Information

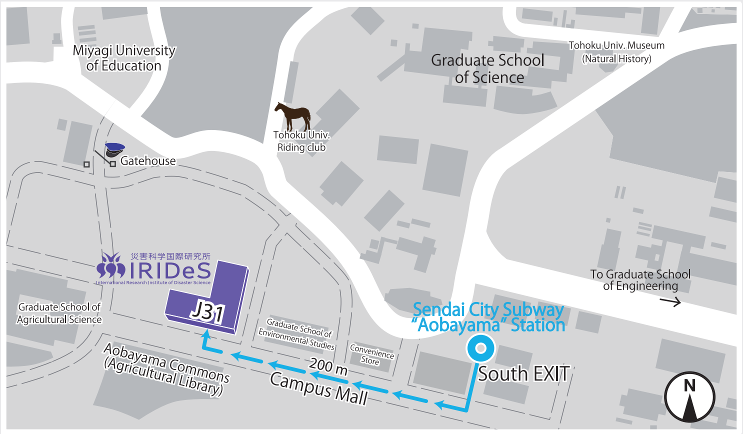
■ Open to the public ■

IRIDeS Exhibition Space shows research examples.
Entrance hall, 1st floor, Mon-Fri 10am-4pm, walk-up
Explanations available in Japanese/English
Closed on weekends, national holidays, New Year holidays and other irregular days.

【Access】

IRIDeS, Tohoku University
468-1, Aza-Aoba, Aramaki, Aoba-ku, Sendai,980-8572
URL: http://irides.tohoku.ac.jp/eng/

3 minutes from Aobayama subway station



Contact
IRIDeS Public Relations Office
Phone: +81-22-752-2049
Email: koho-office@irides.tohoku.ac.jp

Editor's Note

IRIDeS PR office staff members write articles and take photos by ourselves. We will keep searching for effective ways for disaster science communication.

(Natsuko Chubachi, IRIDeS Public Relations Office)

IRIDeS NEWs 2019 Published in March, 2019

Edited and Published by: IRIDeS, Tohoku University
Main writer and article editor: Natsuko Chubachi
Main photographer: Yukie Suzuki

Designed and Printed by: Meirinsha

Cover photo: from the field survey in Palu, Indonesia taken by Prof. Fumihiko Imamura

Conveying the results of practical disaster prevention research from TOHOKU to the world

IRIDeS NEWs

International Research Institute of Disaster Science Tohoku University

2019

Topics

< Report > Field survey of the tsunami damage in Palu, Indonesia
< Feature > How IRIDeS researchers have worked on recovery since the 2011 disaster
< Academic Research > Discovery and understanding of a fault being re-activated with an extreme short interval/ Development of a new damper that protects buildings from long-period ground motion/ Studying problems of *Kitakukonnansha* in provincial cities

IRIDeS International Research Institute of Disaster Science

Organization
IRIDeS

Hazard and Risk Evaluation Research Division
Disaster Medical Science Division
Human and Social Response Research Division
Disaster Information Management and Public Collaboration Division
Regional and Urban Reconstruction Research Division
Endowed Research Division
Disaster Science Division
G-Safety Inter-Graduate School Doctoral Degree Program on Science for Global Safety

Greetings

Director of IRIDeS
Professor Fumihiko Imamura

Throughout Japan, many disasters caused by natural hazards occurred in 2018, including the Northern Osaka Earthquake, the Western Japan Torrential Rain, typhoons, storm surges, and the Hokkaido Eastern Iburi Earthquake, all of which significantly affected communities. The year was assessed as being so severe that 災 (disaster) was selected as the official kanji character of 2018. Researchers at IRIDeS, led by the emergency investigations working group, have been collecting information, analyzing data, conducting fieldwork, and offering support since the immediate aftermath of these disasters.

I spent a great deal of time working in international disaster risk investigation over the past year. Particularly, in collaboration with the Indonesian Government, I conducted fieldwork in the city of Palu on the island of Sulawesi after the major tsunami on September 28, and provided support to the Indonesian Government following the Sunda Straits Tsunami on December 22. Taking account of the need for better disaster risk reduction, we as disaster scientists, must consider the appropriate preparation for and response to disasters that are difficult to predict.

I am pleased to be serving as the chairperson of the executive committee for the Second World Bosai Forum to be held in November 2019. The First World Bosai Forum in 2017, in which IRIDeS fully participated, was a major success. We are working toward the same success for the second forum, which connects Tohoku and Sendai disaster-related findings with the global situation.

Eight years have passed since the 2011 Great East Japan Earthquake, and the importance of research and solutions focusing on disaster prevention and mitigation is only increasing. We appreciate your continuing support and collaboration.

CONTENTS

Report

Photo 1

Photo 2

Photo 3

Photo 4

Photo 1 A building located close to the coastline; the tsunami reached the red line in the photo in Palu

Photo 2 Prof. Imamura conducting an on-site survey in Palu Bay

Photo 3 A bridge along the estuary coastline that was destroyed by the tsunami in Palu

Photo 4 The first floor of the building in Photo 1. The lack of mud traces indicates fast water flow

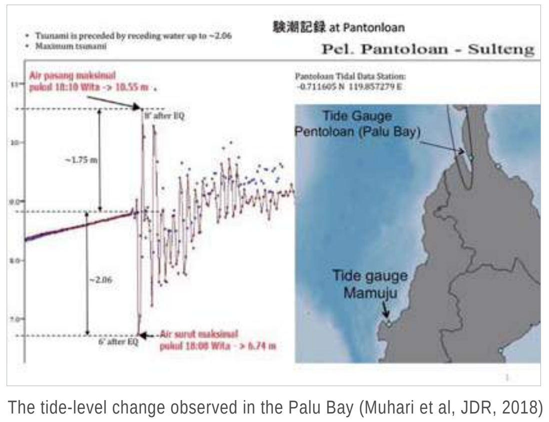
(Photos provided by Prof. Imamura)

Field Survey of the Tsunami Damage in Palu, Indonesia

A M7.5 earthquake occurred on September 28, 2018, at 6:02 pm (7:02 pm Japan time) on the Indonesian island of Sulawesi. A significant amount of damage was caused by the earthquake, subsequent tsunami, liquefaction, and landslides. On October 4–6, Prof. Fumihiko Imamura (Tsunami Engineering) of IRIDeS conducted the first field survey to investigate the damage caused by the tsunami in and around the major city of Palu in collaboration with other researchers and government officials in Indonesia. After returning to Japan, he reported his observations to IRIDeS on October 11.

Based on the water level differences in the tide-level records observed by the Indonesian government at that time, a tsunami with a wave height of 4 m occurred exactly during high tide and arrived six minutes after the occurrence of the earthquake. The tsunami was large and arrived at Palu Bay, which was not close to the epicenter of the earthquake, within a short period of time. Prof. Imamura observed that the water level in Palu Bay was several tens of cm different from that recorded in other areas, such as Mamuju in the coastal area of Sulawesi Island, and that the wave characteristics were considerably different. He noted that the tide-level record obtained from Palu Bay was particularly valuable for its ability to reveal the actual nature of the tsunami that struck Palu.

Prof. Imamura also reported that buildings were damaged in Palu from the coastline to approximately 200 to 300 m inland. The first floors of the buildings located near the coastline were destroyed, and the lack of traces of muddy water indicated that the water current was fast. Further, ground subsidence was confirmed. Based on eye-witness reports, the tsunami may have reached a wave height of 10.4 m because of splashing. The large tsunami in Palu Bay was likely caused by an underwater landslide caused by shaking instead of the earthquake itself. Prof. Imamura supported this observation using topographical maps to explain the scale and direction of the landslide.



The tide-level change observed in the Palu Bay (Muhari et al, JDR, 2018)

IRIDeS Emergency Investigations and Reporting Meetings in 2018

Other Activities

In addition to the above, multiple IRIDeS researchers conducted emergency analysis and on-site investigations to support survivors in the Northern Osaka Earthquake and the Hokkaido Eastern Iburi Earthquake. These earthquakes occurred on June 18, 2018, and September 6, 2018, respectively. Further, researchers held a debriefing session at IRIDeS. We also analyzed the data based on the torrential rain that occurred in July 2018 over western Japan and based on the earthquake that occurred in Kumamoto on January 3, 2019. The results of these surveys and analyses have been published on the IRIDeS website (http://irides.tohoku.ac.jp/eng/).

How IRIDeS Researchers Have Worked on Recovery Since the 2011 Great East Japan Earthquake

Feature

On March 11, 2019, it has been 8 years since the Great East Japan Earthquake. As one of its missions, IRIDeS has been contributing to disaster recovery, with researchers from various fields conducting research in recovery as well as being involved in practical recovery activities. Now that the first stage of many reconstruction projects has been completed and the landscape of the affected areas has undergone major changes, engineering, medical, and social science researchers were asked to provide a progress report on the activities so far.

Study field 1 Radiology

Working on research and communication on radiology and radiation exposure

Disaster Medical Science Division
Professor Koichi Chida

Well before the Great East Japan Earthquake, I was already involved in research, education and practice in the field of radiology and radiation exposure. Following the Fukushima Daiichi Nuclear Power Station (F1NPS) accident, Miyagi prefectural government requested Tohoku University to help their accident response. Thus Tohoku University Hospital became the center for the examination of evacuees from within 30 km of the F1NPS and performed decontamination of evacuees when required. I cooperated in the creation and implementation of this work.

On March 15, 2011, I also started providing support for the "Nuclear accident inquiry counter," established in the Miyagi Prefectural Office. Many telephone inquiries were made, asking about the influence of radiation, among other things. In general, prefectural officials responded directly to telephone queries, and I acted as an advisor to the officials. But in cases specialized knowledge was required, I answered the queries myself. Responding to a wide range of inquiries from local governments, medical institutions, and the public over a period of about a month, I become keenly aware of the extent to which the scientific knowledge of radiation was lacking in society. Thus later I decided to create pamphlets for the public, especially for children and their families, that provide basic knowledge of radiation and its impact on life. The contents include definitions and descriptions of radiation and exposure, their impact on health, necessary precautions in daily life, and things that are not yet completely understood in science. These pamphlets are now widely used especially in Fukushima Prefecture. Other than the pamphlets, I have been making efforts for science communication with the public, through a lecture on radiation education held in collaboration with an IRIDeS disaster risk reduction education specialist, joint development of radiation education materials with Fukushima Medical University faculty members, and public seminars on radiation and protection.

I have also conducted research to illuminate the effects of radiation on the human body from a new perspective. Recent studies have found that exposure to an even smaller dose than previously thought could damage lens of the eye, causing cataracts and other injuries. Research team members and I published a paper to show a new means to accurately measure exposure dose for the lens of the eye, making a recommendation for appropriate protective methods for radiation-related medical personnel [1]. This study outcome has the future potential for protecting the eyes of workers involved in decommissioning work. We have also found a means of estimating the dose of radiation received using a small amount of blood [2]. In the future, even when dosimeters are not available, it could become possible to measure exposure easily. In addition, I was involved in development of radiation-related equipment, including radiation inspection equipment that can be used even during power outages and patented real-time radiation exposure dosimeters for patients. Those dosimeters are safer and easier to use and can measure radiation effects more reliably than conventional ones. [3]

Four kinds of pamphlets on radiation targeting at four different age groups: for early/senior elementary school children, for their parents, and for their grandparents. The pamphlets were created responding to the results of questionnaire surveys conducted beforehand at elementary schools in Fukushima prefecture.

In October 2018, I presided over the Autumn Scientific Congress of the Japanese Society of Radiological Technology held in Sendai, which had the theme "Seven years of reconstruction and studies in radiological technology after the disaster." In the venue we exhibited research items belonging to IRIDeS and disseminated our activities to participants from across the country. Also, I have acted as a supervisor for the radiation emergency response training for accepting exposed persons which is held once a year at the Tohoku University Hospital.

I will continue to explore radiology and radiation exposure through research, education and practice. Over the past eight years, understanding of radiation exposure has been deepened in Fukushima prefecture, and now the knowledge gap between Fukushima and areas outside is a challenge. I would like to keep communicating about radiology in various places in the future.

Study field 2 Civil engineering

Providing practical engineering supports for reconstruction projects

Disaster Information Management and Public Collaboration Division
Associate Professor Katsuya Hirano

I have participated in many reconstruction projects in Miyagi and Iwate Prefectures, and particularly, in Ishinomaki and Onagawa in Miyagi Prefecture. In Ishinomaki, I have been working in the support team with Prof. Yasuaki Onoda and Assoc. Prof. Michio Ubaura (concurrently serving with IRIDeS) of Tohoku University Graduate School of Engineering. The team has covered all fields of civil engineering, architecture, and urban planning. We have been involved in most reconstruction projects in Ishinomaki such as the city center as well as in the projects on the peninsula and in the villages. In Onagawa, I have been the chairperson of the Reconstruction Design Review Board.

I was also involved in the seawall construction. In addition to supporting the formulation of the seawall design guidelines in Iwate and Miyagi Prefectures, I also assisted in the individual plans for the seawalls. Since the seawalls generated widespread social debates, I proceeded with a struggle. Despite seawall advantages such as protecting the area from tsunami and storm surges, there are disadvantages in terms of the expensive construction, ongoing maintenance costs, and possible damage to the environment and landscape. Those who opposed the seawall wanted no negative impact; however, based on reality, I worked hard to reduce the negative effects from 100 to 90.

For some reconstruction projects, I even created preliminary design drawings with team members; however, my main job as an expert was to provide advice to improve the design quality as much as possible. As designs can be both good and bad depending on the designer and because the residents will continue to live in the town for years, the engineering experts endeavored to ensure a town that is easy for people to use, easy to maintain, and attractive to look at. However, we listened to the municipalities and residents and revised the plans when necessary as civil engineering is a collective process.

Frequent inter-project adjustments were also made. For example, the Ishinomaki city center projects were divided into ones of roads, rivers, coasts, cities, and houses, and each project came under a different jurisdiction. The primary contractors also worked on national, prefectural, and city projects. Such sectionalism made the decision-making extremely complicated and fragmented; nevertheless, we endeavored to manage any conflicts so as to be able to deliver consistent urban development projects. Moreover, although the municipality had the primary responsibility for these reconstruction projects, as major infrastructure is mostly a prefectural management responsibility, it was impossible for the municipalities to proceed alone. As we were positioned between the prefecture and the city, we also had a coordinating role to ensure that the projects progressed smoothly.

Continued on page 5

Study field 2 continued

Involvement in these reconstruction projects did not directly lead to civil engineering research papers as the implementation basically involved the gathering of existing knowledge and applying it amid the current systems and constraints. However, I think these records should be archived for future generations, and these experiences flexibly leveraged in response to Nankai megathrust earthquakes in the future.

In developing countries, reconstruction is often regarded as a case of Build Back Better,[4] which increases security compared with before the disaster. The disaster areas of the Great East Japan Earthquake need to be seen in a different context, however. The challenge of Tohoku disaster areas has been how to establish a sustainable city in an area that was flooded by the tsunami and reduced to bare land. I believe Tohoku's Build Back Better is a matter of how to create a low-cost compact town where people can actively live, adding new landscapes and economic attractions and solving regional problems, in this era of declining population in Japan.

Many people in the Tohoku disaster area have been engaged in the reconstruction projects, but it is expected that going forward many of these people are going to leave, resulting in a decrease in the population, which could be difficult for the town. Therefore, we need to consider how we can ensure continuity in this town. Although this is not related to my physical engineering specialty but is a non-physical management problem, I hope to continue to support it.

Onagawa, April 12, 2011.

Onagawa brick street neighborhood in front of the station, September 25, 2016. This district was designed and supervised by the Onagawa Town Reconstruction Urban Development Design Committee, of which Associate Professor Hirano is the chairperson, and received the 2018 City Landscape Award (Ministry of Land, Infrastructure and Transport Award).

※ All photos were taken by Assoc. Prof. Hirano

Study field 3 Urbanology

Bridging people's knowledge and recovery systems in affected areas

Inter-Graduate School Doctoral Degree Program on Science for Global Safety
Associate Professor Michimasa Matsumoto

I have been involved in the reconstruction of Toyoma District in the coastal area of Iwaki City, especially of Usuiso District. I have regularly attended the Usuiso Reconstruction Committee meetings and participated in the Umimachi Toyama Civic Council meetings as an observer. My main role has been to help build connections between local communities and the national/regional governments, and ones among the people within the local communities, serving as a catalyst for reconstruction. Specifically, new and unfamiliar knowledge was introduced to local communities to proceed with reconstruction, but such knowledge can be rooted only when local customs are recognized and respected. My role was to understand both the local community knowledge and the official recovery systems and to bridge the local governments and the residents of affected areas, and also between the residents themselves, as they tend to be in conflict. In other words, I have translated knowledge and helped "traffic control" in the decision-making process.

I have always been concerned about how to deal with the sense of distance with the residents. If the situation becomes one of too much dependence on an observer like me, then it would hinder self-sustaining recovery. Further, although experts have been trained to handle and process relevant information, the difference in the amount of information the general populace has is not as much as it was in the past, because of developments in information and communication technology today. Hence, I have considered the residents as equals, and instead of leading them, I have worked alongside them while cheering them on. At one time, I decided to give a frank opinion to a community leader, when community activities reached a standstill, and it ended up seriously angering him. At another time, residents argued me down, saying "Professor, I think you got it wrong." I provided suggestions, but it has been my goal to ensure that local people decided whether to accept them. These days, I intentionally keep my involvement to a minimum so that residents can continue without any problems even in my absence, although honestly I miss working with them. I consider that, through various trials and errors, now local residents take initiative in building their own community, based on appropriate and collaborative division of roles between the government and the residents.

I believe that Japan's biggest challenge, regardless of the affected area, is the development of local human resources. It is important to nurture the generation below age 60, so that people in their 70s and 80s who led the recovery from the disaster can pass the baton to younger people. The formation and structure of human relationships in the local communities is also an issue related to disaster risk reduction in the entire nation. This is because if human relationships were built at a minimum during non-disaster time, then it would be possible to respond even during disasters. For example, if one participates in the routine handing of notices for circulation and involves oneself in garbage collection, weeding, and festivals, one can understand the situation in the neighborhood and within the town. If these relationships are established, then "cooperation" in the event of a disaster naturally emerges. Human relationships fostered from the past are often considered a burden and are declining in many areas, but given the experience of the 2011 disaster and the reconstruction process, one should recognize once again that forming a certain level of interpersonal relationships is necessary for disaster risk reduction as well. In the sense that freedom was experienced once, we need to consider a new "form of connections" among people that is suitable to present-day society and that contributes to disaster response as a result.

Although the definition of *fukko* (disaster recovery/reconstruction) varies from person to person, I have been supporting the affected areas through an understanding of it as the "restoration and reconstruction of the spontaneous order." Unlike engineering, social science does not constitute an implementation wherein most results take a concrete form, so it may be difficult to understand the results. To evaluate the recovery that I was practically involved in, it is important to await the judgment of future generations. Society is originally a multilayered entity and is difficult to understand. It does not change dramatically after a disaster, and basically, the characteristics before the event get drawn in as is. Social science searches for something that constitutes the basis of people and society, to observe "as objectively as possible" the symbolic representation of the story weaved by people and society, and to then make a "modest" proposal. It is important to avoid oversimplifying and sensationalizing things for understanding, analysis, and making proposals.

August 5, 2016: The Usuiso City Planning Committee Meeting held at Shuutokuin Temple

June 30, 2018: Events held at the Usuiso coastline

※ All photos taken by Assoc. Prof. Matsumoto

1) Haga Y, Chida K, Kaga Y, Sota M, Meguro T, Zuguchi M. "Occupational eye dose in interventional cardiology procedures." *Scientific Reports*, 2017 Apr 3;7(1):569. doi: 10.1038/s41598-017-00556-3.

2) Sun L, Inaba Y, Sato K, Hirayama A, Tsuboi K, Okazaki R, Chida K, Moritake T., "Dose-dependent decrease in anti-oxidant capacity of whole blood after irradiation: A novel potential marker for biodosimetry." *Scientific Reports*, 2018 May 9;8(1):7425. doi: 10.1038/s41598-018-25650-y.

3) Nakamura M, Chida K, Zuguchi M, "Red emission phosphor for real-time skin dosimeter for fluoroscopy and interventional radiology." *Medical Physics*, 41(10), 2014.

4) Build Back Better: increase disaster risk reduction capabilities in a country or community through a post-disaster recovery and reconstruction process, incorporating restoration of infrastructure and social system and revival of livelihood, economy and environment in an integrated manner. Build Back Better is one of a priority actions in the Sendai Framework for Disaster Risk Reduction 2015–2030 that was formulated at the Third UN World Conference on Disaster Risk Reduction.

Challenging Conventional Wisdom: Discovery and Understanding of a Fault Being Re-activated with an Extreme Short Interval of Six Years

Disaster Science Division Associate Professor Yo Fukushima

Discovery of an exception to rare movements of active faults

Active faults are faults that have experienced repeated ruptures in the past and are likely to cause earthquakes in the future. The cause of intraplate earthquakes shallow in the Earth's crust is an abrupt rupture of such active faults. The number of active faults identified on the islands of Japan is approximately 2,000. Naturally, large intraplate earthquakes occur once per a few years somewhere in Japan. The frequency of earthquake occurrence along a single active fault, however, is rare – once per a thousand to a few tens of thousands of years on average [1], reflecting the slow strain accumulation in the crust.

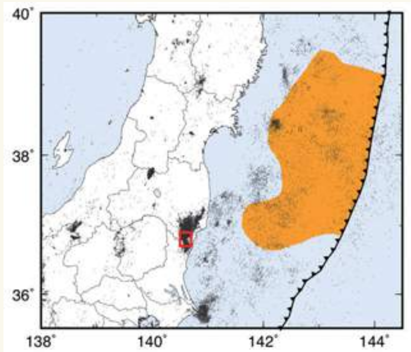
A new study led by Dr. Yo Fukushima, Associate Professor of IRIDeS, discovered that an active fault in northern Ibaraki Prefecture, approximately 130 km north of Tokyo, had ruptured twice on March 19, 2011 and December 28, 2016, with a time interval of only five years and nine months. The research team proposes that the 2011 Great East Japan Earthquake is the cause of these movements. Discovery of this exception to the widely accepted conventional wisdom of infrequent ruptures of active faults leads to updating the way we see earthquake generation on active faults and changing the way we assess future earthquake occurrence.

Evidence and cause of reactivation of an identical fault within six years

Fukushima's expertise has been on the satellite geodesy. There are a number of earth-observation satellites flying around the Earth that are equipped with a specific type of radar called synthetic aperture radar (SAR). A SAR antenna on a satellite emits and receives microwaves to know about the change over the ground surface. More specifically, by detecting the difference in the return time of the microwave signals at two different timings, we can measure the amount of ground displacements that occurred during the acquisition interval on a wide area in the looking direction of the satellite radar.

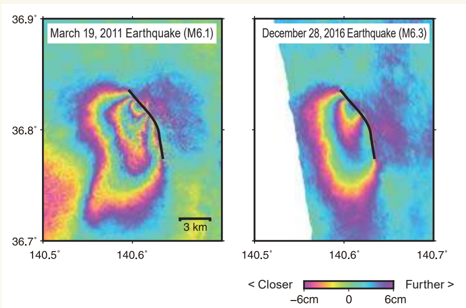
Just after the 2011 Great East Japan Earthquake, Fukushima processed the data of Advanced Land Observing Satellite (ALOS) operated by the Japan Aerospace Exploration Agency (JAXA) to map the ground deformation on northeastern Honshu Island, which included the area of the magnitude 6.1, March 19, 2011 earthquake. When the magnitude 6.3 earthquake on December 28, 2016 struck, Fukushima analyzed the data of ALOS-2, successor of ALOS, caused by the event upon request from another researcher. He did not, however, intend to look further in detail about this event at first. Approximately 5,000 earthquakes on a yearly average are recorded by the Japanese seismological network, and many of them fall into the same region [2]. The northern Ibaraki area in particular had experienced a swarm of earthquakes after the 2011 megaquake, including a few earthquakes larger than magnitude six. "The magnitude 6.3 event was one of them", Fukushima states.

Fukushima was much more intrigued by the earthquake when he heard from his room-mate colleague Professor Shinji Toda that surface ruptures had been observed at the same location as the ones caused by the March 19, 2011 earthquake, and that an identical fault may have been reactivated. Could that really happen? Shouldn't faults be tranquil once they rupture? Maybe the surface ruptures were caused by some surficial process or landslides triggered by the earthquake? Fukushima, who had already computed the deformation caused by the two earthquakes, decided to investigate into further detail [Figure 1].

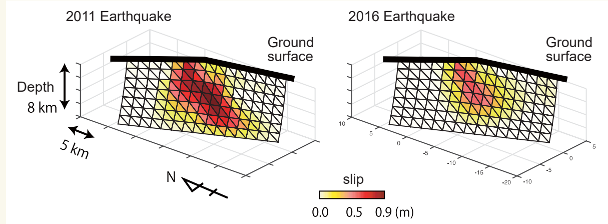


[Figure 1] The region in northern Ibaraki Prefecture (shown by the red square) where the two earthquakes occurred. Orange: The main segment of the plate interface that slipped during the 2011 Great East Japan Earthquake. Black dots: Epicenters of earthquakes of depths less than 30 km that occurred between March 11, 2011, and December 31, 2011.

A deformation map obtained by processing a pair of SAR images may contain signals from other geophysical processes (such as another earthquake) and noise. Fukushima applied necessary corrections, cropped the same area, and compared the cleaned deformation maps of the 2011 and 2016 earthquakes. Surprisingly, the surface ruptures (abrupt color discontinuities in the deformation maps) were placed exactly at the same locations for the two earthquakes [Figure 2]. Furthermore, the fault slip distributions estimated for the two earthquakes from the deformation maps indicated that the fault slipped in the same direction and the majority of the slipped area overlapped for the two earthquakes [Figure 3].



[Figure 2] Crustal deformation maps associated with the March 19, 2011, and December 28, 2016 earthquakes, obtained from satellite radar data analysis. Black lines indicate surface rupture of the active fault. One color cycle change corresponds to about 12 cm of displacement in the looking direction of the satellite radar.



[Figure 3] Fault slip distributions estimated for the March 19, 2011, and December 28, 2016 earthquakes.

In addition to these analyses, Fukushima's colleagues went to the site and investigated the features of displacements and fractures on the ground and human-made structures such as parapets of a bridge, something that cannot be known from satellite data. This survey additionally confirmed the repeating nature of the fault rupture. The double-check, from the sky and from on-site investigation, led the research team to conclude that the same fault was reactivated twice with the short time interval.

Now that the extremely rare phenomenon was confirmed, Fukushima asked himself why this could happen. To look for a clue, he analyzed the GNSS data that recorded displacement time-series in the northern Ibaraki region and surroundings [3]. If the region is very much deformed, it means that the amount of strain accumulation around the fault is large, and this could explain the early earthquake recurrence. The result of the deformation analysis was remarkable – the map clearly indicated a large strain localized around the fault [Figure 4]. Intraplate earthquakes in Japan commonly exhibit only subtle strain after their occurrence, but the level of strain after the March 19, 2011 earthquake was as large as that of the earthquake itself, which had never been observed for Japanese intraplate earthquakes. This period of rapid strain build-up coincides with the period where a wide-scale deformation has been taking place after the 2011 Great East Japan Earthquake. Fukushima and his colleagues inferred that the large-scale post-earthquake movement of the 2011 megaquake induced local deformation around the active fault, stressing the fault with a rate much faster than usual, and eventually caused the fault to re-rupture. The results were published in the journal *Nature Geoscience* [4] last year.

Future Prospects

Fukushima states that there remain a number of mysteries about the mechanism of earthquake generation on active faults. The Earth is extremely complex, and it is impossible to conduct realistic experiments to reproduce and validate the behavior of active faults. To know about past activities on active faults, trench surveys have been effectively used. By combining identification of strata offsets and dating, we can calculate the approximate intervals of fault ruptures. Researchers have widely adopted a model that assumes regular repeating of earthquakes based partially on the outcomes of trench surveys. "But our study made clear that this model is not applicable when a large external force is applied to the fault system," said Fukushima.

Has this kind of phenomenon occurred in the Earth before and in other places? Fukushima thinks yes. "But it is difficult to know that from trench surveys. We cannot distinguish two successive ruptures occurring with a short time interval." The trace of multiple ruptures is recorded in the strata when the events are temporally separated long enough for a new layer of strata to form in between.

The satellite geodesy can be a game changer. Since the early 1990s satellite SAR data have been widely provided to the research community, and analysis techniques have been rapidly developed. This rising trend is still continuing with the advent of new satellite missions. Based on such advancements, research on the mechanism of active faulting using satellite geodesy has been expanding. "The earth observation satellites cover most of the Earth's land surface, and the data are continuously archived. Large earthquakes occur not only in Japan but also in other countries, and we can study them with the SAR data." Finding other cases of extremely rapid fault reactivation using satellite geodesy may lead to development of a new earthquake occurrence model.

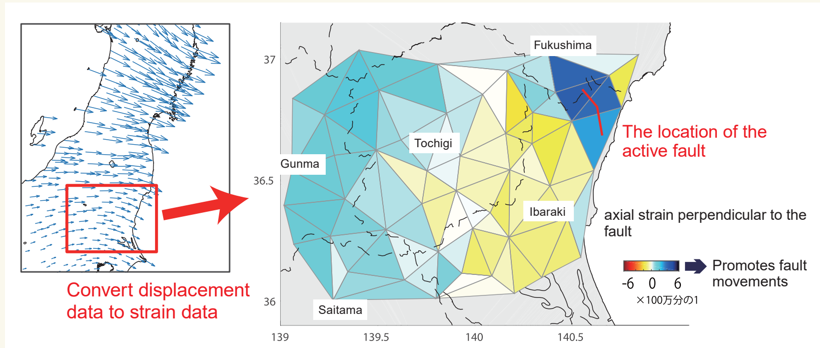
The research deciphered a mystery of a complex behavior of the Earth by conducting a series of careful analysis of high-quality data and logical build-ups in multiple disciplines. However, the inside story indicates that the process toward a discovery is not always elaborate or sophisticated. Human factors such as encountering clues by chance or relying on instinct took an important role for Fukushima's case, and this is perhaps ordinary for scientists.

1) Source: Geospatial Information Authority of Japan
http://www.gsi.go.jp/bousaichiri/explanation.html (in Japanese)

2) Calculated from the earthquake catalogue of the Japan Meteorological Agency, for a period of 2001-2010.
http://www.jma.go.jp/jma/kishou/know/faq/faq7.html (in Japanese)

3) Global Navigation Satellite System (GNSS) Earth Observation Network System (GEONET) operated by the Geospatial Information Authority of Japan.
http://www.gsi.go.jp/ENGLISH/page_e30030.htm

4) Yo Fukushima, Shinji Toda, Satoshi Miura, Daisuke Ishimura, Jun'ichi Fukuda, Tomotsugu Demachi, and Kenji Tachibana, "Extremely early recurrence of intraplate fault rupture following the Tohoku-oki earthquake," *Nature Geoscience*, doi: 10.1038/s41561-018-0201-x.



[Figure 4] Figure on the left shows the displacements in blue arrows that occurred between March 20, 2011 (one day after the first earthquake) and December 27, 2016 (one day before the second earthquake). Figure on the right shows the strain map calculated from the displacement data. Areas with a darker blue color indicate larger amounts of strain. The red line shows the location of the active fault.

Academic Research 2

Development of Devices that Suppress "Slow Shaking" of High-rise Buildings

Hazard and Risk Evaluation Research Division
Professor Kohju Ikago

When an earthquake occurs, various seismic motions occur such as wiggle shaking and slow shaking. The time associated with a single shake is called a "period," a sharp shake with a short cycle is referred to as a "short-period seismic motion," and a slow and large fluctuation with a long period is referred to as a "long-period ground motion." High-rise buildings commonly resonate with long-period ground motion; especially high-rise floors experience significant sway motion*.

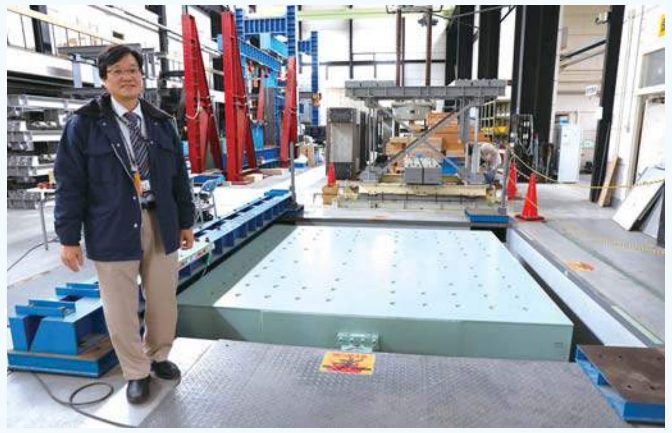
In Japan, especially after the Great Hanshin-Awaji Earthquake of 1995, an increased number of buildings were equipped with seismic isolation to mitigate earthquake shaking and prevent damage due to a large earthquake (there are seismic isolation devices also in the IRIDeS building). Dampers are attached to the seismic isolation structure to attenuate the shaking motion during an earthquake. Recently in high-rise buildings the number of different designs to install dampers has increased. However, while current dampers can effectively reduce building damage caused by sharp and short vibrations, they are not effective at preventing long-term shaking in high-rise buildings. If the number of dampers were increased to reduce the amplitude caused by rarely occurring long-period ground motion during earthquakes, there is a possibility of amplifying the shaking caused by frequently occurring short-period seismic waves.

The research team of Prof. Kohju Ikago has been working on the development of a new "tuned viscous mass damper" that protects buildings from long-period ground motion. This type of new damper system can absorb vibrations from a slow shake. The idea of "dynamic mass" used in this damper was proposed in Japan in the 1970s and was applied to the suspension of race cars abroad in the 2000s. However, Prof. Ikago's group was the first in the world to develop large-sized dampers that can be used to suppress the shaking of large buildings. They succeeded in performing experiments and producing life-size prototype dampers in 2009; in 2013, for the first time, their damping system was installed in a building in Sendai. Since then, they have been working on the development of vibration dampers that are effective at suppressing long-period ground motion.

Prof. Ikago set up a damper, under development, in a university laboratory setting (i.e., a shaking table capable of reproducing the movement of the ground caused by an earthquake), and is conducting experiments to determine how much shaking caused by earthquakes can be suppressed. According to Professor Ikago, "Earthquakes with higher magnitudes easily generate long-period ground motion, and many Japanese cities are on a sedimentary layer where the ground is soft, which easily amplifies long-period motion. Additionally, we have a forest of high-rise buildings and seismic isolation buildings susceptible to long-period ground motion; due to these conditions in Japan, the significance of developing effective dampers to respond to long-period ground motion is crucial." In the future, he anticipates that it will be possible to develop dampers capable of coping with both short-period ground motion and long-period ground motion.

According to Prof. Ikago, Japan is ideally situated to develop effective vibration dampers; furthermore, excellent products have been developed and accepted by society, which enhances their adoption for practical use. However, Japanese dampers are highly precise but expensive by global standards; therefore, their use in building designs can be a difficult sell. Furthermore, according to Prof. Ikago, "the expectation that vibration damping devices can handle all earthquakes is inaccurate." A normal damper is only effective for horizontal sway, and it does not mitigate vertical shaking. Moreover, any damper cannot tackle cases where the ground itself is displaced by an inland earthquake; therefore, the only possible countermeasure, in such cases, is to avoid building structures on or near active fault zones.

＊ Reference: Japan Meteorological Agency website
https://www.data.jma.go.jp/svd/eqev/data/choshuki/choshuki_eq1.html



Prof. Ikago standing next to the experimental equipment–shaking table (central green table)–at the Tohoku University campus. On getting an idea, he promptly designs a prototype and improves the same by repeatedly conducting experiments using the shaking table, which lead to practical applications.

Academic Research 3

Studying Problems of *Kitakukonnansha* (People Who Had Difficulty Returning Home at the Time of Disaster) in Provincial Cities

Human and Social Response Research Division
(left) Assistant Professor Tetsuya Torayashiki and (right) Professor Hiroaki Maruya

At the time of the 2011 Great East Japan Earthquake, the *kitakukonnansha* (commuters stranded because of a disaster) in the Tokyo metropolitan area garnered attention. In metropolitan areas, paralysis of the transportation network had created several issues, as many people had to give up on returning home and stayed in temporary accommodations, or even had a great struggle to walk home for a long distance.

At that time, the issue of *kitakukonnansha* arose not only in metropolitan cities but also in provincial cities, including Sendai. In Sendai City, it is estimated that approximately 11,000 people were stranded around the Sendai station area.** Furthermore, the influx of these people into designated evacuation centers, such as nearby gymnasiums of schools, caused those shelters to become overcrowded, and confusion arose about the evacuation center's administration. Yet, not all the relevant details of *kitakukonnansha* in provincial cities have been fully clarified. Even in provincial areas, it is important to set up appropriate measures that are suitable for the region, considering the fact that the number of people, flow of persons, and regional characteristics differ from those of the Tokyo metropolitan area.

With this in mind, Assist. Prof. Tetsuya Torayashiki and Prof. Hiroaki Maruya conducted an interview survey targeting municipal officials from 12 cities of South Tohoku (including Sendai), Kanto, Chubu, and Kansai regions to identify effective measures to address the issue of *kitakukonnansha* in provincial cities. Officials in municipalities where the Great East Japan Earthquake hit were asked questions about the specific situation at the time and measures adopted for improvement thereafter, and officials of other municipalities were asked about the measures that are currently in progress based on the characteristics of the region.

Survey results showed that most of the local cities that had experienced the earthquake did not have preventive measures set up to address the issue of *kitakukonnansha* at the time. However, the results also show that later, many of them established measures to reduce the concentration of *kitakukonnansha* at train stations when trains stop running because of the disaster and made arrangments to direct *kitakukonnansha* to places other than the designated evacuation centers for local inhabitants.

Additionally, it was observed that some municipalities which learned from the lessons from the disaster have developed effective solutions. For instance, the City of Sendai signed a "Temporary Accommodation Agreement" with companies such as commercial facilities and hotels around the station as well as agreements with organizations related to building technology to dispatch technicians to check the safety of the temporary accommodations. Based on these agreements, in case an earthquake strikes, the city can request the companies under the agreements to open up the temporary accommodations and on the other hand ask the organization to dispatch technicians who can judge the safety of the buildings of the accommodations. These arrangements can enable the accommodation of *kitakukonnansha* at an early stage after a disaster and can prevent excess influx into the designated shelters for local residents. These arrangements also reduce workload and the risk of safety verification work of the companies. Additionally, the City of Sendai has conducted the training for people working around the station to evacuate *kitakukonnansha* every year since 2014.

Prof. Maruya and Assist. Prof. Torayashiki published "A Guide to Address the Issues of *Kitakukonnansha* in Provincial Cities," which presents an outline of the problem and a summary of the advanced measures, including those of Sendai.** Assist. Prof. Torayashiki notes, "Through the survey, we found that there are differences in the approach to the *kitakukonnansha* issue depending on the region. We also found that some municipalities do not have specific know-how yet, despite an awareness of the need for measures to address the issue. It is our earnest desire that they refer to our report and guide."

＊＊ http://www.maruya-laboratory.jp/other01. Currently, this guide can be read at the exhibition space on the first floor of the IRIDeS Building.

2017 Training for evacuating *Kitakukonnansha* around Sendai Station
(Photo courtesy: Assist. Prof. Torayashiki)

IRIDeS Diary

Report from a Disaster Drill for Response to Earthquakes and Tsunamis in Usuiso District of Iwaki City, Fukushima Prefecture

On October 21, 2018, Assistant Professor Kazuya Sugiyasu of IRIDeS and his research group jointly conducted a disaster drill for potential earthquakes and tsunamis in Tairausuiso District (hereinafter Usuiso District) of the city of Iwaki, Fukushima Prefecture. I, a PR staff from IRIDeS, also attended this drill. The below is an account of my experience at the drill exercises.

About

Usuiso District

Usuiso District faces the sea. During the 2011 Great East Japan Earthquake and Tsunami, a 8.51 m tall wave crashed against the district and destroyed 87% of its buildings, killing 115 people[1]. The Fukushima Daiichi nuclear disaster was also a great blow to the district's fishing industry. In 2010, the population of the Usuiso District was 766 people[2], but it had dropped to 156 people[3] by 2018.

Usuiso District was greatly damaged by the disaster, but it has been rebuilding. The newly built houses are situated on higher ground, and trees have been planted to help defend against future tsunamis, to reduce the waves' impact. In summer 2018, the beaches of the district were reopened for swimming for the first time since the 2011 disaster.

The areas of greenery that were planted next by the coast in Usuiso District to attenuate the effects of tsunamis. The pine trees are beginning to sprout.

The drill

After the disaster, Sugiyasu and his group put in great efforts to support the recovery of Usuiso District. Starting in 2014, researchers both within and outside IRIDeS have collaborated with disaster risk reduction experts to hold a drill in the district. This drill takes place once a year and is managed by the townspeople themselves, with additional support from the research group, who also supervise the content of the exercises. Furthermore, the drills use technology to study the training scientifically. For example, a GPS logger is used to keep a record of all movements in space and time performed by the evacuees, and drones capture aerial footage of the evacuation.

Sugiyasu and his group, who are experts in disaster risk reduction, together with the local residents, hold in-depth discussions every year to refine the planning of the training exercises. For instance, during the last iteration of the drill, exercises were conducted to inform residents how to evacuate from the town by car. That drill was based on the experiences of the 2016 earthquake, which had an epicenter in the open sea of Fukushima. If everyone attempts to escape a disaster by car at the same time, chaos ensues. As a general rule, if it is possible to escape by foot, this should be done to avoid obstacles en route more easily. However, there are always some who cannot escape without a car, so Usuiso District does allow some residents to evacuate by car whenever it is required. Special evacuation routes are given to those cars to avoid creating traffic jams.

This was the fifth drill to take place since the 2011 disaster, and it was the first to be held after the physical reconstruction was almost finished in the district. In fact, it is the first to have been performed where all necessary material structures are in place. This time, Sugiyasu and his research group added new types of evacuation to the drill, such as evacuating people in wheelchairs and evacuating tourists from the beach. They spent the last minutes before the drill ensuring all the preparations were in place. I joined in the drill, playing a tourist.

Drones were used to gather aerial footage of the evacuation of tourists.

evacuating in a wheelchair

The day of the exercises

The day was clear, and there were no clouds in sight. At 8:30 am, a major tsunami warning was given, and the exercises finally began. The residents were divided into groups and went to their evacuation sites. But before they left, they placed a sign on their door saying "We have evacuated." The group leaders track these signs to ensure no one is left behind and flee themselves as well. The residents of the southern part of the district went to Toyoma Junior High School, their designated evacuation site. Other residents went to the Usuiso Meeting Hall, located on higher ground in the north of the district. Those playing the tourists on the beach went to the Usuiso Meeting Hall through the areas specifically planted for disaster risk reduction. The path toward the Meeting Hall is steep, but it took us around six minutes, running at top speed, to reach the evacuation site. A team of drone experts from Sugiyasu's collaborative telecommunications research lab and the company Soramusubi used aerial cameras to ensure no tourists were left behind. After everyone arrived at their evacuation sites, each group informed the ward head how many were in the group and the situation of the route they took to reach the meeting place. The first people arrived at 8:41 am, and the last came at 8:53 am. All 126 participants, from infants to the elderly, reached the meeting place in just a little over twenty minutes.

This sign was placed on every door to enable a quick reference for how many had been evacuated. It says: "Evacuated."

Assistant Professor Sugiyasu keeping records of evacuees' time of arrival.

Sugiyasu addressed the crowd of evacuees to end the drill with the following words: "With this drill we have seen that it is possible, even for people who are in wheelchairs, to evacuate the district in roughly 10 minutes from any location in the area. A tsunami might take only 15 minutes to reach Usuiso District, but in this drill, we have clearly seen that it is possible to evacuate everyone safely if you leave your homes within 5 minutes of the start of an earthquake. So, please remember that."

One after the other, the residents arrived at the evacuation area.

Review

After the drill

What left the deepest impression on me from the drill was just how quick and agile all the participants were. Fifteen minutes after the alarm had rung, nearly everyone had reached the meeting points. Even the tidying up following the drill was conducted efficiently, and the entire event ended well ahead of schedule.

I heard someone say, "Now that I've actually performed the evacuation procedure, I found some problems in the designated evacuation route to be solved." This comment and others like it showed that the participants gained something from the experience. More than seven years have passed since the 2011 earthquake, and in areas affected by the disaster, a steady decline in the numbers of people taking part in disaster drills has been evident. However, in Usuiso District, the same number of people took part in last year's drill and in this one, around 80% of the total residents of the district. Those involved in the drill, beginning with the ward head for Usuiso District, all judged that this year's exercises were a great success, and they immediately began planning the drill for next year.

One strong point of this drill is that it makes use of tightly knit human relationships together with advanced technology. The researchers regularly share their results with the townspeople. Sugiyasu commented that "The drills we perform here at Usuiso District always introduce pioneering ideas, but those ideas can only come into play because of the relationship of trust that exists between the researchers and the residents of the district. Now, many of the ideas for the drills have almost reached full maturation. However, some elements still must be revised. We hope to keep improving." Drone implementation is still in its experimental phase, but the goal is to eventually use drones in real evacuations.

1) City of Iwaki *Higashinihon daishinsai no shogen to kiroku* (Testimonies and records regarding the Great East Japan Earthquake), p. 35.
2) From the 2010 National Census.
3) City of Iwaki *Iwaki shi no jinko: Heisei 30 nen 4 gatsu 1 nichi genzai (The population of Iwaki as of April 1st, 2018)*, p. 9.

Activities

Activity 01

Leaving valuable historical data to future generations through networking

Associate Professor Atsushi Kawauchi

In Japan, efforts to save and leave valuable historical data related to disasters involving a network of historians, local governments, and citizens in the Kansai area first became apparent after the Great Hanshin-Awaji Earthquake in 1995. This movement was then followed by the launch of "historical document rescue network" around the country, which sought to preserve data while retaining the unique characteristics of each region. After the Great East Japan Earthquake in 2011, another movement gained momentum, which saw regions in the "historical document rescue network" unaffected by the disaster taking part in the remote rescue of historical material in disaster zones during times of wide area disasters.

As a result, the "Inter-University Research Institute Corporation Network Project for the Conservation of Historical and Cultural Data" was formally established in 2018. This project was initiated by Tohoku University, Kobe University, and the National Institutes for the Humanities, to promote research on the conservation of historical materials, the training of personnel/techniques in the handling of historical materials, and the utilization of historical materials by connecting universities across Japan and each region's "historical record net." In particular, IRIDeS at Tohoku University has played a key role in running the project. It has embarked on various ambitious endeavors, such as holding disaster science symposiums inclusive of historical perspectives, largely due to the collaboration of the humanities and science departments in 2018.

Post-disaster data rescue (Credit: Miyagi record net)

Associate Professor Atsushi Kawauchi, who is in charge of this project at IRIDeS, believes that the network took off due to "a sense of danger of losing historical and cultural materials around the country as a result of wide area disasters in recent years, as well as aging and declining populations in numerous regions." A large volume of historical and cultural records, especially those from the Edo period onwards, are thought to be scattered across Japan. This data would reflect real conditions in each region, including the social and economic situations of past eras, and how countermeasures were implemented during times of disaster. To lose these materials would be like losing vital clues to the answers to fundamental questions such as "Where did we come from?" "Universities in Japan, especially in the field of humanities, are now faced with the same challenge. This network was formed to allow scholars to further utilize and cooperate through the sharing of resources because we believe it is our responsibility to pass these valuable materials onto future generations," said Assoc. Prof. Kawauchi. The ultimate goal of the project is to digitize the data of the entire nation to make it available to the public.

Although disasters have destroyed many prized sources of historical data, this has also alerted us to the importance of preserving this data. Going forward, we shall continue to take advantage of this blessing in disguise, and strive to make better use of these telling records of humanity's relationship with nature by passing them onto future generations through the continued efforts of the network.

Activity 02

Announcing the launch of the 2nd World Bosai Forum in Davos, Switzerland

(from left) Prof. Imamura, Dr. Ammann and Prof. Ono

The "Symposium on Risk, Resilience, and Disaster Management," hosted by the Global Risk Forum (GRF), was held in Davos, Switzerland, on November 23, 2018. A total of 20 people participated, including representatives from UNESCO, the Joint Research Centre of the European Commission, as well as disaster management experts from various countries, and members of the media. Prof. Fumihiko Imamura, the Director of IRIDeS, was also invited to the symposium, along with other IRIDeS faculty members. He reported on his on-site research on the earthquake and tsunami in Paru, Indonesia and participated in a discussion on the importance of flexible solutions to disaster management and personnel training, alongside other honorable guests. The launch of the 2nd World Bosai Forum was also announced jointly by Dr. Walter Ammann (founder and the CEO of GRF), Prof. Imamura (chairperson for the executive committee of the 1st World Bosai Forum), and Prof. Yuichi Ono (Secretary general of the 1st World Bosai Forum). The second forum is scheduled to be held in Sendai, from November 9 to 12, 2019. Prof. Imamura stated his prospect that the 2nd forum would also be attended by multiple stakeholders involved in disaster risk reduction in government, academia, private sectors, the media, etc.

Public Relations Office Column "Forecasting"

Head, Public Relations Office
Kiyoshi Ito
Deputy Director and Professor of IRIDeS

2019 is the last year of the Heisei period (in the Japanese calendar). Exactly 50 years ago, in 1969, humankind landed on the moon for the first time through the Apollo space program. Those days were the peak of confidence in science, and it was thought that in 50 years human beings would certainly be living on the moon and earthquakes and disasters would be predicted as a matter of course. As you can see, the result is that we are reminded each year how natural phenomena are profoundly beyond human control and knowledge. Moreover, 30 years ago, in 1989, was the beginning of Heisei, with the stock market at its highest value in history and Japanese economy reaching its peak. The word "bubble" was given in retrospect. In those days, people in it, including myself, were all ecstatic believing that the economic boom would last forever. Prediction is impossible even for familiar events such as human economic activity. It was also the year that the Berlin Wall collapsed, an event that nobody expected. Speaking of expectations, 1999 was regarded as the year the Earth would be destroyed and met its unprecedented end after a century of predictions deemed the "Prophecies of Nostradamus," but naturally, nothing happened.

Eight years have passed since the Great East Japan Earthquake, an enormous disaster that it is said to happen only once in 1,000 years. This disaster made people realize how difficult it is to predict these types of events; therefore, an approach that involves mitigating the effects of a natural disaster was adopted throughout the country in an effort to flexibly cope with the next disaster, which is absolutely possible, and to reduce its damage. However, there are two years left until the end of the government's 10-year reconstruction period (end of March 2021). Although the development of the difficult aspects is almost complete, from now on, the results of the easy aspects are important, such as passing down memories and lessons learned from disaster survivors and victims.

Torahiko Terada, an authority in physics and seismology and also known as an essayist, says, "It is easy to be too afraid or not afraid at all, but to be duly afraid is rather difficult." To be properly afraid, it is essential to communicate accurate information, knowledge, and lessons that are easy to understand. In the public relations office, we will continue to disseminate information domestically and internationally while considering this perspective. As the saying goes, "The today you lived in vain is the tomorrow that the person who died yesterday so wished to live." While praying for those who have passed away because of earthquakes and disasters, we, who are alive, should all together think about what we can do to prepare for future disasters and what kind of work can be done.