOW NOISE

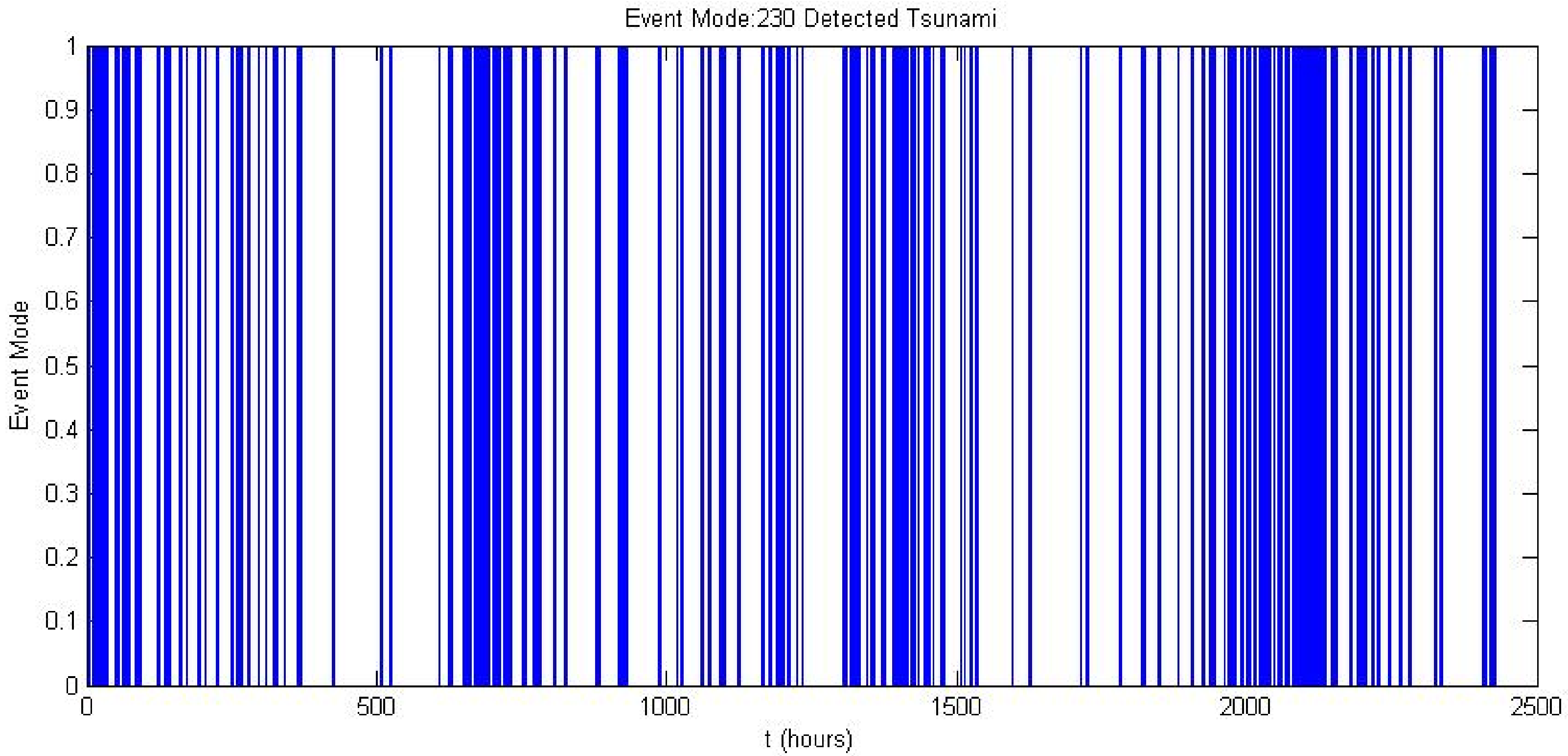
No Real Tsunamis

24 Syntethic (60 min. period) Tsunamis inserted

(1.1 cm. Tsunami Amplitude vs 1.0 cm. Treshold)

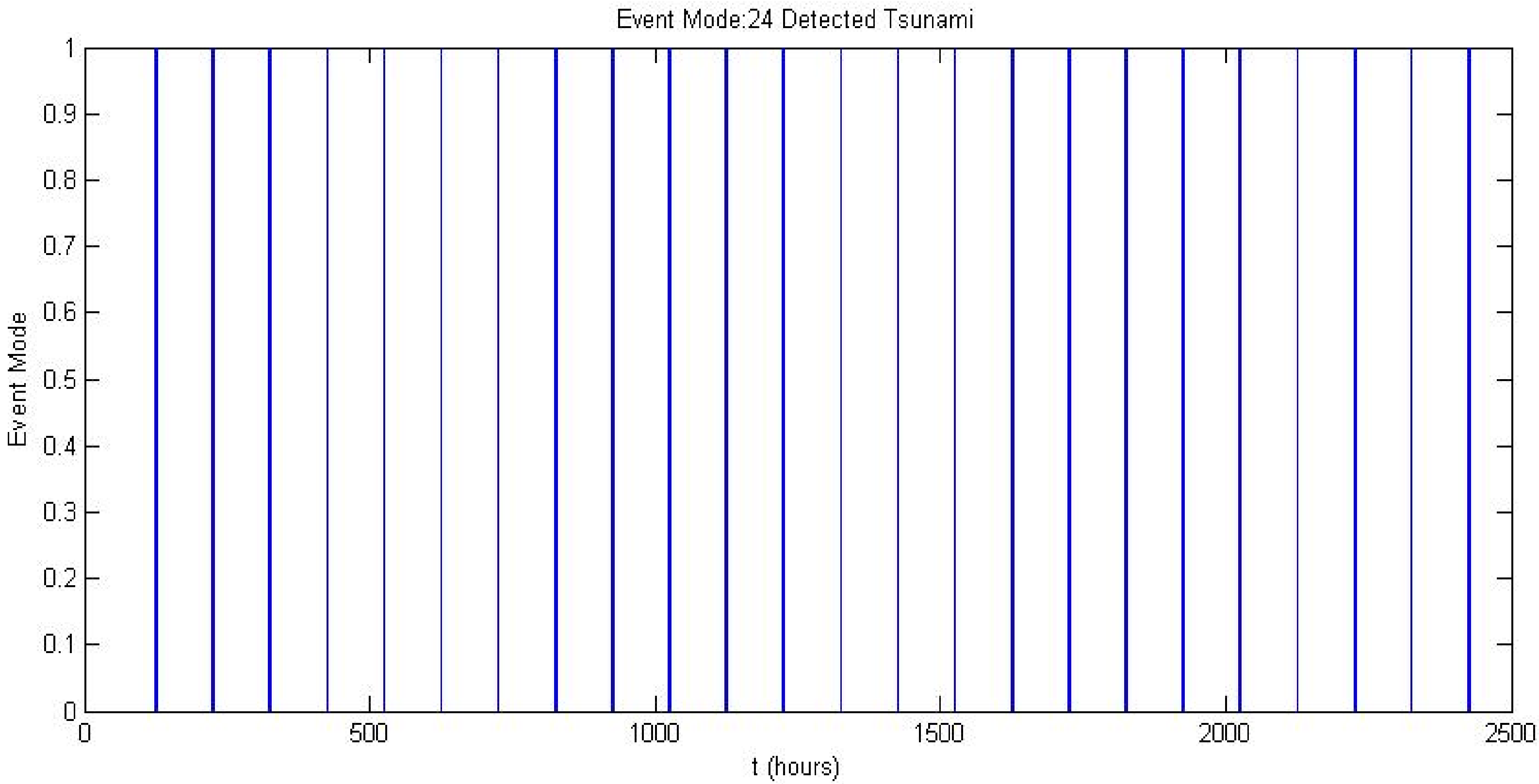
EVENT MODE STATE

DART Algorithm ; 30 min. Average Interval



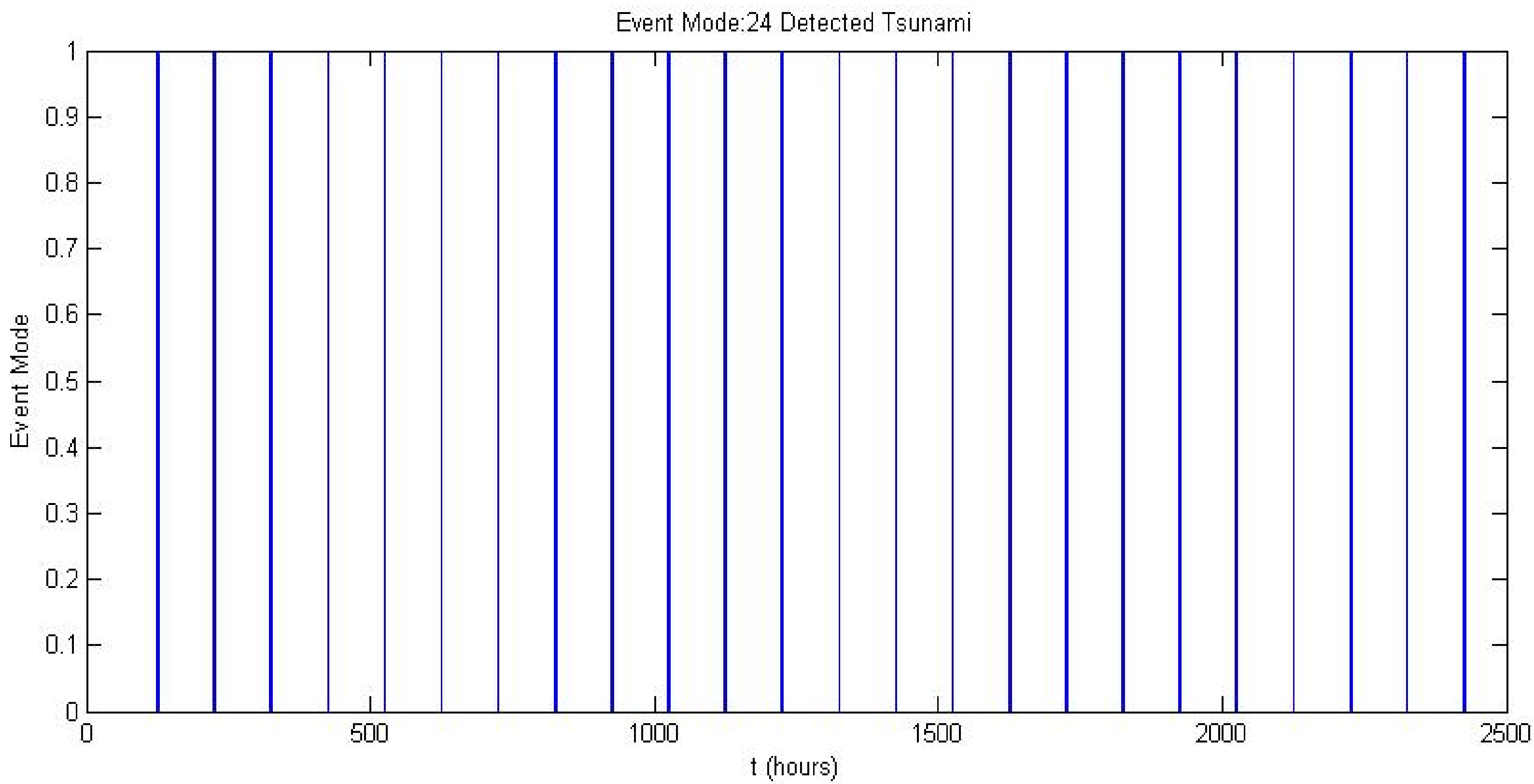
230 (206 false !) Detected Tsunamis vs 24 synthetic Tsunamis!

EVENT MODE STATE (MODIFIED DART Algorithm)



24 Detected Tsunamis vs 24 synthetic Tsunamis!

EVENT MODE STATE (BAND PASS FILTER Algorithm)
Band Pass Filtering
Windowing: Hann
Band Pass Period: 120 sec. < T < 80 min; Points: 4000



24 Detected Tsunamis vs 24 synthetic Tsunamis!

Example 3: d125_2002-ed.dat

LOW NOISE

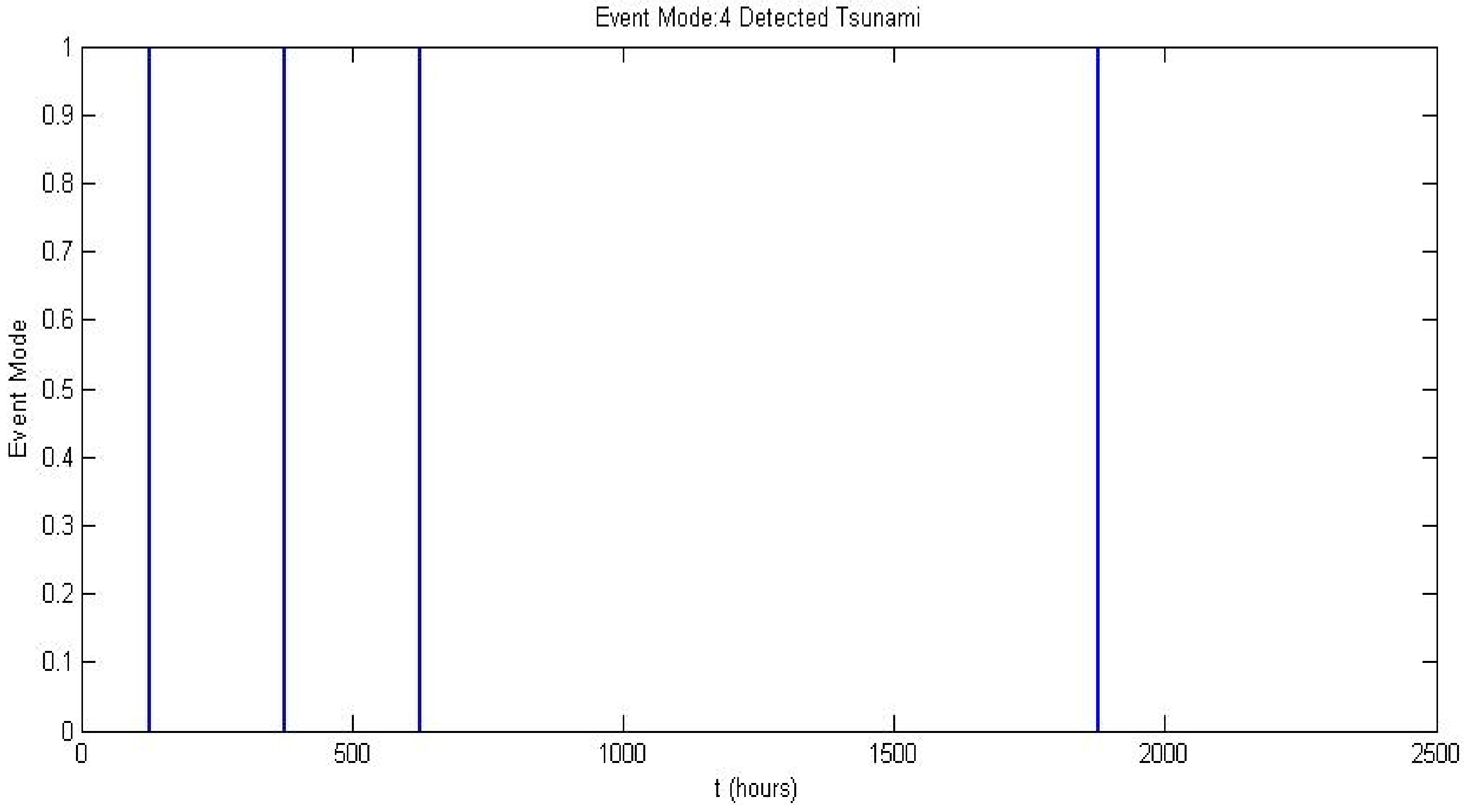
No Real Tsunamis

10 Synthethic (45 min. period) Tsunamis inserted

(1.1 cm. Tsunami Amplitude vs 1.0 cm. Treshold)

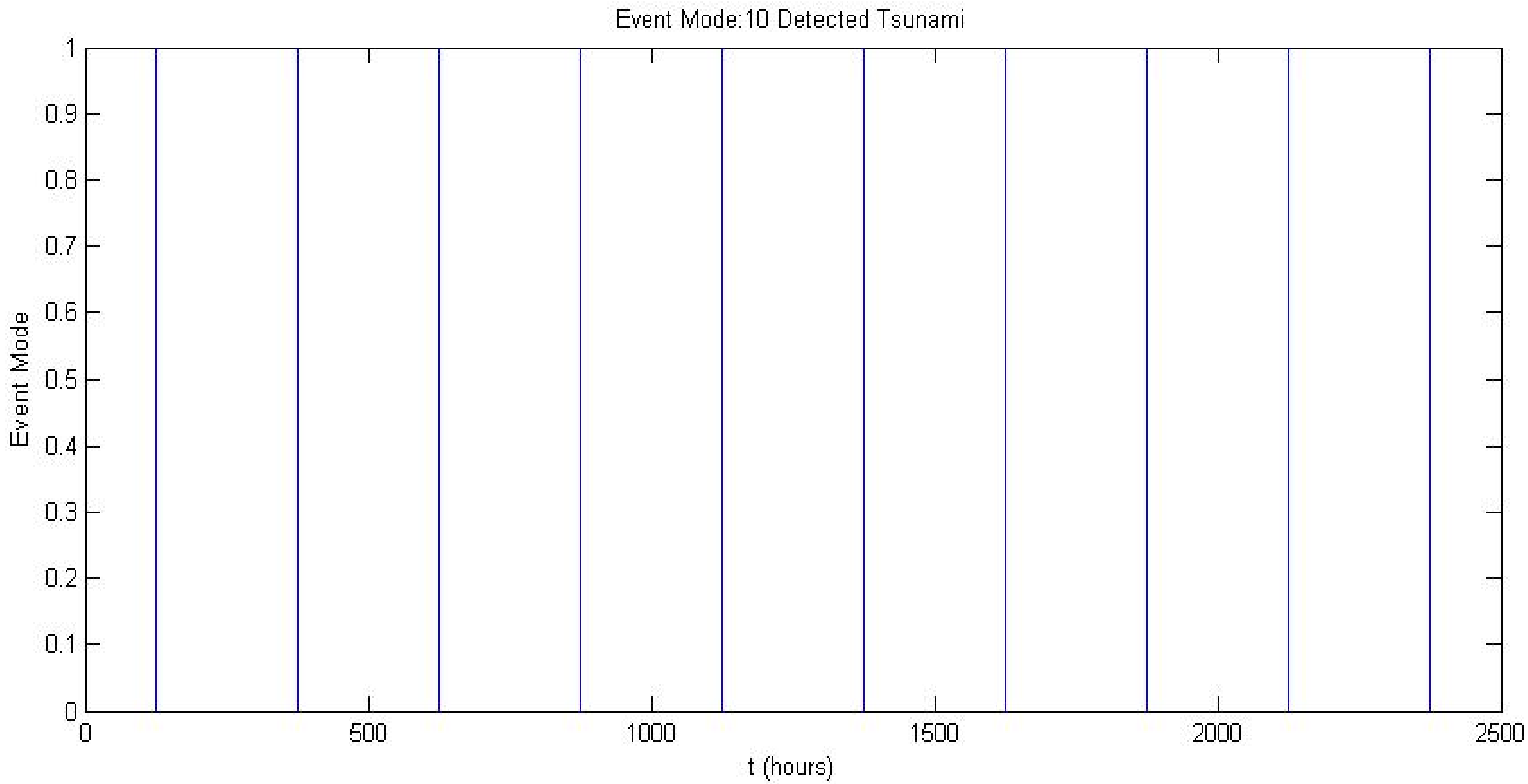
EVENT MODE STATE

DART Algorithm ; 10 min. Average Interval



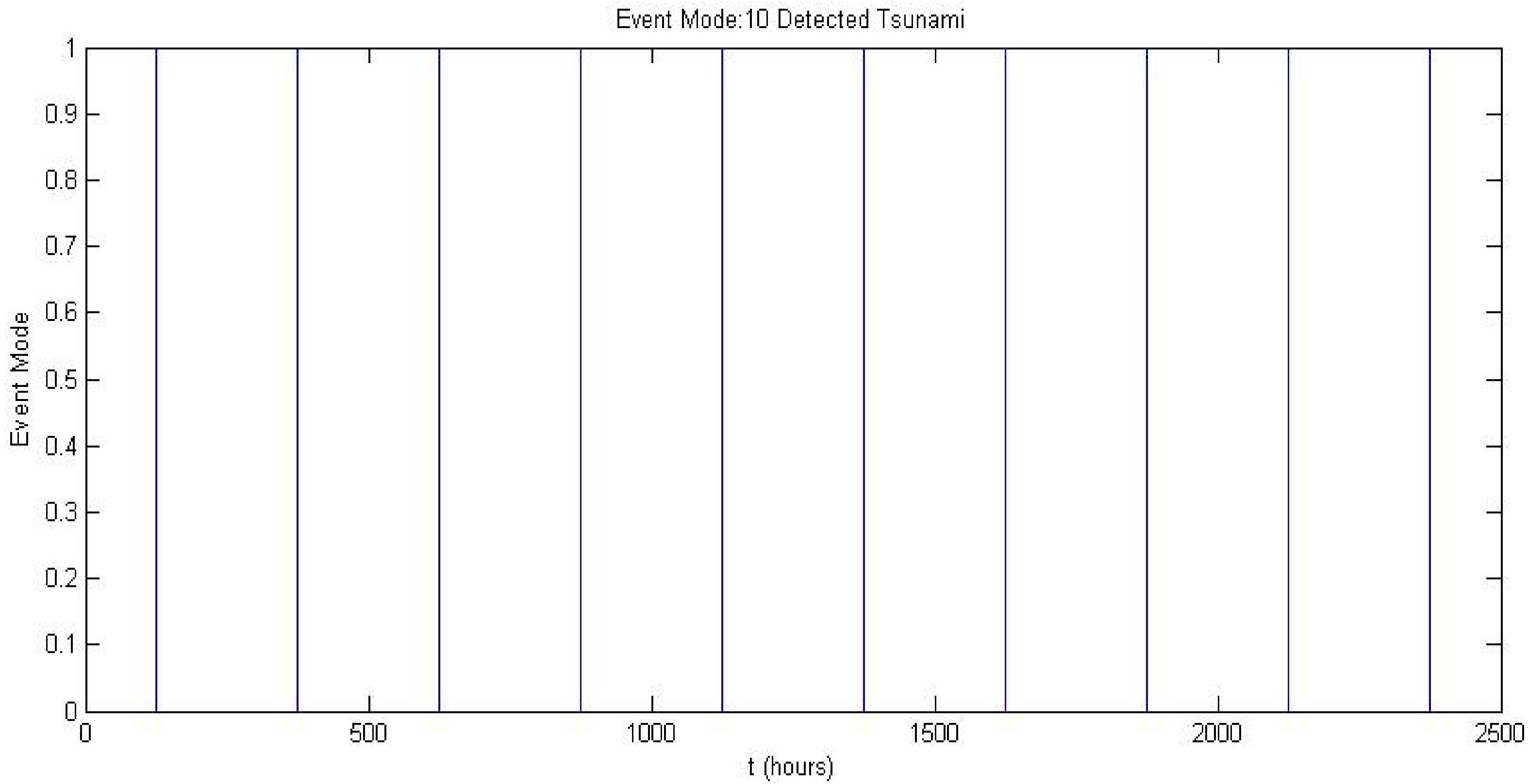
4 (6 not detected !) Detected Tsunamis vs 10 synthetic Tsunamis!

EVENT MODE STATE (MODIFIED DART Algorithm)



10 Detected Tsunamis vs 10 synthetic Tsunamis!

EVENT MODE STATE (BAND PASS FILTER Algorithm)
Band Pass Filtering
Windowing: Hann
Band Pass Period: 120 sec. < T < 80 min; Points: 4000



10 Detected Tsunamis vs 10 synthetic Tsunamis!

Example 4: d125_2002-ed.dat

LOW NOISE

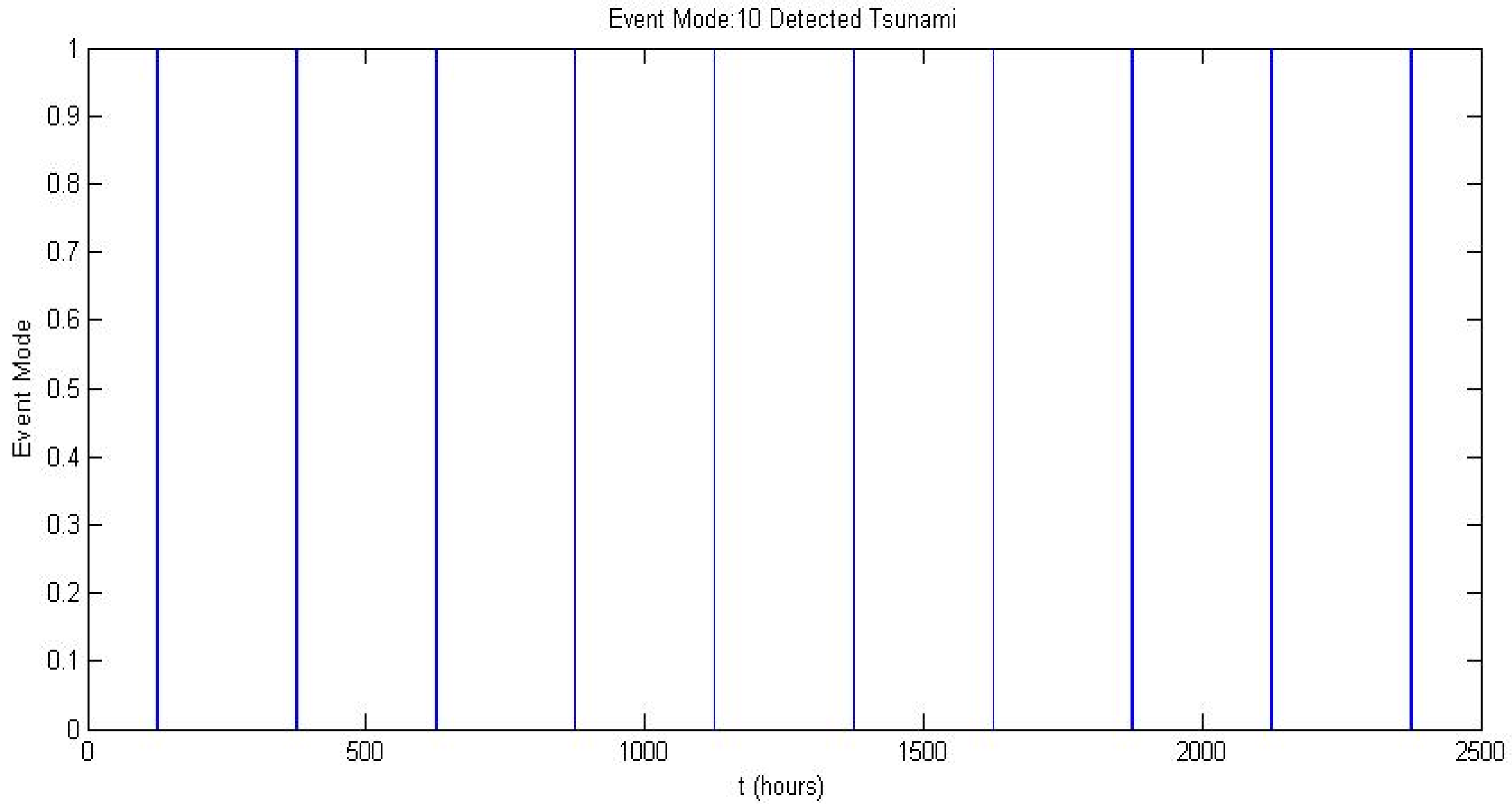
No Real Tsunamis

10 Syntethic (45 min. period) Tsunamis inserted

(3.5 cm. Tsunami Amplitude vs 3.0 cm. Treshold)

EVENT MODE STATE

DART Algorithm ; 30 min. Average Interval



10 Detected Tsunamis vs 10 synthetic Tsunamis!

TSUNAMI DETECTION ALGORITHM PROPOSAL

First 3 months after deployment: we cannot calculate tide coefficients

↓

DART Algorithm + Spikes Removing and Low Pass Filtering

> 3 months after deployment: we can recover tide coefficients, thanks to the 2 way bottom-surface communication system and input them into the code

↓

MODIFIED DART Algorithm

OR

BAND PASS FILTERING

Treshold is a key parameter !

DART System estimated a suitable treshold amplitude (3 cm.) based on one year data noise analysis.

We don't have any bottom pressure data in the area and so initially we will proceed using the same 3 cm. treshold.

After the sea floor station will be recovered, we can estimate more precisely the amplitude treshold in the deployment site

PRESSURE MEASUREMENT IN A TSUNAMI GENERATION AREA

The sea floor motion due to seismic event will move the pressure sensor

↓

Pressure measurement perturbation

↓

Not realistic seal level estimation

Dynamics and kinematics effects

1. Height variation of the sensor Δh:

$$\Delta P_1 = \rho\, g\, \Delta h$$

Where:

Δh is the sea water density

g is the gravitational acceleration

2. Drag pressure induced by the sea floor station motion:

$$\Delta P_2 = \frac{1}{2} \rho C_D V^2$$

Where:

C_D is the sea floor station drag coefficient

V is the modulus of the station velocity

3. Pressure field locally generated in the fluid by the sea floor motion:

$$\Delta P_3 = \rho h \frac{\partial^2 w}{\partial t^2}$$

Where:

h is the water column height

$\frac{\partial^2 w}{\partial t^2}$ is the sea floor bottom vertical acceleration

Many other effects such:

1) The Salinity and Temperature local variation

2) The fluid squeezing in and out the sea floor induced by the stress caused by the quake

should be taken into account in future development.

Bibliography

Tsunami Detection Algorithm

- MOFJELD H.O., "*Tsunami Detection Algortihm*", **not published**, 2000, 5 pp (available at: http://nctr.pmel.noaa.gov/tda_documentation.html)

2) MOFJELD , H.O., P.M. WHITMORE, M.C. Eble, F.I. González, and J.C. Newman, "*Seismic-wave contributions to bottom pressure fluctuations in the North Pacific- Implications for the DART Tsunami Array* ", **Proceedings of the International Tsunami Symposium 2001** (ITS 2001), Session 5-10, Seattle, WA, 7–10, August 2001, (on CD-ROM), 633–641 (2001)

Perturbation on Sea Floor Pressure Measurement

- FILLOUX J.H. "*Tsunami recorded on the open ocean floor*", **Geophys. Res. Lett**., 1982, Vol. 9, 25-28

- ZIELINSKI A., SAXENA N. K. "*Tsunami detectability using open-ocean bottom pressure fluctuations*", **IEEE journal of oceanic engineering**, 1983, vol. 8, no4, pp. 272-280

- DRISCOLL F., LUECK R., NAHON M., "*Development and Validation of a Lumped-Mass Dynamics Model of a Deep-Sea ROV System*", **Applied Ocean Research**, 2000, Vol. 22, No. 3, pp. 169-182.