Real time Monitoring System for Earthquakes and Tsunamis (DONET)

Yoshiyuki Kaneda
Japan Agency for Marine-Earth Science and Technology (JAMSTEC)
POGO@Seoul Presentation
Earthquakes in the Nankai Trough

M8+ class earthquakes occur every 100-200 years.
The historical EQs. around the Nankai trough

<table>
<thead>
<tr>
<th>Year</th>
<th>CD(TONANKAI)</th>
<th>E(TOKAI)</th>
<th>AB(NANKAI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1707</td>
<td>+</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>1854</td>
<td>+</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1944</td>
<td>+</td>
<td>+</td>
<td>+</td>
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</tbody>
</table>

1707: CD(TONANKAI) + E(TOKAI) + AB(NANKAI)
1854: CD(TONANKAI) + E(TOKAI) → 32 hours AB(NANKAI)
1944: CD(TONANKAI) + E(TOKAI) → 2 years AB(NANKAI)

M8 class EQs. are occurring with the interval of 100-200 years.

Complex recurrence patterns!
Simulation of Earthquake Occurrence in the Nankai Trough

01009y_297d_22h_14m_24s

Relative velocity along to the plate boundary

Nankai  Tonankai  Tokai

Coupled (Non Earthquake)
Variations of recurrence patterns are simulated qualitatively. First ruptures are starting from the Tonankai seismogenic zone. These results are consistent with past two earthquakes 1944/1946 and 1854 EQs.

The Tonankai seismogenic zone is very important field to understand the recurrence system of mega thrust earthquakes around the Nankai trough.
Dense Ocean floor Network System for Earthquakes and Tsunamis

DONET

Real time monitoring system for Seismogenic zone
Concept of DONET

Number of Science Node: 5 Nodes
Number of User Interface: 8 ports / Node
Power Distribution: 30 W / Port
Data Transmission: 50 Mbit / s / Port
Precise Timing Control: < 1 μ sec
Ground Motion Sensing System

Observation Target: Broad Band Phenomena

Long period seismic wave: $0.001 - 0.1 \text{ Hz}; 1 \times 10^{-9} \text{ m/s}^2$ – (at 0.05Hz)

Micro earthquake: $0.1 - 100 \text{ Hz}; 1 \times 10^{-7} \text{ m/s}^2$ – (at 10Hz)

Large earthquake: $0.01 - 100 \text{ Hz}; -19.6 \text{ m/s}^2$ (at 10Hz)
Pressure Sensing System and Peripherals

Observation Target: Broad Band Phenomena

Crustal Deformation: 1 day - 100 sec; >1 Pa
Tsunami: <100 sec; >1 Pa
Long period seismic wave: 0.001 - 0.1 Hz; >1 Pa
Micro earthquake: 0.1 - 100 Hz; >1 Pa
Large earthquake: 0.01 - 100 Hz; >3 MPa
Redundancy:
Equipping redundant configuration on backbone cable and node

Expandability:
Branching unit enables wide-spread distribution of observation points. Node plays the role of hub that connects underwater instruments to the backbone cable system.

Replaceable function:
Replacing observation unit at the seafloor by using underwater removable connector

Maintainability:
Operation on the seafloor by using Remotely Operated Vehicle (ROV)
Installation of Science Node

- Installed Termination Equipment 33-43.344N, 136-33.209E, Depth: 2009m
- Construction of Installation hole for seismometer
- Japanese research ROV Hyper Dolphin
- Installation of sensors 33-38.911N, 136-36.210E
Movie of DONET deployment
Installation of DONET (2011 Jan.)

8 Observatories are working
5 Nodes are deployed

Construction of Installation hole for seismometer

Deployment of extension cable

Installation of sensors
Choosing appropriate sensors for target phenomena

DONET sensor chooses seismometers and pressure gauges suitable to observe very small to large earthquakes, Tsunamis, and slow ground deformation.

We need set of sensors of very broad frequency range and wide dynamic range.
Earthquake early warning

The red parts show the DONET detects earthquakes earlier than land stations.
The red parts show the DONET detects tsunamis earlier than land stations.
2010/08/13 21:19 (UTC) Mariana
(M=6.9)

Location: 12.5N, 141.5E
Depth: 10km (USGS)

Broadband seismometer
Strong motion accelerometer
Seismic wave
Observed Tsunami
Pressure gauge

(a) pressure-tide
Mainshock
Tsunami
Aftershock

(b) filtered 100-2000 sec

Pressure gauge
The seismic signals recorded by the DONET installed in the Kumano-nada reached 5 to 10 seconds earlier than land stations.
Tsunami observation by the ocean-bottom pressure gauges of DONET: An earthquake off Marianas on 13. August, 2010

- 21:19 August 13, 2010 (UTC)
- Epicenter: off Marianas
- Depth: 12 km
- Mw: 6.9
- Normal fault with some strike slip component
Comparison of the observed tsunami between the offshore and coastal stations

DONET Data

The tsunami signal is very clear in comparison with the background noise.
The seismic wave is also recorded at the data.
Non-linearity of tsunami propagation could not be required because of open sea observations.
DONET 2
A similar seafloor network system (DONET2) is needed for region off Kii Peninsula and Shikoku to decrease disasters caused by the seduction zone earthquakes in the Nankai Trough.

- Achievement of early detection of earthquake and tsunami in a wider area
- Advancement of earthquake occurrence simulation
- Development of Most Advanced and Leading Technologies
DONET2 High Voltage System

After DONET completion, move on to DONET2 with High Voltage System, then observational area expand to the Nankai seismogenic zone.

Middle-voltage system

Cable length 300km

DONET type NODE 5

(40 ocean floor sites)

DONET1

High-voltage system

Cable length 1000km

DONET type NODE over 10

(100 ocean floor sites)

DONET2
Improvement of Simulation Models

-Data assimilation-

**Observation data**

**Time range for data assimilation**

**Predict 2**

**Predict (n)**

**Optimization**

**Long-term predict using predict (n)**

**Without improvement**

**Improvement**

**Simulation model**
Expected slip velocity on the plate interface before the Tonankai earthquake

Slip acceleration before Tonankai earthquake
Red: DONET1, Blue and Green: DONET2
Expected seafloor crustal deformation before the Tonankai earthquake

Slip acceleration before Tonankai earthquake

DONET1 (Node E)

Tonankai Earthquake

Subsidence

Uplift

Vertical displacement

Years before Tonankai Earthquake

1 cm
Expected slip velocity on the plate interface after the Tonankai earthquake

00118y_122d_02h_56m_21s

After slip of Tonankai earthquake propagates westward and triggers nucleation of Nankai earthquake starts.
Expected seafloor crustal deformation after the Tonankai earthquake

Slip acceleration following after slip

After slip of Tonankai earthquake

Donet 2 (green) Donet 2 (blue) Donet 1 (red)

Nankai

Tonankai

Nankai

Subsidence

Uplift

Vertical displacement

5 cm

Days after Tonankai earthquake
DONET, DONET2, and DONET3

Extended Part

Tokyo
Osaka
Nagoya
Collaboration and Integration

Further, we have to develop more network systems.

The international collaboration is very important.
Connection of NantroSEIZE borehole observatories

These observatories will be connected to DONET to assure long-term monitoring.

Location of the borehole observatories are planned within the reach (10km or 20km) of DONET.

Connection of the borehole observatories will be funded as a part of JAMSTEC’s borehole observatory project (not by DONET).
Appearance of Installation of Long-term borehole measuring device

[photo] descent to moat grinding borehole of the appearance of installation of long-term

The photograph of appearance of work for seafloor at an unmanned probe on Dec. 8th, 2011

Video (five times faster)

Head_Landing_5times.avi on desktop

Reference: CDEX/JAMSTEC
Advanced estimation of the earthquake and Tsunami

Evaluate of Seismic Linkage around the Nankai trough

- Prevention and mitigation
- It’s important to collaborate with many countries
Thank you for your attention