S-NET PROJECT, CABLED OBSERVATION NETWORK FOR EARTHQUAKES AND TSUNAMIS

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Abstract: The S-net project is an undertaking to construct a large-scale ocean floor network of cabled 150 observatories around the Japan Trench. The S-net covers a wide region of 1000 km x 300 km off the Japan's Pacific coast at a station spacing of 30-50 km with using an optic cable of 5,800km in length. NIED (National Research Institute for Earth Science and Disaster Prevention) takes in charge of the project which is supported by MEXT (the Ministry of Education, Culture, Sports, Science and Technology) financially. The purpose of the S-net is to provide the in-situ and real-time earthquake and tsunami data which will be used for disaster prevention.

1. INTRODUCTION

The 2011 off the Pacific coast of Tohoku earthquake (Tohoku-oki Earthquake), the Mw 9.0 interplate earthquake associated with the subducting Pacific Plate along the Japan Trench, occurred off the Pacific coast of Tohoku district, the northeastern part of Japan, on 11th of March in 2011. A devastating tsunami over 10 m in height which was triggered by Tohoku-oki Earthquake hit the Pacific coastal area of the northeastern part of Japan. By the gigantic tsunami, the communities and infra-structures were severely damaged in and around this area.

The initially issued magnitude of Tohoku-oki Earthquake was 7.9. The tsunami warning system by the Japan Meteorological Agency (JMA) was a method based on land seismic data. The underestimated magnitude of 7.9 led to the coastal tsunami height of 3-6 m within the first 28 minutes of Tohoku-oki Earthquake accordingly. The big human damage might be a resultant of the initially issued under-estimated tsunami height. Then, the S-net project started in 2011 just after Tohoku-oki Earthquake in order to enhance the reliability of the tsunami warning.

2. EARTHQUAKE OBSERVATION NETWORK IN JAPAN

At the time back to the occurrence of Tohoku-oki Earthquake, the Japanese on-line real-time earthquake observatories were 1490 sites in land area and 55 sites in sea area (Figure 1). As we can notice two scientific cabled systems off Hokkaido district and off Tohoku district, earthquake observatories and tsunami meters were quite limited in number in the sea area along the Chishima Trench and the Japan Trench. Tohoku-oki Earthquake occurred at the plate boundary along the Japan

Trench where the observational gap existed.

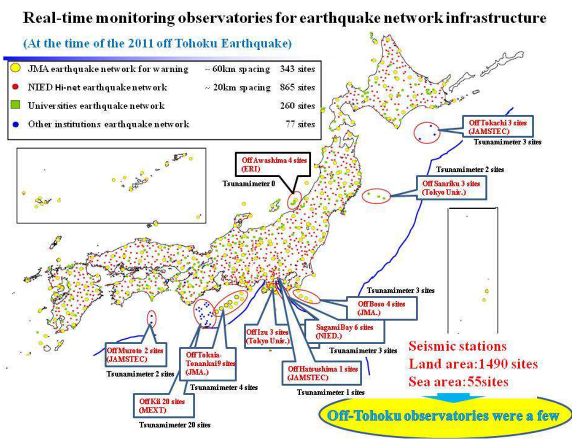

Figure 1: Map of the Japanese online earthquake observation network at the time back to Tohoku-oki Earthquake

3. EFFECTIVENESS OF SEAFLOOR WATER-DEPTH METER

The off-Sanriku (Tohoku district) scientific cabled system, equipped with three seafloor seismometers and two seafloor water-depth meters (TM1 and TM2), was operated by Earthquake Research Institute (ERI), the University of Tokyo at the time of Tohoku-oki Earthquake [1]. TM1, locating 75 km off the coast, caught tsunami of 5 m about 10 minutes before the tsunami coastal attack. And TM2, locating about 50 km off the coast, caught tsunami of 5 m, too, about 5 minutes before the tsunami coastal attack (Figure 2). The TM1 and TM2 data were not included in the JMA monitoring routine and were not effectively utilized for the tsunami warning and the tsunami height estimation in real time.

However, the TM1 and TM2 data showed that the seafloor water-depth meter is very important and very effective for tsunami warning and also for precise estimation of earthquake and tsunami source [2]. Then the S-net project for the disaster prevention started in the sea area along the Japan Trench in 2011 just after the Tohoku Earthquake.

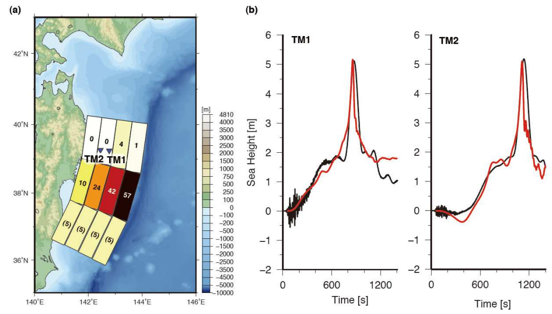

Figure 2: TM1 and TM2 tsunami records (Maeda et al.)

4. NETWORK CONCEPT OF S-NET

The S-net is the online and real-time seafloor observation network for earthquakes and tsunamis along the Japan Trench (Figure 3).

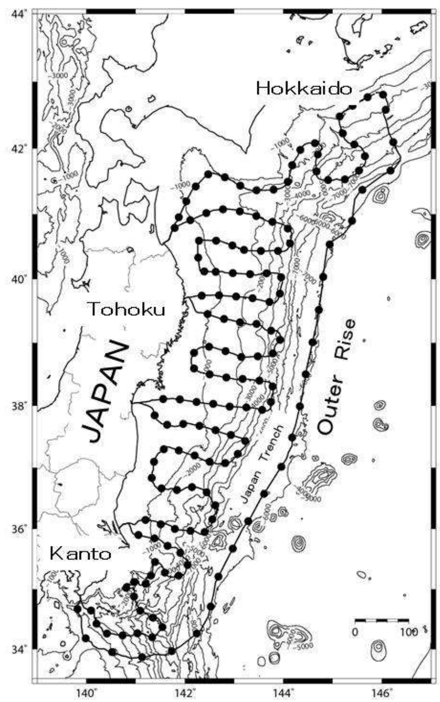

Figure 3: Map of the S-net

The 150 observatories cover the whole plate boundary associated with the subducting Pacific Plate under the Japan arc from off-Hokkaido to off-Kanto. The network covering area is vast, about 1000 km x 300 km in total. The observatory spacing is about 30 km in the east-west direction that is almost perpendicular to the Japan Trench axis and is about 50-60 km in the north-south direction that is almost along the Japan Trench axis. There exists one observatory in the focal region of M7.5 earthquake which may trigger a remarkable tsunami. The S-net is composed of six segment networks of about 25 observatories and 800-1,600 km optic cable. About 5,800 km optic cable is used in total to connect the 150 observatories to land.

The installations of the five segement networks except the outer rise segment network are scheduled to be finished before March, 2016 and the S-net observation will start within FY2015.

5. SEGMENT NETWORK OF S-NET

The conceptual scheme for the five segment network installed in the region between the coast and the Japan Trench is shown in Figure 4.

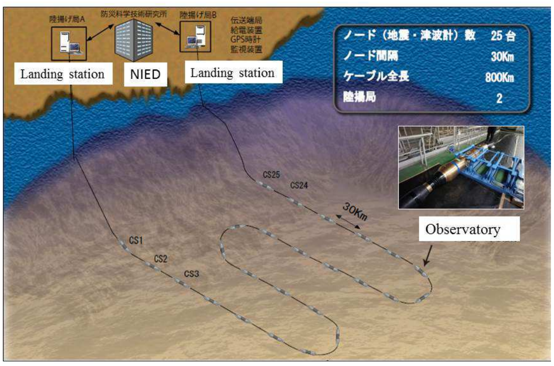

Figure 4: Schematic concept of the segment network of the S-net

Earthquake and tsunami observatories (ETOs) are equipped with optical cables and placed at 30 km spacing. Optical cables are laid for about 800 km with a continuous "S" pattern, by which the around 25 ETOs are distributed two-dimensionally [3-4]. The configuration of the Japan Trench outer rise segment network is different from the other five segment networks. Optical cables are laid for about 1600 km almost in the north-south direction along the trench axis. 25 ETOs are placed at 60 km spacing. Both ends of optical cables are landed. Observed data are transmitted bi-directionally to the both landing stations for redundancy. The two landing stations are the uninhabited control center of the offshore cabled system of the segment network, equipped with a power supply to the optic cable, a data storage system, a GPS clock and an emergency power supply. Time stamps are attached to the observed data based on the GPS clock at the landing station.

The observed data are transmitted from landing stations to NIED data center, JMA and related institutions via IP-VPN network. The S-net management center is placed in NIED. The center manages and operates each of the offshore cabled systems. Data backup center locates in the base isolation building of ERI, the University of Tokyo. And the center has a roll of functions of data storage and control sub-center of the offshore cabled systems for redundancy.

6. BURIAL OF THE OBSERVATORY AND CABLE

In the sea area off Hokkaido, Tohoku and Kanto districts, fishery works are very active. The trawling with using otter boards and the shellfish fishing with using dredge net are the risks damaging the S-net cables. We planned to bury the S-net cables and the S-net observatory packages one meter or deeper below the seabed in the sea area where water depth is shallower than 1,500 meters.

The burial of the observatory package blow the sea bottom is expected to have some advantages in the seafloor observations. The advantages are, 1) the ground coupling of the seismometers will be enhanced, and 2) the level of the noises exited by a water current and temperature changes around the observatory package is expected to be lowered. Such advantages are the key elements of the high quality observations. It was already proved by the experiment of the Sea of Japan cabled earthquake observatories that the burial of the seismometers is very effective to the seafloor seismic observations [5]. The burial of the S-net packages is expected to show a similar advantage in the tsunami observation by a buried water-depth meter.

7. S-NET OBSERVATORY

Figure 5 shows the S-net earthquake and tsunami observatory. Outer size is 34cm in diameter and 223 cm long. The observatory can be placed on the sea bottom down to 8,000 m water depth.

Figure 5: S-net earthquake and tsunami observatory

One of the main objectives of the S-net is to enhance the earthquake early warning system. Earthquake warning using S-net data can be broadcasted around twenty to thirty seconds earlier than the JMA ongoing system in the case of the earthquakes occurred near the Japan Trench, about 200 km off the coast. For the warning system, the observed waveforms should be neither distorted nor clipped. Therefore the seismic sensors should have a wide dynamic range and are rugged for strong motions and in further the failures of the seismic sensors should not happen. In order to answer these requirements, S-net observatory equips an analog output type accelerometer, a frequency output type accelerometer and a conventional velocity meters with a natural frequency of 15 Hz. The sampling is 24 bits and 1 kHz.

Two units of a high sensitive water-depth sensor are equipped to the S-net observatory as a tsunami meter. The resolution of water depth changes are expected to be caught in sub-centimeter order. The frequency outputs of the pressure sensors are counted at every 1 kHz. The temperature data from the water-depth sensors are also counted and are utilized to compensate the temperature dependent characteristics of the sensors in real time. The vertical component of crustal movements is also detected in the same way.

8. CONCLUSION

The purpose of the S-net is to provide the in-situ and real-time earthquake and tsunami data which will be used for disaster prevention. Such real-time data makes it possible to forecast an earthquake warning much earlier than the present JMA system. Also the data makes it possible to forecast an early tsunami warning of the next generation. The next generation of tsunami information or tsunami forecasting is expected to have highly raised quality and quantity with utilizing the real time offshore tsunami data produced from the S-net. The S-net will start to operate in FY2015 and will open a new era in disaster prevention.

9. REFERENCES

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