PACT – a bottom pressure based, compact deep-ocean tsunameter with acoustic surface coupling

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1 Introduction

After the December 26, 2004 Indian Ocean tsunami, the German-Indonesian Tsunami Early Warning System (GITEWS) was initiated. Seismic and GPS data provide fast information on earthquakes, but accurate tsunami predictions require direct measurements of the sealevel.

To detect tsunamis in the deep ocean, a *Pressure Acoustically Coupled Tsunameter* (PACT) was developed by AWI and two German SMEs, with support from MARUM, Bremen, and University of Rhode Island, USA.

Similar to the US DART ® system, PACT measures ocean bottom pressure, performs automatic tsunami detection, and acoustically transmits the data in near real time to a surface unit (Fig. 1).

Using specially designed computing and communication technology, PACT integrates the entire ocean bottom package into a single, compact unit.

Several PACT systems are scheduled for their first deployment off Indonesia in April 2009. Here, the technical specifications of the PACT system are presented.

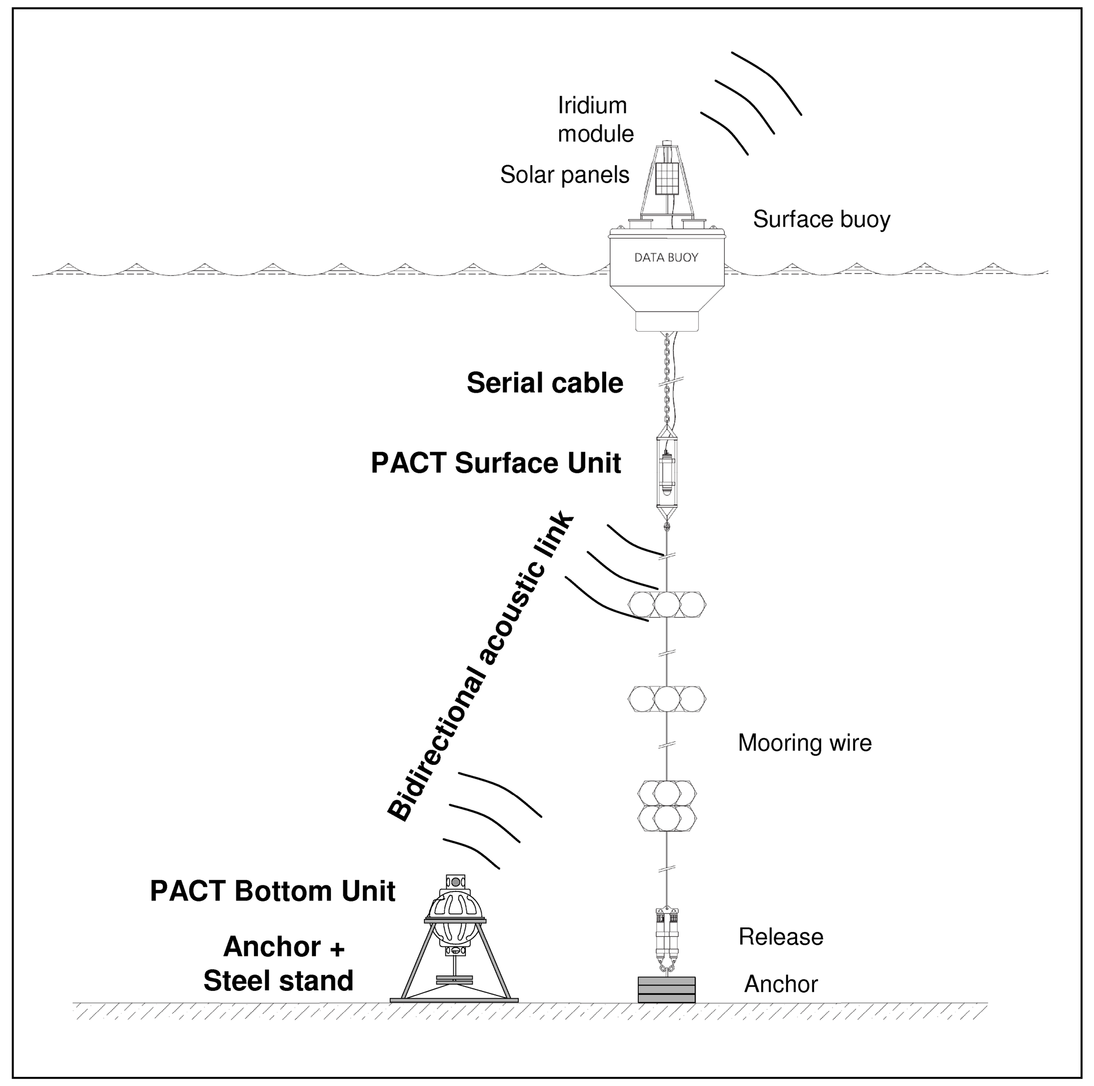


Fig. 1: Sketch of PACT system, with the bottom unit located at the sea floor, and the surface unit attached to a surface buoy for satellite transmission of the data.

2 PACT Bottom Unit

PACT's BU (Fig. 2) developed by OPTIMARE Sensorsysteme AG, Bremerhaven, Germany, consists of a single 17" Vitrovex glass sphere rated for 6000 m. The BU and its steel stand are designed for a free-fall deployment. For recovery, a burn-wire release is activated acoustically. VHF transmitter and flashlight aid relocation at the surface. The design resembles the Pressure Inverted Echo Sounders (PIES) developed by URI [6].

- Pressure sensor: Paroscientific Digiquartz 410K, resolution 1 mm. Measurements every 15 s.
- Microcontroller-based on-board computer performing pressure measurements, automatic tsunami detection and acoustic modem control
- Acoustics: HAM.NODE modem
- Energy: 4000 Wh Lithium cells for > 2 years

Fig. 2 (left): PACT bottom unit and steel stand. The black cylinder at the top is the HAM.-NODE modem; the burn-wire release of the BU is located in the lower cage. For deployment, additional weights are attached between the release and the steel stand.

Fig. 3 (right): HAM.NODE modem (surface unit) attached to a steel frame which takes the load of the surface buoy.

3 PACT Surface Unit / HAM.NODE modem

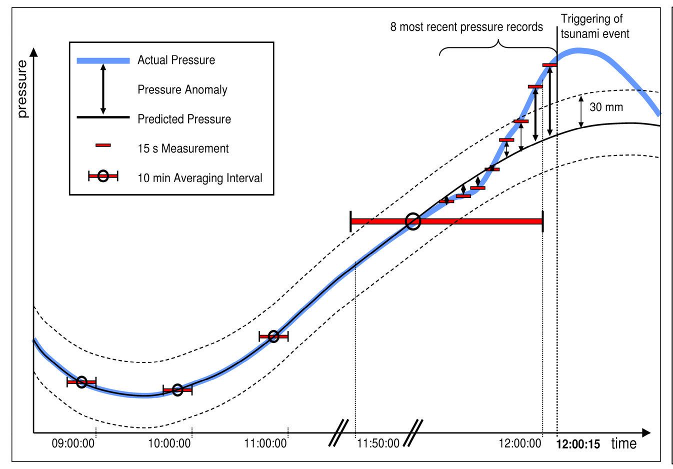
PACT is equipped with a pair of acoustic modems developed by develogic GmbH, Hamburg, Germany.
The BU modem is integrated into the BU housing, whereas the surface unit (SU; Fig. 3) is located in a frame 15 m below the surface buoy. HAM.NODE's coding and modulation is optimized for maximum reliability and energy efficiency.

- 11 – 14 kHz, n-m-FSK and DPSK modulation
- range > 6000 m vertical, transmission rate 200 bps
- Energy: SU externally powered from surface buoy

4 Tsunami detection and prediction

The automatic detection of a tsunami event is performed identical to the proven DART® tsunami detection algorithm [7,8]. Every 15 s, the actual pressure is compared with a prediction of a cubic polynomial calculated from 4 10 min averages during the last 3 hours (Fig. 4). The tsunami mode is triggered when two most recent 15 s values depart more than 30 mm from the prediction, and a spike criterion to exclude false measurements was passed.

Actual pressure and its deviation from the prediction are transmitted to the DSS (Decision Support System), where event time and wave height are used to select pre-modelled inundation scenarios for accurate tsunami hazard warnings.



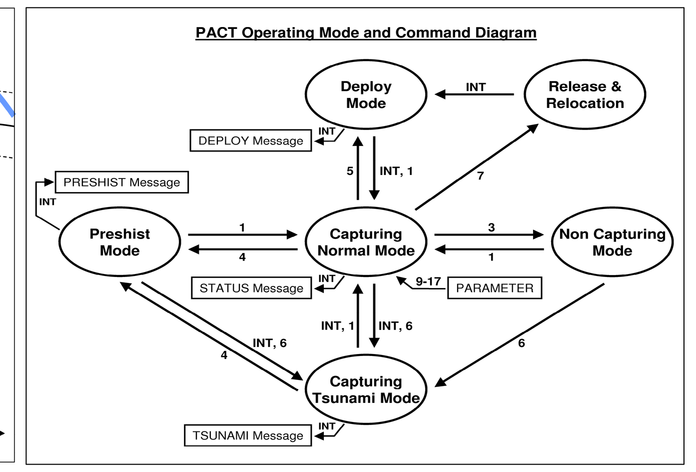


Fig. 4 (left): Sketch illustrating the tsunami detection algorithm. For clarity, the figure does not show real data, and the time axis is not to scale. In this example, the 30 mm anomaly threshold starts to be exceeded during the 11:59:45 – 12:00:00 measurement. The tsunami mode is triggered at 12:00:15.

Fig. 5 (right): Operating modes of PACT. "INT" marks changeovers automatically controlled by the PACT software, and automatical generation of messages. Numbers refer to explicit commands necessary to switch to another mode.

5 Operation modes

The PACT bottom unit operates in different modes (Fig. 5), which can be remotely controlled from the surface and/or the GITEWS warning centre.

- *Normal Capturing Mode*: Standard mode, status message transmitted every 4 h.
- *Tsunami Mode*: Triggered automatically by tsunami detection algorithm or manually by the warning centre. Tsunami messages with most recent 15 s pressure data and pressure anomalies transmitted every 2 min.
- *Pressure History Mode*: Download all 15 s records of the last 3 hours.
- *Deploy Mode*: Allows to verify the upright position of the BU after deployment.
- *Release and Relocation Mode*: Enabled by acoustic command from ship for recovery.
- *Non-Capturing Mode*: sleep mode e.g. during transport.

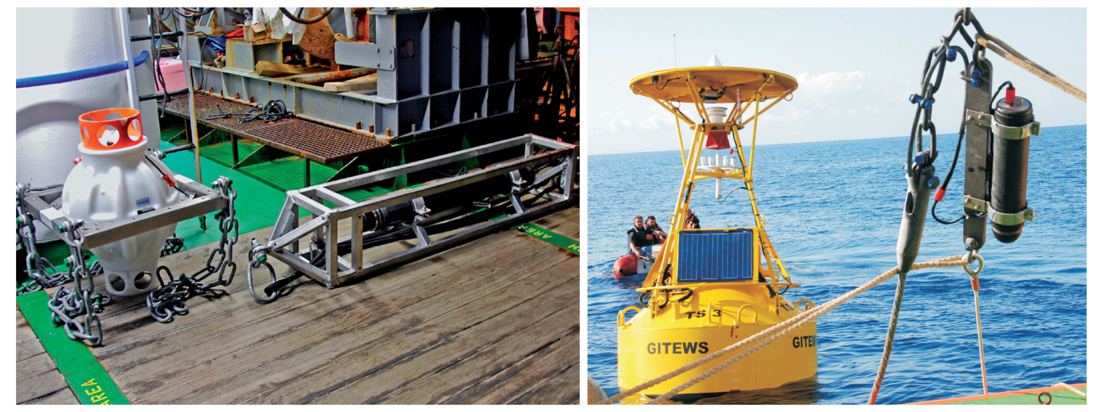


Fig. 6: Left: PACT and HAM.NODE modem prepared for a short-term at-sea test, attached to the ship's hydrographic wire. Right: Test deployment of GITEWS GPS buoy with HAM.NODE modem.

6 Tests

PACT's functionality was proven by extensive tests:

- mechanical layout of bottom unit indentical to proven PIES design [6]
- long-term laboratory tests with high-pressure loading, simulation of tsunami events and remote acoustic control of the bottom unit
- at-sea tests of hydroacoustic communications (Fig. 6)
- 6 months test deployment with real time transmission of bottom pressure data at the DOLAN mooring site (60 nm off Canary Islands)

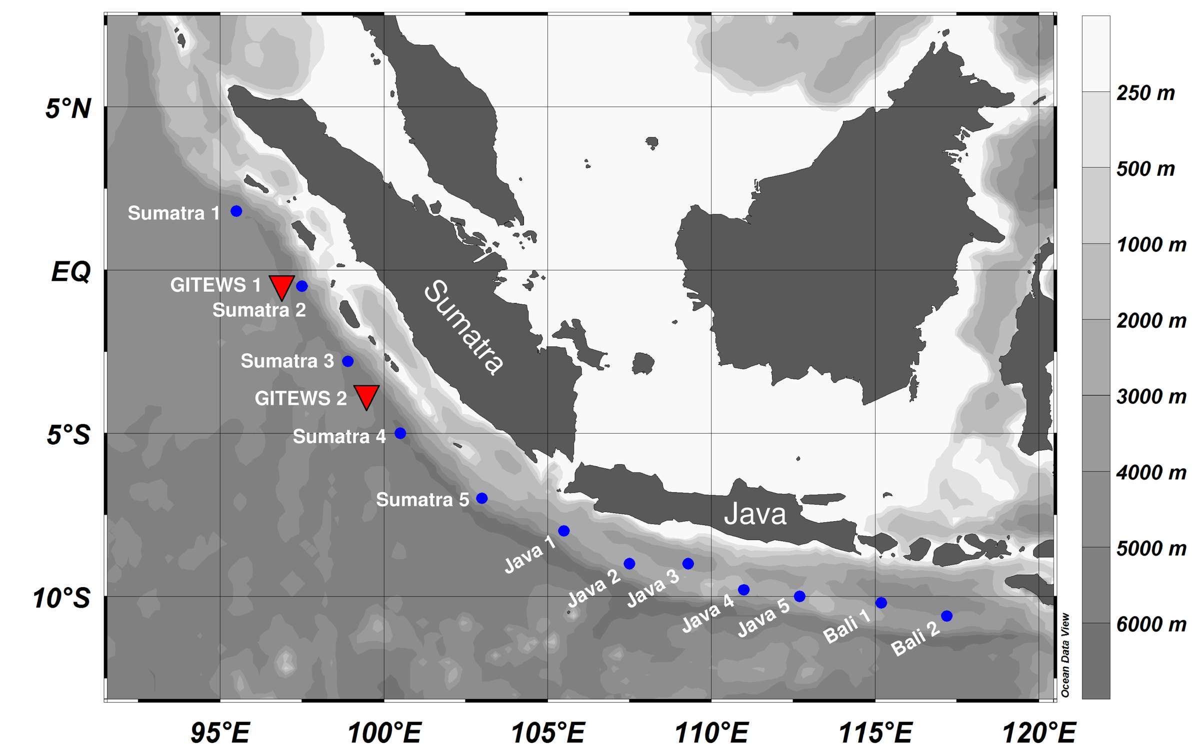


Fig. 7: Proposed GITEWS deployment positions off Indonesia [9]. Triangles mark two surface moorings already deployed in 2005. Sumatra 1-5 and Java 1-5 (dots) are scheduled for deployment in April 2009, five of these with PACT.

7 Scheduled deployments in GITEWS

5 PACT systems are scheduled for their first deployment as a part of GITEWS off Indonesia (Fig. 7) by RV Sonne during April 2009

Acknowledgements

The development of PACT was founded by the Federal Ministry for Education and Research (BMBF) as a part of the German-Indonesian Tsunami Early Warning System (GITEWS). The bottom unit was developed by Michael Busack and co-workers from OPTIMARE Sensorsysteme AG, Bremerhaven. The HAM.NODE acoustic modems were developed by Markus Motz and co-workers from develogic GmbH, Hamburg. We acknowledge the technical advice of University of Rhode Island and MARUM, who also supported at-sea test opportunities at the DOLAN mooring.

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