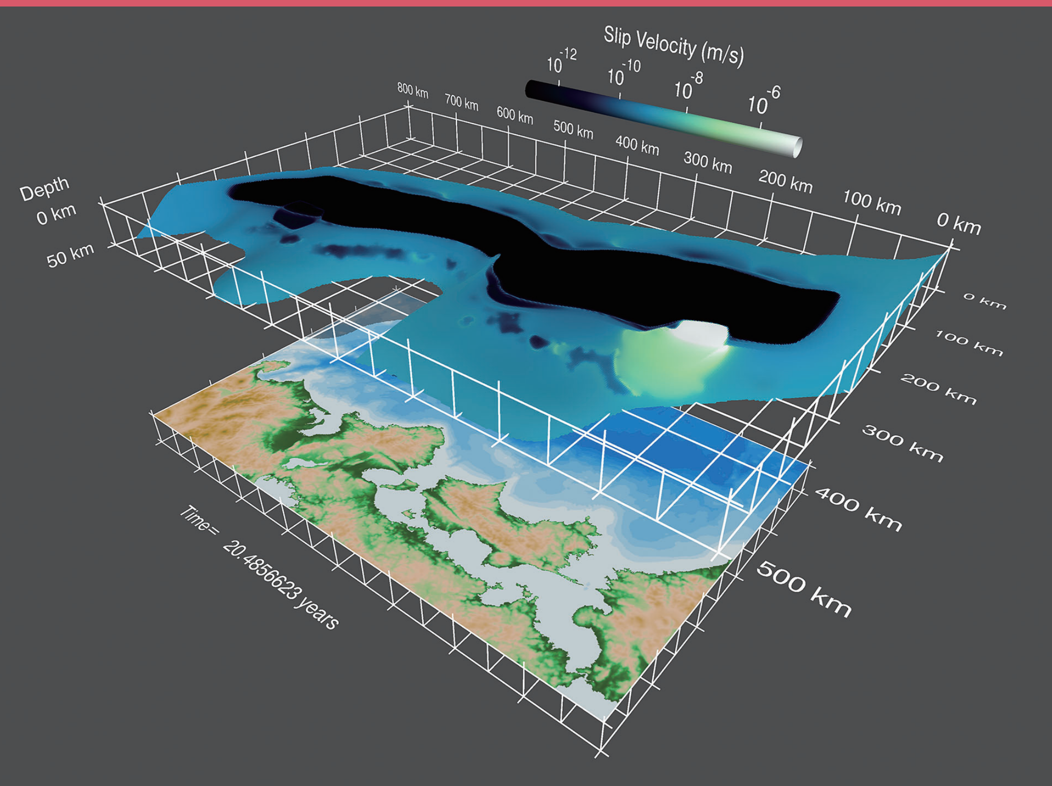
Grant-in-Aid for Transformative Research Areas (A)

SCIENCE OF SLOW-TO-FAST EARTHQUAKES

NEWSLETTER

Vol.1 March 2022



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Grant-in-Aid for Transformative Research Areas (A)

Science of Slow-to-Fast Earthquakes

A Grant-in-Aid for a scientific research project entitled "Science of Slow-to-Fast Earthquake" focuses on slow earthquakes (e.g., tectonic tremor and slow-slip events) that have been discovered in recent years, as well as ordinary (or fast) earthquakes, including huge earthquakes. During fast earthquakes, faults rupture rapidly, releasing strong seismic waves. During slow earthquakes, faults also rupture, but slowly, so the shaking is not as intense. Since the first slow event was discovered in Japan about 20 years ago, slow earthquakes have also been identified in other regions worldwide (Fig. 1), and study of these slow events has allowed their characteristics to be well defined. However, the relationship between slow earthquakes and fast (including huge) earthquakes is not well understood. In this new project, we aim to develop a comprehensive understanding of both slow and fast earthquakes and the relationship between them.

Researchers from various fields will participate in this project. In addition to seismologists, researchers with particular experience and expertise in slow earthquakes, as well as geodesy, geology, geochemistry, and physics, will participate to understand the materials in which earthquake faults occur and to clarify the laws of friction and fracture. In addition, researchers in engineering will participate to develop new observation techniques, and researchers in information science and statistics with expertise in data science will also participate. To enable these researchers from various fields to collaborate effectively, six research subgroups have been established (Fig. 2): the A01 Physicochemical Processes Group, A02 Structural Anatomy Group, A03 International Comparison Group, B01 New Technology Observation Group, B02 Information Science Group, and B03 Modeling and Forecast Group. In addition, we will call for research proposals every two years. Approximately 100 researchers, and many students who will lead the next generation of scientists, will work within this five-year-long research projectto better understand both slow and fast earthquakes and more reliably forecast their future occurrence.

The administrative group of the project includes the lead investigator of the main research area and the principal investigators of the planned research subgroups. The administrative group will be in charge of communication within the main research area, maintenance of the shared database, publicity and publication activities, and communication with members of other research projects, local governments, and public organizations. The administrative group will organize various research exchange programs, such as annual international joint workshops, special sessions at domestic and international conferences, field trips, and casual meetings. Internationally, the group will organize overseas workshops and manage programs for the interchange of researchers. Activities to encourage young and diverse researchers are also planned. The office of the administrative group will be located at the Earthquake Research Institute of the University of Tokyo.

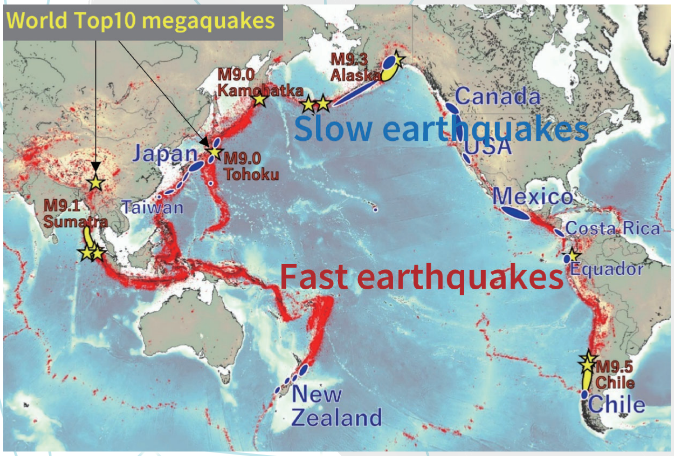

fig.1

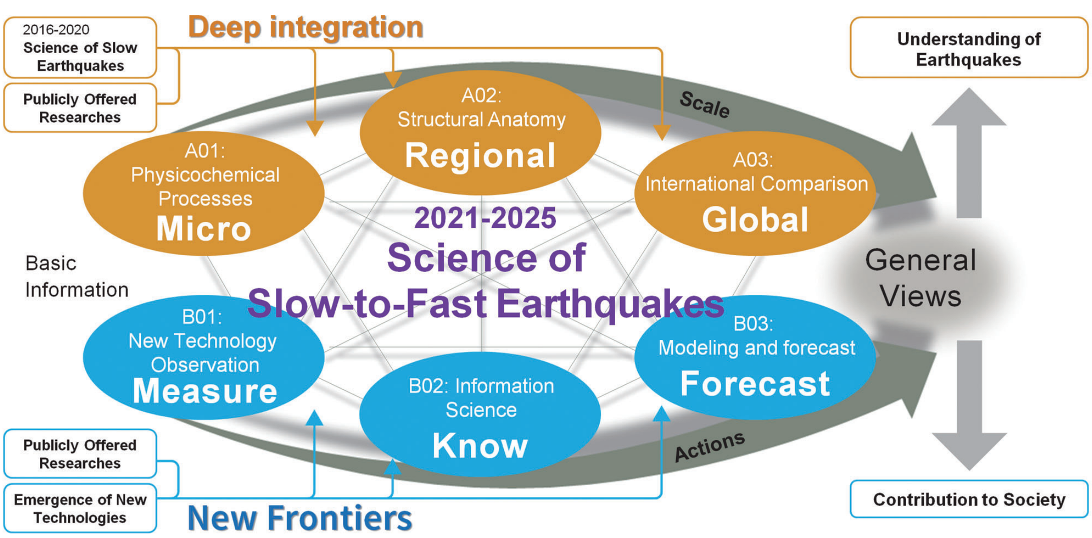

fig.2

Getting started on the Science of Slow-to-Fast Earthquakes

Satoshi Ide (The University of Tokyo)
Project leader of "Science of Slow-to-Fast Earthquakes"

We are pleased to announce the start of our new research project entitled "Science of Slow-to-Fast Earthquakes".

Slow earthquakes were first discovered about 20 years ago. Since then, numerous studies have contributed important findings about these slow events and have brought them to public attention. The occurrence of slow-slip events has been reported on TV news and has featured in the TV science fiction drama "Sinking of Japan". In addition, the handling of information about slow earthquakes has become an important issue in Japanese national earthquake countermeasures, which have been reconfigured since 2017.

Slow earthquakes are interesting and important phenomena both in terms of basic science and in respect of their potential impact on society, particularly with regard to their relationship with fast earthquakes. However, our understanding of the relationship between slow and fast earthquakes, including huge earthquakes, is still limited. To address this issue, we are starting a new project entitled "Science of Slow-to-Fast Earthquakes," which will be an extension of "Science of Slow Earthquakes" project. This new project is expected to change the way in which we think about earthquakes by better understanding slow earthquakes, fast earthquakes, and the relationship between them, including the possible transition of the former to the latter, and various associated phenomena.

Expectations for the Science of Slow-to-Fast Earthquakes

Kazushige Obara (Earthquake Research Institute, the University of Tokyo)
Project leader of "Science of Slow Earthquakes"

I am very pleased that the project "Science of Slow-to-Fast Earthquakes" has been funded by the Grant-in-Aid for Transformative Research Areas (A) by MEXT as the successor to "Science of Slow Earthquakes".

Slow earthquake research has made considerable progress globally since our world-first discovery of slow slip events and tremor at the beginning of the twenty-first century. About 10 years after this discovery, slow earthquake research moved from the "era of discovery" to the "era of understanding", and research by overseas scientists started to make important contributions to the field. To further develop slow earthquake research in Japan, we initiated the project "Science of Slow Earthquakes" in 2016 funded by a Grant-in-Aid for Scientific Research on Innovative Areas.

The project "Science of Slow Earthquakes" set a goal of working towards a unified understanding of all earthquake events, from low-speed deformation to high-speed slip, and clarifying the mechanisms, environmental conditions, and principles of slow earthquakes. This project has advanced our understanding of such earthquakes. In particular, collaboration between different research fields of geophysics, geology, and non-equilibrium physics has been improved through various interdisciplinary activities such as field trips. In addition, this project has contributed greatly to human resource development by sending young researchers overseas and strengthening of international leadership by our country for slow earthquake research through the planning and management of overseas workshops in New Zealand and Chile.

In the post-project evaluation of "Science of Slow Earthquakes", it was pointed out that the relationship of slow earthquakes to high-speed rupture was not yet fully understood. Developing this understanding is therefore the main objective of "Science of Slow-to-Fast Earthquakes." It is understood that the funding of this new project reflects high expectations for generating new understandings and insights regarding slow-to-fast earthquakes. It is anticipated that this new project will produce excellent research outputs that fulfill and even exceed expectations within five years, as well as encourage and develop young scientists and leaders within the field of slow-to-fast earthquakes.

A01

[MEXT KAKENHI Grant Number 21H05201]

Physicochemical processes in slow-to-fast phenomena

Principal Investigator
Yohei Hamada, X-star, Japan Agency for Marine-Earth Science and Technology

The aim of A01 group is to understand how fault slip begins and propagates into a wide range of earthquakes including slow–to–fast. Elucidating this mechanism from micro fundamental processes is an essential theme for generalizing, modelling, and predicting catastrophic seismic phenomena demonstrating various forms. Recent investigations have found the presence of water has a significant influence on the elementary processes of slow–to–fast earthquake generation and development. On the other hand, the specific effects of water or the heterogeneity and scale-transformability in the extension of the fundamental processes to fault slip in macro scale have not yet been clarified. In this research group, we will conduct laboratory experiments including friction and compression tests, chemical analysis, and structural analysis, as well as numerical experiments based on non-equilibrium physics and elastodynamic modelling to shed light on the seismic slip process in the presence of this fluid and scale–shape effects, and to model the elementary process of slow–to–fast earthquakes. These will be output for comparison with natural phenomena and for large-scale modelling in other research groups with the aim of understanding the underlying physico-chemical processes of generation mechanisms of slow earthquakes and the transition and development to fast earthquakes.

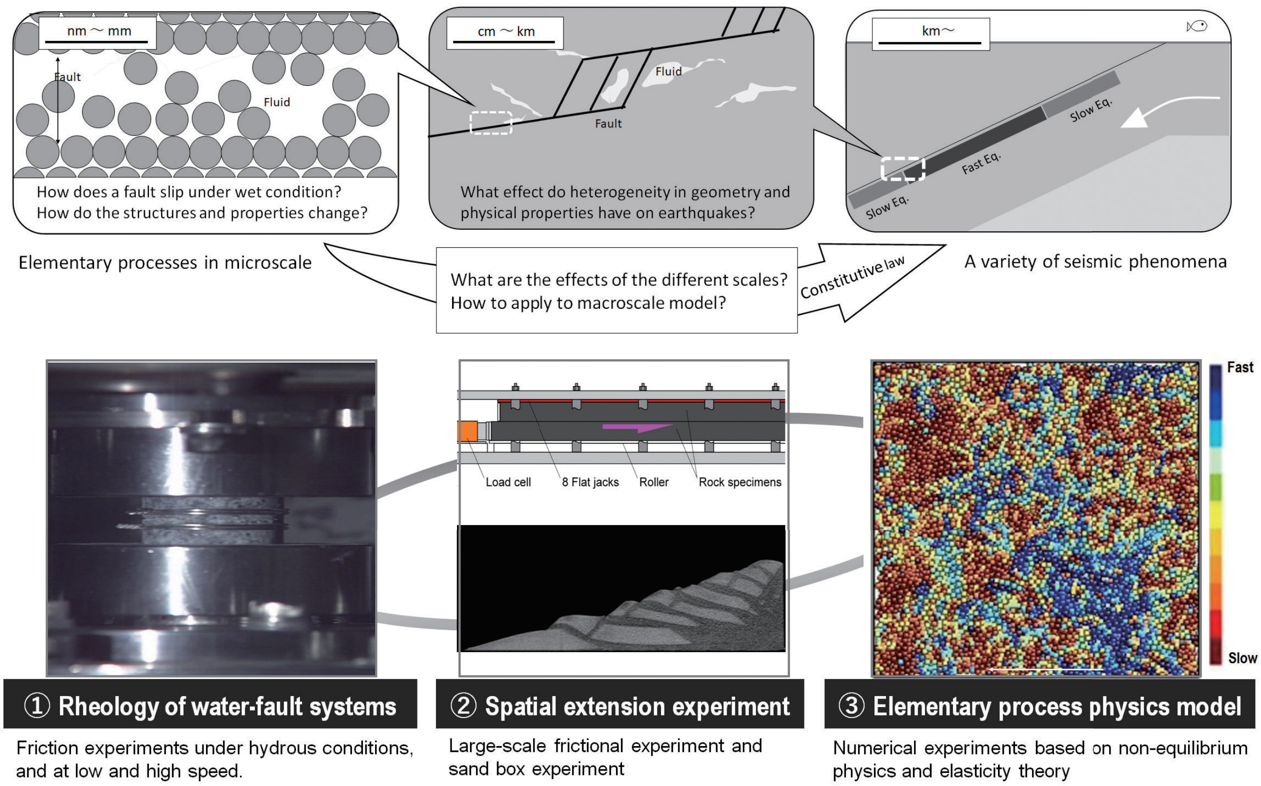

Figure: Schematic of the issues covered by A01 group (upper part), and the three subgroups linked to each other to address them (lower part).

As of Dec. 7, 2021

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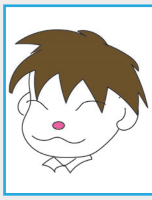

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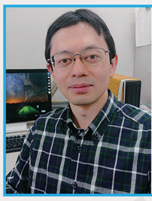

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A02

[MEXT KAKENHI Grant Number 21H05202]

Anatomy of slow-to-fast seismogenic zones

Principal Investigator
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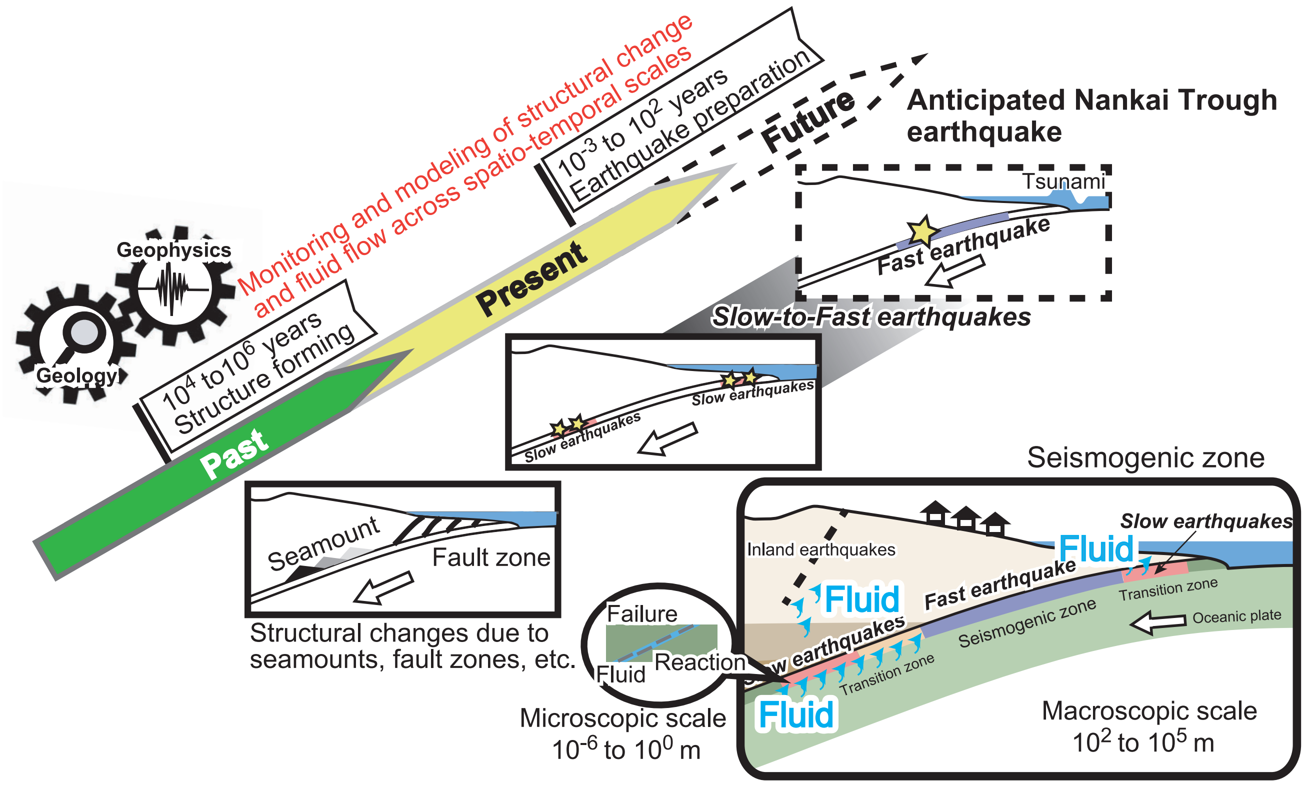
The A02 Structural Anatomy Group will "dissect" the structure and changes in the state of the source regions of Slow-to-Fast earthquakes (Slow-to-Fast seismogenic zones) with unprecedentedly high spatio-temporal resolution. By combining precise imaging of the subsurface structure and monitoring of changes in physical properties by geophysical observations, deciphering of earthquake histories and fluid traces in rocks by geological material research, and the latest findings of chemical analysis, experiments, and simulations, we aim to understand the behavior of materials and fluids that characterize Slow and Fast earthquakes, and the preparation process for Fast earthquakes. We have set southwest Japan (especially the Kii Peninsula to the Nankai Trough off Kumano), where the most accumulated research on land and sea has been conducted, as a test field, and will integrate observation and material research from shallow to deep in cooperation with other groups. It is expected that the fusion of geophysics and geology will enable us to create a live map of the fluids that cause earthquakes, which will be supported by material science. In the test field, there are concerns about the occurrence of Nankai Trough earthquakes, and we will also work to disseminate our research results and return them to society in cooperation with the Nanki-Kumano Geopark.



As of Dec. 7, 2021

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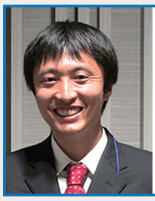

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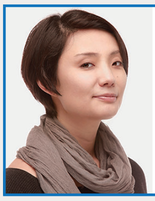

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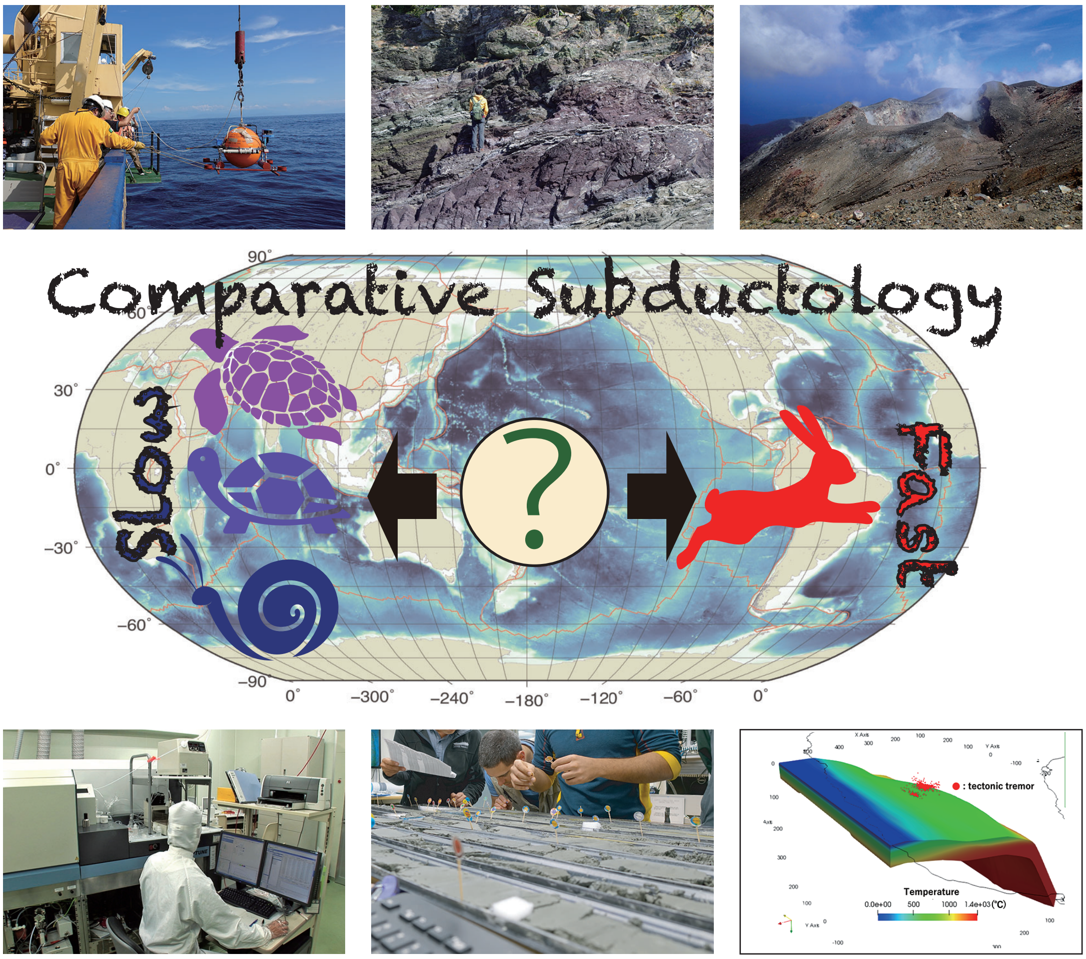
A03

[MEXT KAKENHI Grant Number 21H05203]

Slow-to-fast earthquakes through comparison across global subduction zones

Principal Investigator
Yoshihiro Ito, Disaster Prevention Research Institute, Kyoto University

Both extremital processes of slow and fast ruptures on a fault are commonly observed within the seismogenic zone worldwide as well as the subduction zones in the Pacific Rim. Similar rupture processes with time scales from slow to fast have also been frequently observed during a volcanic eruption globally. Group A03 aims to identify the factors that control such slow and fast rupture processes during earthquakes and volcanic phenomena in the subduction zones worldwide based on some of the results obtained from the onshore and offshore seismic and geodetic observations, geological fieldwork, and information on the core materials obtained from the ocean drilling projects. Here, we try to highlight the novel achievements of comparative subductology on Science of Slow-to-Fast Earthquake, in collaboration with the interdisciplinary scientists within the field of seismology, geodesy, volcanology, geology, and geochemistry. With a focus on discriminating both globality and regionality controlling the slow and fast rupture processes through comparative subductology, we aim to capture the actual images of the two extremital rupture processes and further conduct its modeling.



As of Dec. 7, 2021

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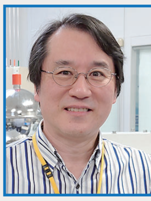

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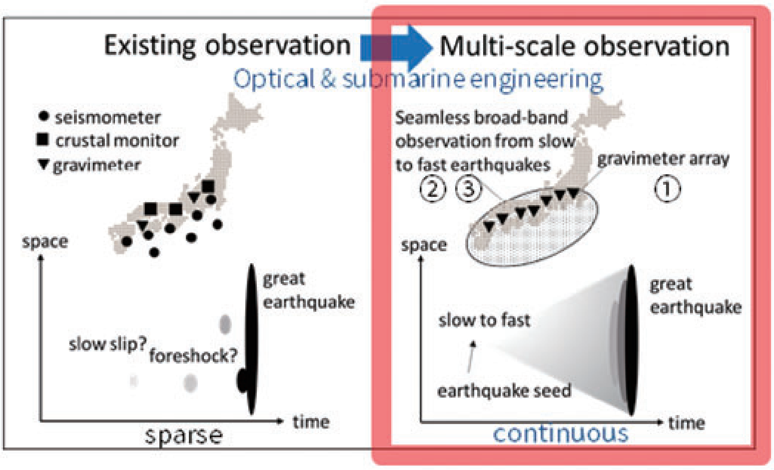
B01

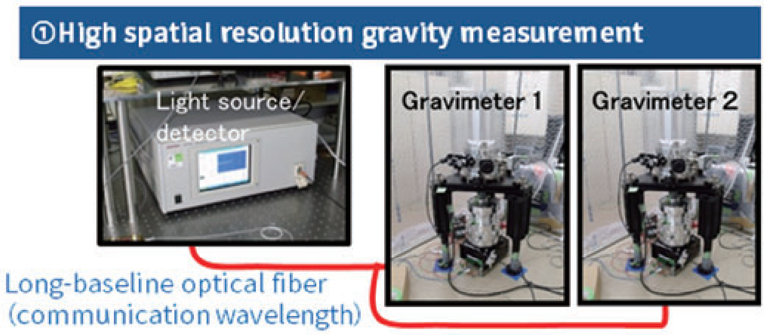
[MEXT KAKENHI Grant Number 21H05204]

Development of multi-scale observation techniques for monitoring slow-to-fast earthquakes

Principal Investigator
Yoshiyuki Tanaka, Graduate School of Science, The University of Tokyo

Observation data form a basis for predicting geophysical phenomena. In Japan, the development of the dense geodetic and seismological observation networks has led to the first discovery of slow earthquakes. However, the existing observation networks are limited in a sense that each observational technique has a specific spatiotemporal band, by which only discretized nature of a geophysical phenomenon can be observed. In particular, precise instruments which are able to observe slow phenomena such as slow slip events are small in number, causing a gap in a spatiotemporal coverage. Therefore, the full picture of how slow phenomena transit to fast phenomena has been still unclear. In order to reveal an accurate picture of the transition process and to construct a prediction model based on such a picture, this group develops ‘multi-scale observation techniques’, which allow a seamless observation in a spatiotemporal coverage, making use of optical and ocean engineering. To be specific, we develop an absolute gravity measurement method to effectively assess an underground fluid migration, a highly stable and precise fiber sensing method to capture a wider range of earthquakes including slow slip, ocean-bottom geodetic measurement with a high temporal resolution and a seismological observation in an ultra-deep sea near a trench to observe slow-to-fast earthquakes.





As of Dec. 7, 2021

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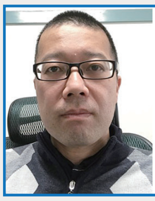

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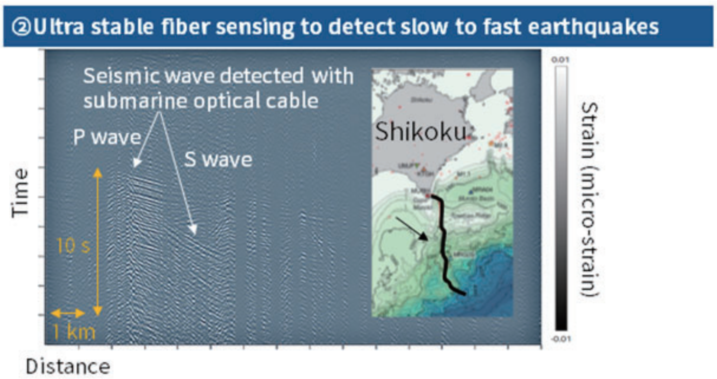
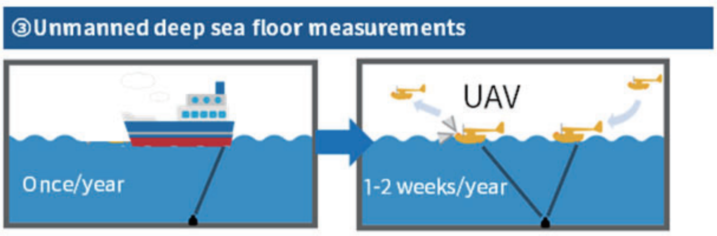
Keywords: GNSS-A, Seafloor crustal deformation, Marine acoustics





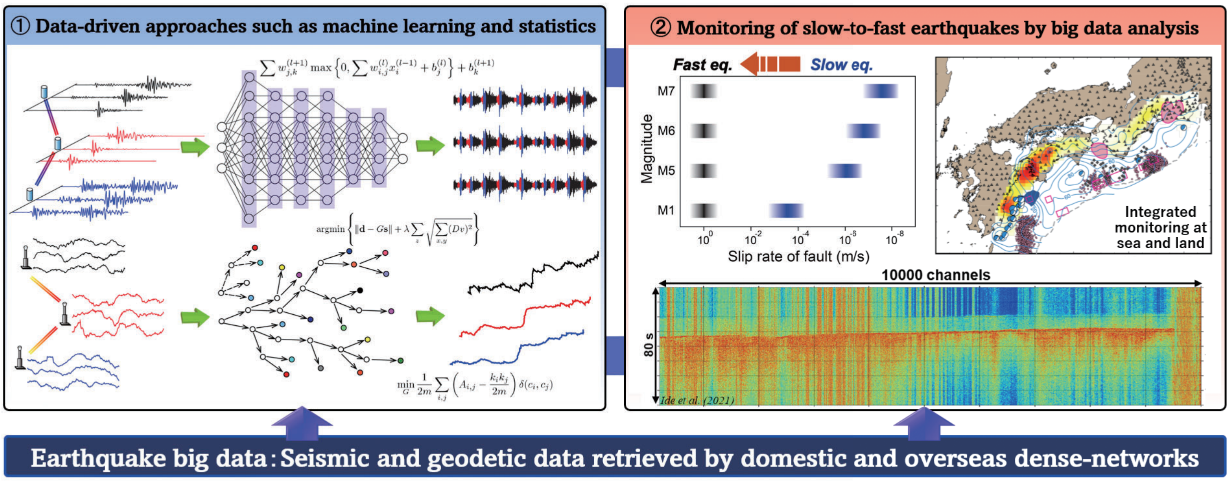
B02

[MEXT KAKENHI Grant Number 21H05205]

Data-driven discovery and monitoring of slow-to-fast earthquakes

Principal Investigator
Aitaro Kato, Earthquake Research Institute, The University of Tokyo

By promoting integrated research of information science and geophysics, the B02 group will search for unknown slow-to-fast earthquakes hidden in earthquake big data and analyze the statistical and geophysical properties that characterize slow-to-fast earthquakes. This group is working on two main themes. In "(1) Data-driven approach such as machine learning and statistics", we will extract some features of slow and fast earthquakes propagating throughout a network consisting of multiple stations. These features will be leveraged to innovate technology for comprehensive detection of seismic and geodetic events. We challenge to discover the transition phenomenon of slow-to-fast earthquakes. In ”(2) Monitoring of slow-to-fast earthquakes by big data analysis", we aim to deepen a comprehensive understanding of slow-to-fast earthquakes by renewing the monitoring method in sea and land through information science, unified understanding of scaling law and expansion of "slow earthquake catalog. We will also develop a high-speed algorithm suitable for ultra-high density seismic observation data (DAS), which is 1000 times that of conventional seismic networks.



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Keywords: Time series data analysis, Waveform classification, Unsupervised learning

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Assistant Professor, ERI, the Univ. of Tokyo

Specialty: Observational seismology
Keywords: Broadband seismic observation in SW Japan, Very low frequency earthquakes

RC

Mamoru Nakamura
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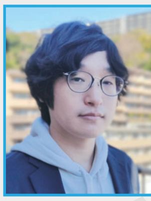
Specialty: Observational seismology
Keywords: Ryukyu Trench, Very low frequency earthquakes, Low frequency earthquake



RC

Daisuke Sugiyama
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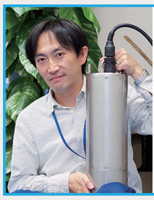
Specialty: Machine Learning, Computer Science
Keywords: Realtime estimation for earthquake, Discrimination of tectonic tremor signals, HPC&AI



RC

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Specialty: Observational seismology
Keywords: Very low frequency earthquakes, Interplate earthquakes, Ryukyu trench, Japan trench

RC

Hisahiko Kubo
Researcher, NIED

Specialty: Strong-motion seismology
Keywords: Strong motions, Earthquake source process, Application of machine learning in Geophysics

RC

Sachiko Tanaka
Chief Researcher, NIED

Specialty: Seismology
Keywords: Seismicity, Strain energy

RC

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Specialty: Seismology
Keywords: Seismic wavefield, Earthquake triggering, Friction physics

RC

Hiromichi Nagao
Professor, ERI, the Univ. of Tokyo

Specialty: Mathematical methods beneficial to solid Earth science
Keywords: Data assimilation, Bayesian statistics, Machine learning, Deep learning

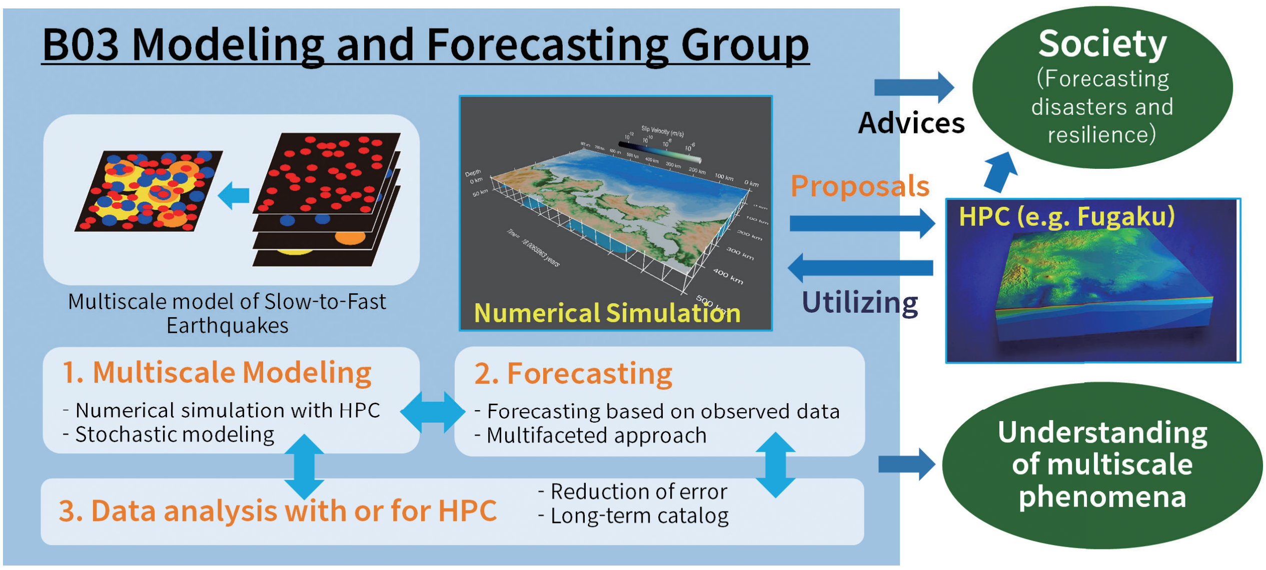
B03

[MEXT KAKENHI Grant Number 21H05206]

Spatio-temporal multiscale modeling and forecast of slow and fast earthquakes

Principal Investigator
Takanori Matsuzawa, National Research Institute for Earth Science and Disaster Resilience

Slow earthquakes have a seismic moment of more than 10 orders of magnitude, and fast earthquakes have a larger range of seismic moment than slow earthquakes. In addition, slow and fast earthquakes obey different scaling relationships over both temporal and spatial scales. The goal of Group B03 is to model and forecast the occurrence of slow and fast earthquakes and the transition between them. We also aim to develop a research area linked to the field of high performance computing (HPC). We will model slow and fast earthquakes, especially large-scale numerical simulations that maintain hierarchy of slip distribution and multi-scale complexity. We also aim to integrate stochastic/statistic models with physical models. We will conduct earthquake forecasting based on a multifaceted approach using new perspectives, in addition to an HPC-based approach, and aim to incorporate real-time information. Regarding data analysis for large-scale modeling, we will conduct research to reduce model errors by applying HPC and to extend the spatio-temporal range of the catalogs of slow and fast earthquakes through the analysis of past data. We intend that these studies will lead to a new scientific basis for disaster prediction.



As of Dec. 7, 2021

P I

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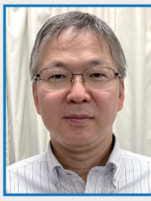
Specialty: Seismology
Keywords: Numerical simulation, Very low frequency earthquake, Analog seismogram



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Specialty: Forecasting of earthquake generation
Keywords: HPC, Subduction zone, Forecast of transition

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Keywords: Physics of earthquake source, Earthquake scaling, Stochastic earthquake process

Co-I

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Keywords: Earthquake source physics, Seismic-cycle simulations, Full-waveform tomography

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Keywords: GNSS data, Inversion analysis, Energy balance

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Keywords: Point process, Repeating earthquakes, Foreshock discrimination

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Keywords: Crustal deformation, Slow slip events, Strain budget

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Keywords: Fault slip inversion, Bayesian inference, Uncertainty quantification

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Keywords: Large-scale earthquake simulations, Slow and fast earthquakes, Paleoseismology

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Keywords: Data assimilation, Slow slip event, Information science

R C

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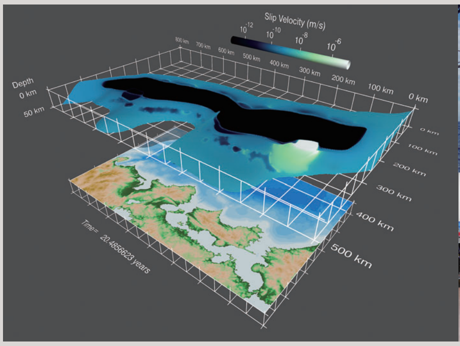
Specialty: Earthquake mechanics
Keywords: Megathrust earthquake, Tsunami, Energy



【Cover photos】

(Left) An example slip velocity distribution of numerically reproduced slow-slip events (SSEs) in the Nankai Trough. Brighter colors indicate higher slip velocities. This example is for a long-term SSE that occurred in the Bungo Channel.
(Upper right)A thermometer and flowmeter were installed using the Remotely Operated Vehicle (ROV) KAIKO (shown) to verify whether or not the fiber strain variations in the fiber-optic cable measurements off Muroto Peninsula may be caused by seafloor temperature changes (KR21-13 Kaiko Dive #867).
(Lower right) A 4-m-long rock friction experimental device for detailed observations of stick–slip phenomena on a fault.

Activity Report

Kick-off field trip

On Saturday, January 8th, we held a kick-off field trip to Jogashima, Kanagawa Prefecture. Although there were a number of last-minute cancellations due to the rapid spread of the Omicron variant, 33 people from both inside and outside the region participated in the field trip.

Jogashima Island is located off the southern tip of the Miura Peninsula, and is an ideal location to observe the Misaki Formation of the Miura Group, which was deposited about 10 to 4 million years ago. The Misaki Formation is composed of volcaniclastic sediments (scoria and pumice) from the Izu-Bonin Arc and hemipelagic mudstone deposits, and it records both soft-sediment deformation immediately after deposition and tectonic deformation in the shallow part of the accretionary prism. During the trip, we carefully observed the tilted strata and their constituent materials, flame structures, fault structures, and fault zone materials, and had a lively discussion about the structures that formed via density instability and shearing, fault slip due to shallow slow earthquakes, and the tectonics of the northern part of the Philippine Sea Plate. Families were welcome to participate in the field trip due to Jogashima's popularity as a tourist destination, and four families joined the trip, making it a good opportunity for socializing.

Participants discussing at the outcrop (Photo taken by Yoshinori Tashiro)

Reverse fault cutting the flame structure (Photo taken by Yoshinori Tashiro)

Group photo

< Participant comments >

The field trip was very good because the air was clean and the temperature was not too cold. Although we had our meals either separately or in the open air, we were able to somewhat interact with other researchers during the field trip. Since recent meeting presentations have largely been via Zoom, I think that this field trip was beneficial in promoting in-person communications among the participants, thereby creating a new networking format during COVID-19. It was a good opportunity to make new acquaintances, especially with students, young researchers, and people from different fields. Thank you very much. (Saeko Kita)

Upcoming Events

International Joint Workshop on Slow-to-Fast Earthquakes 2022
Date: September 14 (Wed.)-16 (Fri.), 2022
Venue: Nara Kasugano International Forum, Nara

Japan Geoscience Union Meeting 2022
Hybrid (in-person & online): May 22 (Sun.)-27 (Fri.), 2022
Online Poster Session: May 29 (Sun.)-June 3 (Fri.), 2022
On-site: MAKUHARI MESSE, Chiba

Session: [S-CG44] Science of slow-to-fast earthquakes
Oral: May 26 (Thu.), 27 (Fri.)
On-site poster: May 27 (Fri.)

Grant-in-Aid for Transformative Research Areas (A)

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