SyDE
WISE Program for Sustainability in the Dynamic Earth

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WISE program for Sustainability in the Dynamic Earth

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Theme: (1)

Pre-Discharge Operation: A Flood Solution with a Potential Cost

Atsuya Ikemoto

Rain, Reservoirs, and Farming

In recent years, Japan has seen an increasing number of reports of "record-breaking rainfall." When heavy rain persists, rivers overflow, flooding homes and farmland. A promising method to reduce this damage is called **pre-discharge**.

The idea is simple: If heavy rain is forecast, water is released from the reservoirs in advance. This lowers the water level so that when rain actually occurs, the reservoir can store more water and prevent flooding downstream.

However, this approach poses serious risks. What happens if rain does not arrive? For irrigation reservoirs that provide water to rice paddies, releasing excessive water could leave farmers with insufficient water for their crops. This "false alarm" is what our study focused on.

The Aim of the Study

We wanted to answer the following question:

When irrigation reservoirs carry out pre-discharge, how often do they run out of water afterward?

In other words, we aimed to balance the two needs: protecting communities from floods and securing sufficient water for agriculture.

How We Studied It

- We used a large climate database that includes past and possible future weather patterns.
- Using a machine learning model, we generated **550 years' worth of artificial rainfall forecasts**.
- Using these forecasts, we created "virtual reservoirs" with different catchment sizes (areas that collect water) and farmland areas.
- We then calculated how often these reservoirs failed to provide sufficient irrigation water after the pre-discharge.

What We Found

The results were sobering:

- In most cases, pre-discharge led to water shortages.
- Failure rates were extremely high, close to **100%** under many conditions.
- Even in the best scenario, the failure rate was about 78%.
- However, when the farmland area was small and the catchment area was large, the risk was lower.

Put simply, **small reservoirs serving large fields are most vulnerable, whereas reservoirs that gather water from larger catchments are somewhat safer.**

Why This Matters

This study highlights the difficult trade-offs faced by irrigation reservoirs. Pre-discharge protects communities from flooding; however, farmers can be left without vital water for their crops.

By presenting these risks in numbers, we can provide a clearer picture for policymakers and farmers. In the future, better weather forecasts, improved irrigation practices (such as rotational water-sharing), and new crop varieties may reduce this risk. However, we must first understand the scale of the problem.

Conclusion

Pre-discharge is a powerful idea, releasing water to prevent future disasters. However, the risk of "false alarms" in irrigation reservoirs cannot be ignored.

Our research uses long-term data to demonstrate the frequency of these failures and the conditions under which they are most likely to occur. These findings will help guide decisions that protect both **flood safety** and **food security**, which are two essential needs for society in a changing climate.

Theme: (1)

Efficient Nitrogen Removal From Pig Wastewater

Cha Junho

Global meat production reached 362.86 million tons in 2023, an increase of 1.2% compared to 2022. This growth rate will surpass the global population growth rate of 0.8% by 2023. These statistics are indirect indicators of the significant proportion of meat consumed in food. As global meat consumption continues to rise, the livestock industry is playing a crucial role in the global food supply. However, alongside the expansion of livestock production and technological advancements to boost productivity, environmental issues related to livestock farming, such as water pollution and odors caused by animal excrement, are becoming increasingly severe. In particular, the expansion of pig farms has resulted in the production of more complex and larger quantities of waste. Globally, the distribution of livestock is as follows: poultry (40%), pigs (35%), bovine (21%), and ovine (4%). Thus, pig wastewater accounts for the second largest proportion. Pig wastewater is estimated to comprise a substantial portion of the 24 billion tons of livestock wastewater generated annually worldwide. This can lead to severe environmental problems. In particular, pig wastewater contains high concentrations of nitrogen and COD. However, it has a lower C/N ratio than other livestock wastewaters. It also contains pollutants such as antibiotics, heavy metals, and persistent organic matter, which makes efficient and stable treatment difficult. These problems pose challenges for wastewater treatment processes that use conventional methods. In particular, when environmental conditions are limited, the activity of critical bacteria is inhibited, leading to a decrease in removal efficiency. Thus, the conventional process, which requires an external energy supply, incurs high energy and operational costs.

To solve these problems, Partial Nitritation and Anammox (PNA) processes have received considerable attention. The PNA process consists of two microbial reactions involving AOB and AnAOB. During the PN process, bacteria (AOB) convert some of the NH_4^+ into NO_2^-. In the Anammox process, bacteria (AnAOB) convert the remaining NH_4^+ and NO_2^- to N_2 gas. This process does not require external energy sources. Therefore, the PNA process is energy-saving and cost-effective. However, the application of the PNA process for treating livestock wastewater remains limited. Moreover, stable operation is difficult due to the high concentrations of nitrogen and organic matter.

This research was conducted to overcome these challenges by utilizing a two-stage PNA process for the treatment of pig wastewater. The influent wastewater was collected from a pig farm on Zao Mountain. This wastewater has several detrimental features. The concentration varied whenever I gathered the wastewater and across different seasons. However, this problem is not significant when the two reactors are operated separately. This operational method avoids some challenges, such as varying optimal environmental conditions for each bacterium and chain issues. During operation for 210 days, several issues arose, including environmental shocks, concentration fluctuations, and a rapid decrease in efficiency. Nevertheless, these issues can be mitigated by maintaining steady operations. Thus, the research achieved an efficiency of 85%.

In conclusion, this study suggests that the two-stage PNA process is an energy-efficient and eco-friendly method for treating swine manure with high nitrogen and COD concentrations. Additionally, this study demonstrated high adaptability and stability under complex conditions. These results can be used as data for future full-scale applications of the PNA process for treating livestock wastewater and for developing control strategies, given the limited data available for pig wastewater treatment systems. PNA is a new research topic in this field. Although there have been several studies on the PNA process, they did not remove high concentrations of approximately 1000 mg/L. Some studies have removed 2000 mg/L of nitrogen from synthetic wastewater. However, this study focuses on actual wastewater from a pig farm, where the concentrations ranged from 1500 to 2000 mg/L. Therefore, this research can contribute valuable data for future full-scale application processes and the development of efficient strategies.

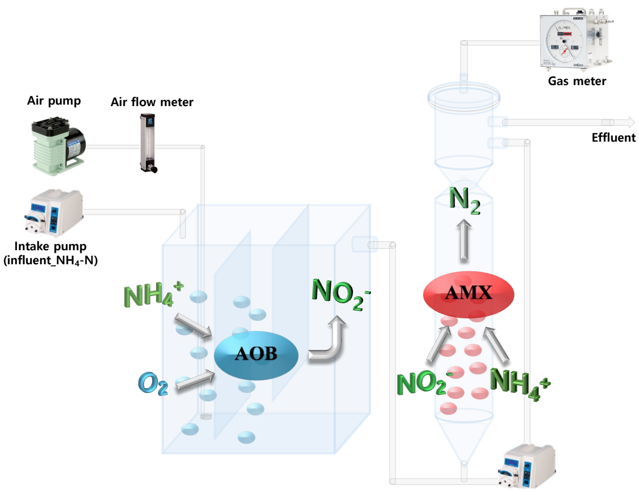

Illustration of the two-stage PNA process

Theme: (1)

Investigation of Low-Temperature C_2H_2-CVD on $CaCO_3$ Surface

Zhou Hanzhang

Introduction

Graphene is a two-dimensional material with extraordinary properties, such as a high specific surface area, high electron mobility, and high Young's modulus. Template-assisted or substrate-assisted CVD has become the most promising approach among all synthesis methods. However, several challenges remain. Methane (CH_4), as the general carbon source, shows a reaction temperature higher than 850 °C. Therefore, some substrates are damaged at these high temperatures, limiting the choice of substrates and increasing energy consumption.

Compared to CH_4, acetylene (C_2H_2) requires lower reaction temperatures. Unlike CH_4, its unsaturation and bond strain make it more reactive, facilitating self-decomposition under certain conditions and leading to a lower decomposition temperature that increases the number of substrate candidates. Although the mechanism of C_2H_2 decomposition remains unclear, the investigation of C_2H_2-CVD is necessary.

Calcium carbonate ($CaCO_3$) is an inorganic mineral that has attracted considerable attention, particularly in nanometric form. Generally, the thermal decomposition (calcination) of $CaCO_3$ occurs at temperatures lower than 850 °C. Therefore, to apply CVD to this metal salt, C_2H_2 becomes an ideal carbon source. In this study, C_2H_2 was used as the carbon source, and its deposition mechanism on $CaCO_3$ was investigated by measuring the deposition starting temperature and gas emission.

Experimental design

In this study, *in situ* CVD thermogravimetry (CVD-TG) and X-ray diffraction (XRD) were used for characterization. CVD-TG was employed to analyze the starting temperature of the C_2H_2 decomposition reaction and the carbon growth rate. The $CaCO_3$ substrate (denoted as SK-I, 220 nm) was placed into a holder in the TG system, and the sample was heated to the target temperature with a heating rate of 5 °C min^{-1} under a mixed gas flow of Ar (80 vol%) and C_2H_2 (20 vol%). X-ray diffraction (XRD) was utilized to determine whether the crystal structure changed during the reaction.

Results and discussion

Fig. 1a shows the weight change of SK-I during the C_2H_2-CVD. The heating rate was 10 °C min^{-1}

from 25 °C to 600 °C, then maintained at 600 °C for 2 h with C_2H_2 flowing from the beginning. Around 520 °C, which is lower than the C_2H_2 self-decomposition temperature, the weight increase of SK-I can be clearly observed. This indicates the catalytic ability of SK-I to enhance the decomposition of C_2H_2. In Fig. 1b, XRD patterns of SK-I under different treatment conditions are presented. The characterization of CaO peaks occurred after 600 °C heat treatment for 30 minutes (in an Ar atmosphere), while the characterization of $CaCO_3$ peaks still existed at the same time. However, there were no CaO peaks remaining after the C_2H_2-CVD at 600 °C for 2 h with C_2H_2 continuously flowing. This suggests that CaO generation was inhibited by C_2H_2. Since CaO peaks appear after 600 °C heat treatment, the nucleation sites of CaO are believed to be the active sites for C_2H_2 decomposition, superseding the formation of CaO (Fig. 1c).

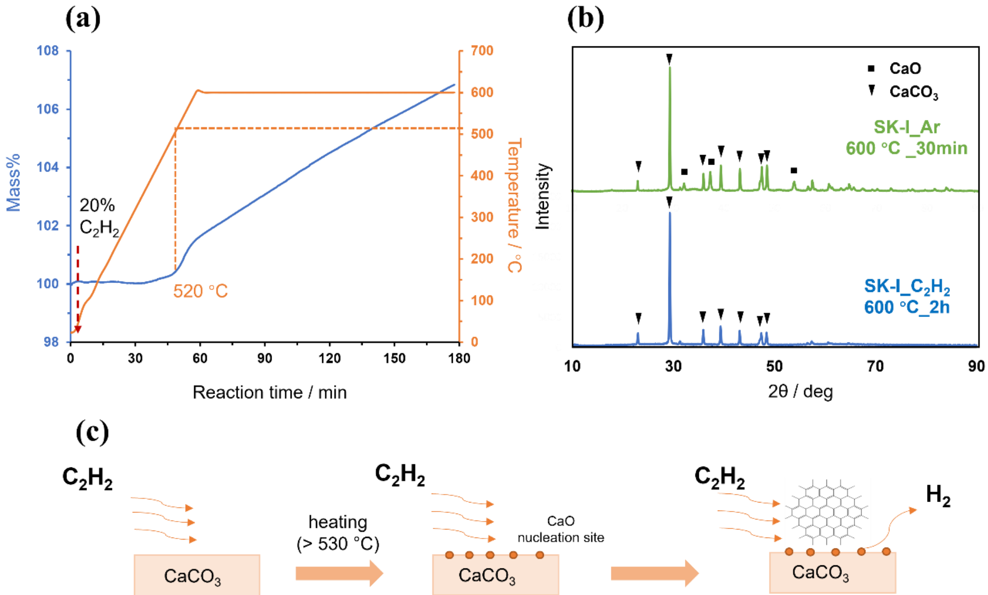

Fig. 1 (a) Carbon growth of SK-I during C_2H_2-CVD; (b) XRD patterns of SK-I after 600 °C heat treatment for 30 min and 600 °C C_2H_2-CVD for 2 h, respectively; (c) Schematic of C_2H_2-CVD on SK-I.

Conclusion

In summary, C_2H_2-CVD on $CaCO_3$ particles demonstrates that this metal salt exhibits good catalytic performance in the decomposition of C_2H_2. However, the generation behavior of CaO shows a unique difference with C_2H_2 flowing; it is considered that the nucleation sites of CaO act as active sites for C_2H_2-CVD. Nonetheless, the detailed underlying mechanisms remain unclear. In the future, we aim to investigate the C_2H_2 decomposition behavior of $CaCO_3$ in detail.

Theme: (1)

Quantitative Evaluation of Long-Term Sediment Supply by Grain Size from River to Coast

Shimon Suzuki

1. Introduction

Recently, there has been growing concern over the increasing severity and frequency of heavy rainfall and sediment-related disasters. Various problems have become apparent, including reduced storage capacity in dam reservoirs due to sediment accumulation, increased flood risks due to rising riverbeds, unsafe river structures due to degradation, altered habitats due to the coarsening of riverbeds, and accelerated coastal erosion caused by reduced sediment supply from rivers. These problems are expected to worsen in the near future. Coastal erosion is progressing worldwide because the effects of human activity are becoming more severe as coastal populations increase. It is necessary to understand the balance of sediment budgets in coastal sediment systems to address coastal erosion. It is essential to comprehend the long-term sediment dynamics of grain size to understand the deformation of beaches and the phenomenon of sediment transport, assess the impacts on water quality and ecosystems, and recognize the morphological changes in river channels.

Sediments produced in mountainous areas are transported downstream through rivers to the plains and supplied to the coast. The sediment production volume in mountainous areas and its grain size distribution are among the most critical factors for estimating sediment dynamics in the lower reaches of rivers. Sediment production is broadly categorized into two main processes: surface erosion, which occurs continuously, primarily because of rainfall, and slope failure, which occurs less frequently but supplies large amounts of sediment. Although methods for physically estimating sediment production from these phenomena have been established in recent years, research on the quantitative evaluation of grain size distribution remains limited. The objective of this study is to understand the long-term sediment dynamics in a river basin, from sediment production in mountainous areas to sediment supply to the coast, for each grain size. This study estimates the sediment production volume and grain size distribution resulting from surface erosion and slope failure. Furthermore, this study evaluates their impact on sediment dynamics in the lower reaches of the Abukuma River.

2. Methods

This study used a one-dimensional riverbed evolution model to reproduce sediment transport within river channels and the sediment supply from the river to the coast on a decadal scale for each grain size. In this analysis, it was crucial to appropriately input the sediment inflow volume and its grain size distribution upstream as boundary conditions. However, in Japan, many rivers still do not have established measured data for sediment; therefore, it is difficult to use the measured data as boundary conditions. For these rivers, the method of inputting an equilibrium sediment load upstream is generally adopted. This assumes an equilibrium state in which no bed evolution occurs at the upstream boundary and is calculated within the model based on hydraulic conditions.

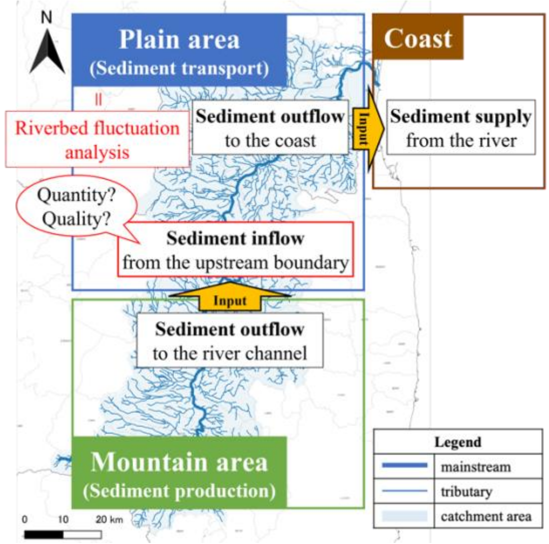

Fig. Research Concept Map (Abukuma River)

3. Results

First, sediment transport within rivers in a plain area was simulated and evaluated. The main conclusions are as follows: The model used in this study reproduced the riverbed fluctuations with good overall accuracy. In sections where the simulated values showed an excessive erosion tendency compared to the measured values, the importance of considering the sediment inflow from tributaries upstream of the affected section was suggested.

A sensitivity analysis was conducted on the upstream boundary conditions for the sediment to evaluate the relationship between sediment inflow from the upstream boundary and sediment outflow into the coast for each grain size. Because the majority of silt and very fine sand (~ 0.106 mm) was transported as wash load, it was observed that changes in sediment inflow significantly affected sediment outflow into the coast during the first year of analysis. Under the analysis conditions of this study, the sediment outflow for fine sand (0.106–0.250 mm) and medium sand (0.250–0.425 mm) was confirmed to exhibit changes on a scale of several years and decades, respectively. For coarse sand (0.425–0.850 mm) and very coarse sand (0.850–2.00 mm), no significant changes attributable to variations in inflow were observed during the 20-year analysis period. Differences in grain size demonstrated that the timescale at which changes in sediment inflow from the upstream boundary significantly affected sediment outflow into the ocean varied.

Theme：(Number)　1 : (1)

Uncovering Hidden Crustal Deformation in Japan Using an Ultra-Dense GNSS Network

Miku Ohtate

Japan is one of the most earthquake-prone countries in the world. Almost every year, we experience large earthquakes and volcanic eruptions that affect our daily lives and can cause serious disasters. For example, the 2011 Tohoku Earthquake and the more recent events in Kumamoto in 2016 clearly reminded us of the destructive power of these hazards, while volcanic activities, such as those at Sakurajima or Asama, continue to influence daily life in many regions. To prepare for such events, scientists are studying how the Earth's crust, the outermost layer of the Earth, slowly changes its shape. My research focused on mapping these gradual changes, known as crustal deformation. By understanding where the land is stretching or being squeezed, we can identify areas where the stress is increasing.

For more than two decades, numerous researchers have utilized GEONET, the GNSS Earth Observation Network System operated by the Geospatial Information Authority of Japan (GSI). GEONET consists of approximately 1,300 observation stations spread across Japan, with each station located about 20 km from the next. Every day, these stations accurately measure their positions using satellite signals. From this data, scientists can track how land in Japan has moved over time. Thanks to GEONET, we have learned much about broad patterns of crustal movement. For example, scientists discovered the Niigata–Kobe Tectonic Zone, a long band across Japan where stress tends to accumulate. In addition, GEONET supports disaster management in Japan by providing real-time monitoring data during major earthquakes and tsunamis, helping authorities respond more effectively. However, because the stations are relatively far apart, GEONET alone cannot always detect small local changes near individual faults. This makes it difficult to fully evaluate the earthquake risks in specific areas.

The SoftBank Corporation, a telecommunications company, has emerged as a new opportunity. To support its services, SoftBank constructed more than 3,300 GNSS stations across Japan, nearly three times the number of GEONET sites. Although these stations were initially developed for applications such as high-accuracy positioning services, their data have also proven valuable for monitoring ground deformation. Tohoku University took the lead in establishing an industry-academia consortium to utilize SoftBank's GNSS data for geoscientific applications. Owing to their dense spatial coverage, these stations are expected to drive innovation not only in scientific domains but also in industrial sectors such as precision agriculture, logistics, and autonomous driving technologies, highlighting how scientific and commercial interests can mutually reinforce each other. Researchers at Tohoku University have evaluated the quality of SoftBank's GNSS data and found it to be comparable to that of GEONET, even during major seismic events.

By combining the GEONET and SoftBank networks, we can take advantage of an ultra-dense observation system with stations spaced less than 10 km apart. This is similar to upgrading from a standard camera to a high-definition one; suddenly, much finer details become visible.

Using this enhanced network, we created high-resolution maps of crustal strain rates, which revealed several significant findings. "Crustal strain" refers to a change in the shape of the Earth's crust due to tectonic forces. First, the Niigata–Kobe Tectonic Zone may not be a wide zone but rather a collection of smaller clusters of localized stress. This indicates that the processes that concentrate strain in inland Japan are more complex than previously thought. Second, I found a clear correspondence between the strain concentration and seismic activity in regions such as northern Hokkaido and the San-in Shear Zone (SSZ). The SSZ was previously recognized, but my results suggest that the strain concentration may extend further west, possibly in agreement with the patterns of seismic activity. Third, in Tohoku, high-strain regions correlate with both the volcanic distributions and seismic velocity anomalies reported in earlier studies. This suggests that deep crustal structures such as magma reservoirs or low-velocity zones influence surface deformation.

These findings highlight the importance of collaboration between the science and industry sectors. SoftBank's data, shared through a special consortium, have made it possible to study Japan's crust in greater detail. Without this partnership, we would not have been able to uncover the hidden features. The implications of this study extend beyond academic interest. Identifying where the strain is increasing can lead to improvements in earthquake hazard maps and provide better information for disaster preparedness, infrastructure planning, and public safety. A deeper understanding of the movement of the crust could ultimately help reduce the risks associated with future earthquakes.

In conclusion, by integrating GEONET with SoftBank GNSS data, we revealed previously invisible fine-scale patterns of crustal deformation across Japan. These insights not only advance scientific knowledge but also contribute to building a safer and more resilient society.

Acknowledgments: The GNSS observation data used in this study was provided by SoftBank Corp. and ALES Corp. through the framework of the "Consortium to utilize the SoftBank original reference sites for Earth and Space Science".

Theme: (1)

Why the Corona Is So Hot: A New Look at Alfvén Wave Self-Splitting

Hayato Saguchi

The Sun's surface is approximately six thousand degrees, but the layer just above it, the corona, can reach more than a million degrees. However, the upside-down temperature profile remains a long-standing mystery. At the same time, a steady wind of electrified gas, the solar wind, blows into space at very high speeds. Where does the extra energy come from, and how is it delivered to the gas? This research examines simple and testable answers.

A useful way to visualize this is to imagine invisible strings stretching through the Sun's atmosphere. These "strings" are magnetic field lines. When the solar surface churns, it shakes these lines and launches magnetic waves along them, similar to plucking a garden string. These are known as Alfvén waves. They can carry large amounts of energy upwards. If part of this energy turns into heat, it can warm the corona and push the solar wind outward. These observations indicate that waves are likely to carry sufficient energy. However, the question remains as to how the energy becomes heated.

Turbulence is a well-known phenomenon. Many waves travel in different directions, collide, and break large motions into smaller ones, similar to an ocean turning into foam. The smallest motions rub against the gas and generate heat. Turbulence matters, but several studies have suggested that it may not supply sufficient heat everywhere by itself. For this reason, I focused on a complementary process that can enhance the turbulence and heat gas more directly. I call this "self-splitting," although its formal name is parametric decay instability.

Self-splitting occurs as follows: starting with one strong magnetic wave moving away from the Sun. Under the right conditions, that single "parent" wave breaks into two "children." One is a magnetic wave that travels back toward the Sun. The other is a wave that squeezes and stretches the gas, changing its density like a sound wave. This pair is powerful: the returning magnetic wave meets outward-moving waves and boosts the turbulence, whereas the density-changing wave can sharpen into a shock that heats the gas efficiently. Self-splitting converts large waves into forms that are easier to convert into heat.

When does self-splitting grow quickly and fade? In my work, I adjust two intuitive "dials." The first type compares the push from the particles (gas pressure) with the pull from the magnetic field (magnetic pressure). The second captures a "temperature preference." Because particles spiral around magnetic lines, the gas can be denser across the field than along the reverse direction. Earlier studies have suggested that when the gas is hot across the field, self-splitting tends to occur more easily.

For realism, I do not treat the Sun's atmosphere as uniform. Farther from the Sun, the magnetic field weakens, and the gas thins. The temperature preference can also change as the gas expands into space.

Several sets of radial profiles are constructed to detect these changes. Some are simple textbook patterns, whereas others use information from spacecraft, such as the Parker Solar Probe, and from large computer simulations. Using these profiles, I estimated how fast self-splitting grows at each distance from just above the corona to approximately 30 solar radii.

I also compare two wave "calculators." The first was a basic model that assumed the same temperature in each direction. The second method allows for different temperatures across and along the magnetic field. Both consider the local conditions and predict whether a wave will split and how fast the splitting will grow. You can think of them as two lenses in the same physics: one simpler and one more detailed.

The results are clear. Self-splitting was strongest close to the Sun. In many of the profiles, the growth is most vigorous within approximately 20–30 solar radii; beyond that, it tends to weaken. The reason for this is straightforward: as we move outward, the magnetic field becomes weaker, and the gas becomes thinner; therefore, a special mix of conditions that favors rapid splitting becomes less common. A model with different temperatures across and along the field typically predicts slightly faster growth than a single-temperature model. However, near the Sun, the magnetic field is so dominant that this temperature-direction effect adds only a modest boost.

These findings suggest a practical strategy for achieving this purpose. If we want to catch self-splitting "in the act," the best place to look is very near the Sun, the same region where the Parker Solar Probe is now flying. In computer models, it makes sense to give self-splitting a larger role close to the Sun because it can create returning waves, feed turbulence, and form heating shocks. Furthermore, more mature turbulence and other mechanisms may occur.

As in any previous study, there are certain limitations. I focus on the early linear stage of self-splitting when the effect is small but growing. In real space, several influences can change the outcome, such as the overall expansion of the solar wind, shifts in the frequency of the wave as the wind carries it (similar to a changing siren pitch), and background turbulence, which can either help or hinder effective splitting. These factors affect the final heating rate and should be included in future work; however, even with these caveats, the message is simple. The Sun launches magnetic waves that carry energy upward. These waves can break into new waves, making it easier for them to convert into heat. Two dials set the pace: the balance of particle push versus magnetic pull and whether the gas is moving across or along the magnetic field. As the solar wind expands, the dials change. When we account for realistic changes with distance, we find that self-splitting is the most important process close to the Sun and quietly farther out. This provides a clear, testable explanation for why the corona is so hot and how the solar wind pushes it.

Theme: (1)

Understanding Carbonatite Formation Through Natural Samples

Honoka Umemiya

Mineral resources such as fossil fuels and metals are essential for modern and future societies. In recent years, marked by rapid technological innovations, a stable supply of these resources has become indispensable for the future development of society. To secure these resources, it is crucial from a geoscientific perspective to understand the formation mechanisms of mineral deposits and their relationship to material circulation within the Earth's interior. Such an understanding is not only fundamental to academic research but also plays a vital role in improving the efficiency of resource extraction and exploration, as well as in promoting environmental conservation. Furthermore, advancing this knowledge may contribute to the development of refining processes and sustainable resource recycling strategies. I conduct research on "carbonatite," which is a type of igneous rock. Unlike typical igneous rocks such as granite, basalt, and andesite, which are mainly composed of silicon, carbonatite is characterized by very little silicon and, conversely, a high concentration of carbon. Owing to its chemical properties, carbonatite often contains high concentrations of resource-critical elements, such as rare-earth elements, and is therefore utilized as an ore deposit in many regions. A deep understanding of the formation processes of carbonatites is crucial not only from a geoscientific perspective, particularly in relation to the carbon cycle within the Earth's interior, but also from the standpoint of securing sustainable resource development for future society. With this motivation, I am working to better understand the formation process of carbonatites through detailed observations and analyses of natural samples. In geoscience, research approaches are generally divided into three categories: observation and analysis of natural samples, experimental studies that simulate natural conditions, and statistical or simulation-based studies based on accumulated observational and experimental data. Among these, I value research based on natural rock samples. Experiments and simulations are very useful for understanding how materials behave under controlled conditions; however, they often simplify complex processes and many variables found in nature. In contrast, natural samples may preserve evidence of multistage reactions and interactions between different substances that have taken place over long periods deep within the Earth. Understanding these natural complexities is essential for grasping deposit formation. For this reason, I focused on carefully observing and analyzing natural samples to deepen our understanding of how carbonatites form.

Theme：①

Gas Permeability Evolution During the Magma Ascent in the Conduit

Takeru Ohata

Background of my research

Volcanoes sometimes erupt explosively, like Pinatubo in 1991 or Sakurajima, while at other times they erupt effusively, as seen in the eruptions at Unzen during 1991–1995 or at Mt. St. Helens during 2005–2008. Explosive eruptions are caused by volcanic gases, primarily H_2O. These gases are dissolved in the magma chamber or the deeper part of the conduit.As magma ascends and undergoes decompression, gas solubility decreases, leading to the formation of bubbles in the ascending magma. The formation of bubbles provides buoyancy to the magma, and as the pressure decreases, the bubbles expand. At the surface, a small percentage of water constitutes more than 90% of the volume of the magma, resulting in an explosive eruption. For an effusive eruption, magma degassing must occur during this process.

Figure 1. shows a schematic image of ascending magma and degassing. Degassing by bubble buoyancy does not occur because the migration of individual bubbles is slow due to high viscosity. Instead, degassing is caused by a permeable flow through connected gas bubbles and fractures. The gas flux (q) of degassing can be calculated using Darcy's law:

$$q = \frac{k}{\mu} \cdot \frac{\Delta P}{L} \quad (1)$$

where μ is gas viscosity, $\Delta P/L$ is the pressure gradient, and the proportional constant k is the gas permeability, which indicate gas flowability. The gas permeability of magma changes with its pore structure, which in turn varies with the process of magma ascent in the conduit.

My research methods

Permeability changes with the pore structure of the magma; therefore, information on permeability in the deep parts of the conduit does not remain in the volcanic rocks collected from the Earth’s surface. For this reason, I primarily conduct experimental research. Additionally, X-ray computed tomography (CT) was used to determine changes in the pore structure.

Focus of my research

The permeability and porosity of the collected samples varied among the volcanoes and eruptions. This variation corresponds to the complexity of the ascent process. To understand this complex process, we focused on the continuous measurement of changes in permeability with deformation at high temperatures. In previous studies, permeability changes were obtained from measurements taken before and after deformation. However, this method requires numerous experiments to understand a single change process and involves variability due to differences in the starting materials. The continuous measurement of permeability changes enables us to obtain more detailed data with fewer experimental runs.

Applications for future work

These experimental results can enhance the application of the experimental data to model calculations and the interpretation of natural samples. In the field of conduit flow modeling, calculations are conducted by assuming permeability change processes without experimental validation. If this research clarifies how the permeation rate changes, it will be possible to enhance these calculations by incorporating permeability change processes with experimental validation.

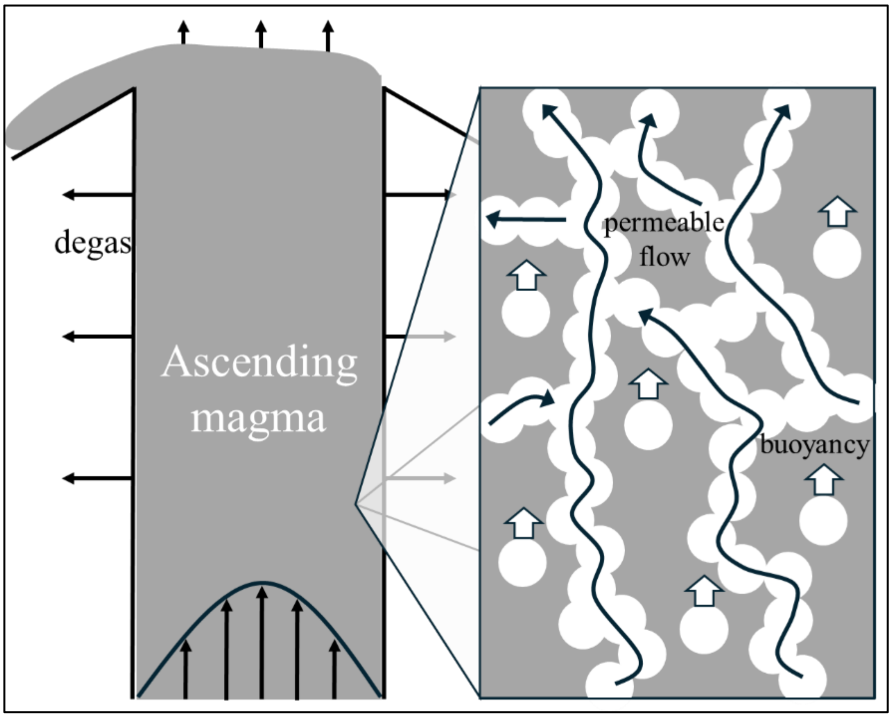

Figure 1. A schematic image of permeable flow and outgassing in the ascending magma.

Theme：(1)

Separation of exosome by size using porous electrode

Hiroshi Yuzawa

Since 1981, cancer has been the main cause of death in Japan. Currently, one in every four Japanese dies from cancer. As the population continues to age and the birthrate decreases, the number of people dying from cancer is expected to increase further. Therefore, reducing cancer deaths has become an urgent issue. The five-year survival rate for cancer patients depends significantly on the extent of cancer metastasis. For localized cancer, the survival rate is 92.4%, whereas for regional cancer and distant metastasis, the survival rates are only 58.1% and 15.7%, respectively. These numbers highlight the importance of detecting cancer at an early stage. Early diagnosis not only increases the survival rate but also reduces the burden of treatment, helps patients maintain a better quality of life, and reduces medical costs. Currently, two primary methods are used for early cancer detection: imaging and biomarker tests. Imaging tests include Magnetic Resonance Imaging and Computed Tomography scans, which detect tumors directly. Biomarker tests analyze body fluids, such as blood or urine, to measure the amount of certain proteins or other substances associated with cancer. Each method presents its own advantages and disadvantages. In terms of sensitivity, imaging can detect visible tumors, whereas biomarker tests may predict cancer prior to the emergence of a tumor. Regarding invasiveness, CT scans expose patients to radiation, whereas biomarker tests require only a small blood or urine sample, thus causing less physical stress. From a cost perspective, imaging requires expensive machines and is unsuitable for frequent screening, whereas biomarker tests are cheaper and easier to perform regularly. However, accuracy remains a problem in biomarker tests. Imaging is highly accurate because it shows a tumor directly, whereas biomarker tests can yield false results. This occurs because the protein level in blood can change temporarily owing to external factors such as alcohol consumption or diet. Hence, new biomarkers that can detect cancer at an early stage with high accuracy, high sensitivity, and low invasiveness must be developed urgently. Such biomarkers would enable the earlier and more reliable detection of cancer, thus contributing to mortality reduction and improving patients' lives. Exosomes are a type of extracellular vesicle and are secreted by all cell types. They typically measure 30–200 nm in diameter and contain various protein and nucleic acid such as DNA, mRNA, and microRNA, which reflect the characteristics of secreted cells. Because exosomes exit from bodily fluids (e.g., blood, saliva, and urine), they perform intercellular communication and are expected to function as biomarkers for early disease diagnosis. Recent studies show that the characteristics of secreted cells are related to not only nucleic acid but also its size. Therefore, the separation of exosomes by size can contribute to early disease diagnosis. However, conventional separation methods, such as size-exclusion chromatography (SEC) and density gradient centrifugation (DGC), present several disadvantages. SEC can separate exosomes based on the differences in the path length traversed through a packed filler. However, the separable volume is small, and this method is not applicable for early cancer diagnosis. DGC can perform separation based on density difference. However, this method causes the loss of many exosomes during the centrifugation process used for separation. Therefore, a new method for separating exosomes by size is required. In this study, we develop a novel size-selective method for exosome separation using carbon-coated anodic aluminum oxide (C/AAO: Fig. 1a, left). Anodic aluminum oxide is prepared by anodizing aluminum in an acidic aqueous solution. AAO has a highly porous structure, and its pore diameter can be precisely controlled between 20 and 300 nm by adjusting the anodization voltage and the duration of the pore-widening process. Moreover, carbon can be coated on its surface via chemical vapor deposition, thus endowing it with electrical conductivity. When a positive voltage is applied to C/AAO, negatively charged exosomes can be captured within the pores (Fig. 1a, center). The captured exosomes can be released by applying a reverse voltage (Fig.1a, right). In this study, C/AAO with a pore length of 15 μm and a pore size of 155 ± 31 nm was used (Fig. 1b). The C/AAO was immersed in exosomes dispersed in phosphate-buffered saline, and exosomes smaller than the pore size of C/AAO were captured by applying a voltage of 0.9 V. Nanoparticle-monitoring analysis indicated a significant decrease in the number of exosomes exceeding the C/AAO pore size after the capture-and-release process (Fig. 1c). These data suggest that the method using C/AAO is highly promising for the size-selective separation of exosomes.

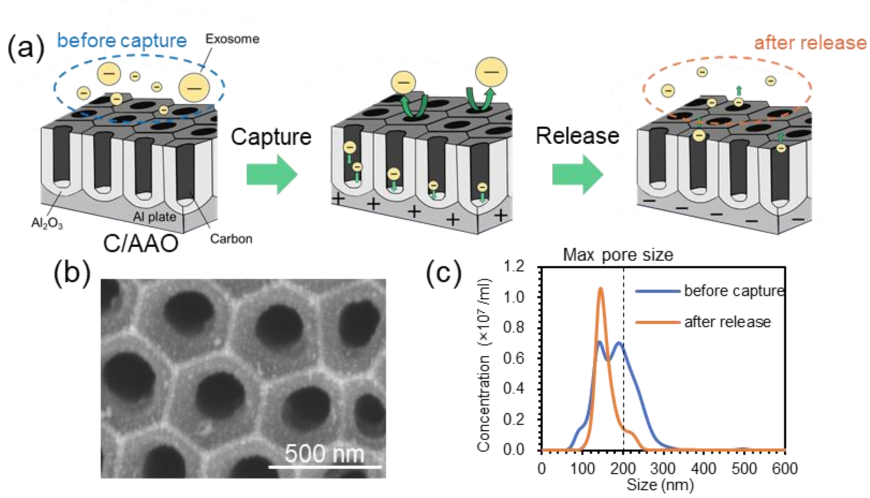

Figure 1. (a) Schematic illustration of size-selective separation of exosomes.
(b) SEM image of oriented C/AAO pores. (c) Size distribution of before and after size-separated exosome dispersion evaluated via nanoparticle-monitoring analysis.

Theme：C4TM6009

My research for advanced SPH

Inoue Yoshitaka

My name is Yoshitaka Inoue, and I am a second-year Master's student. My research focuses on the numerical analysis of unsaturated soils. In recent years, climate change has caused frequent and severe typhoons and heavy rainfall, often resulting in disasters such as landslides and floods. These disasters not only cause serious loss of life but also have significant economic and social impacts. Therefore, improving prediction techniques is an urgent issue. My motivation for pursuing this research also comes from my personal experience of witnessing a landslide in my community, which made me strongly aware of the importance of disaster prevention and mitigation.

Traditionally, the finite element method (FEM) has been widely used in geotechnical engineering. However, FEM is not well suited for problems involving large deformation, such as landslides, because the computational mesh often fails. To overcome this difficulty, I focused on the Smoothed Particle Hydrodynamics (SPH) method, which is a fully mesh-free approach. SPH has been widely applied in fluid mechanics and, has been extended to geotechnical problems in recent years. Some studies have applied SPH to simulate landslides in unsaturated soils. However, most of these studies relied on empirical parameter fitting in constitutive models, which limits their generality. My aim was to develop a more fundamental constitutive model by directly reproducing the microscopic physical behavior of soil particles and recording their responses under different conditions.

To achieve this, it is necessary to model the multiphase interactions among the soil particles, pore water, and pore air. I applied a resolved coupling approach within SPH to capture these particle-scale behaviors. Recent advances in SPH, such as high-order discretization schemes like LSSPH and LSMPS, have improved its accuracy, making it possible to reproduce realistic physical processes more reliably than before.

At the same time, long-term simulations require precise time integration. I primarily worked with the Incompressible SPH (ISPH) method, which is based on a projection approach that solves velocity explicitly and pressure implicitly. ISPH can be applied to large deformation problems such as landslides and multiphase flows at the particle scale. However, ISPH suffers from "splitting errors," which reduce its accuracy. To address this issue, I explored incremental formulations, improved boundary conditions, and multi-stage time integration schemes, such as the Runge–Kutta method.

One promising approach in my research is the “Fast Projection method.” In this scheme, the pressure is linearly approximated from previous values for intermediate steps; therefore, the Pressure Poisson equation is solved only once per time step. This significantly reduces the computational cost. Previous studies have shown that this method maintains almost the same accuracy and convergence as the Runge–Kutta method while achieving faster performance. I am currently applying this method to ISPH and evaluating its convergence, although further algorithmic improvements are required.

Internationally, SPH and related numerical methods are attracting increasing attention. Researchers in Europe and Asia have actively combined computational science with geotechnical engineering. I would like to contribute to this global research community by presenting my work at international conferences and by learning from interdisciplinary collaborations.

By the end of my master’s thesis, I aim to establish a reliable high-accuracy method and then shift my focus to the large-deformation analysis of unsaturated soils. My research seeks not only to advance numerical methods but also to support practical disaster prevention and mitigation. Looking ahead, I plan to continue my doctoral program, deepen my interdisciplinary research, and grow into a researcher who can contribute internationally. Ultimately, I hope to bridge computational science and geotechnical engineering to help build a safer and more sustainable society.

Theme: (1)

Diversity of Mid-Infrared Reflectance Spectra of Samples from Asteroid Ryugu

Taiga Takase

The spacecraft Hayabusa2, launched in 2014, reached the carbonaceous asteroid Ryugu in 2018. During the mission, infrared spectroscopic remote sensing was conducted, an artificial crater was created, and two sampling events were carried out. The spacecraft successfully returned to Earth in December 2020 (Tsuda et al., 2019, 2020; Tachibana et al., 2022). After curation at JAXA, the returned samples were distributed to research teams in Japan and to investigators worldwide. These efforts revealed a wide range of properties (e.g., Nakamura et al., 2022; Yokoyama et al., 2022; Okazaki et al., 2022; Noguchi et al., 2022).

Based on its shape, spectral observations, and theoretical modeling, Ryugu is predicted to be a rubble-pile asteroid formed by the re-accumulation of fragments following the catastrophic disruption of its parent body (Watanabe et al., 2019; Sugita et al., 2019). Mineralogical investigations of the returned samples confirmed that Ryugu consists of breccias composed of lithic fragments measuring approximately 10 to 500 μm (Nakamura et al., 2022). The degree of aqueous alteration was also found to vary among individual fragments, indicating that the asteroid formed after the breakup of its parent body and the subsequent re-aggregation of the fragments (Nakamura et al., 2022).

The Ryugu samples exhibited volatile element abundances, isotopic compositions, oxygen isotopic ratios, and mineral assemblages similar to those of the CI chondrites. Because their bulk composition is close to the overall composition of the Solar System, they represent some of the most primitive materials known (Yokoyama et al., 2022; Nakamura et al., 2022). However, there were also significant differences from the CI chondrites. Minerals such as sulfates, which are commonly found in CI chondrites, are absent in the Ryugu samples, and the amount of interlayer water in phyllosilicates is considerably smaller (Nakamura et al., 2022). These differences also appear in their reflectance spectra, for example, in the 3 μm absorption band due to molecular water and in the Christiansen feature, which is strongly influenced by the presence or absence of sulfates (Amano et al., 2023; Nakamura et al., 2022). The CI chondrites also display higher reflectance, indicating brighter spectra, although the direct cause of this difference remains unclear. These discrepancies are thought to result from the terrestrial alteration of CI chondrites after their fall to Earth through reactions with the atmosphere and liquid water (Amano et al., 2023). Therefore, the Ryugu samples are pristine materials that have not undergone terrestrial alteration. In this respect, they provide essential clues regarding the early evolution of solar systems.

In this study, we conducted reflectance spectroscopic analyses on approximately 400 fine Ryugu particles and obtained reflectance spectra in the mid-infrared wavelength range. These data were used to systematically investigate the properties of the Ryugu samples.

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Theme: The relationship between your research and a sustainable society

Mitigating Greenhouse Gas Emissions From Wastewater Treatment Processes by a Down-Flow Hanging Sponge Bioprocess

Ryota Maeda

Nitrous oxide (N_2O) is a greenhouse gas and an ozone-depleting substance. N_2O has a global warming potential approximately 273 times greater than that of carbon dioxide (CO_2) and contributes approximately 6% to the warming effect. It is also recognized as the most significant ozone-depleting substance of the 21st century, and its atmospheric concentration has been extremely elevated in the last 100 years. Among anthropogenic N_2O emissions, those emitted from wastewater and waste account for approximately 5% of the total N_2O emissions, including emissions from wastewater treatment processes. Although some studies have focused on reducing N_2O emissions from wastewater treatment processes, research on the removal of emitted N_2O is limited.

In this study, we developed a bioprocess for N_2O removal using a down-flow hanging sponge (DHS) reactor. This process specifically targets N_2O generated from anoxic tanks during nitrogen treatment in wastewater treatment processes, such as anaerobic ammonium oxidation (anammox). Continuous N_2O treatment experiments achieved over 94% N_2O removal efficiency within approximately 3 minutes at concentrations ranging from 5 to 300 ppm, and within 18 minutes even at a high concentration of 2,000 ppm under anoxic conditions.

This process utilizes microbial reactions to remove N_2O, eliminating the need for chemicals or other substances. Furthermore, the DHS reactor allows gas-phase N_2O to naturally dissolve into the liquid phase of the sponge carrier via gas–liquid equilibrium. This eliminates the need for power-consuming aeration, making this process an energy-saving technology. The mitigation of gas emissions can reduce N_2O emissions from wastewater treatment processes and contribute to building a sustainable society.

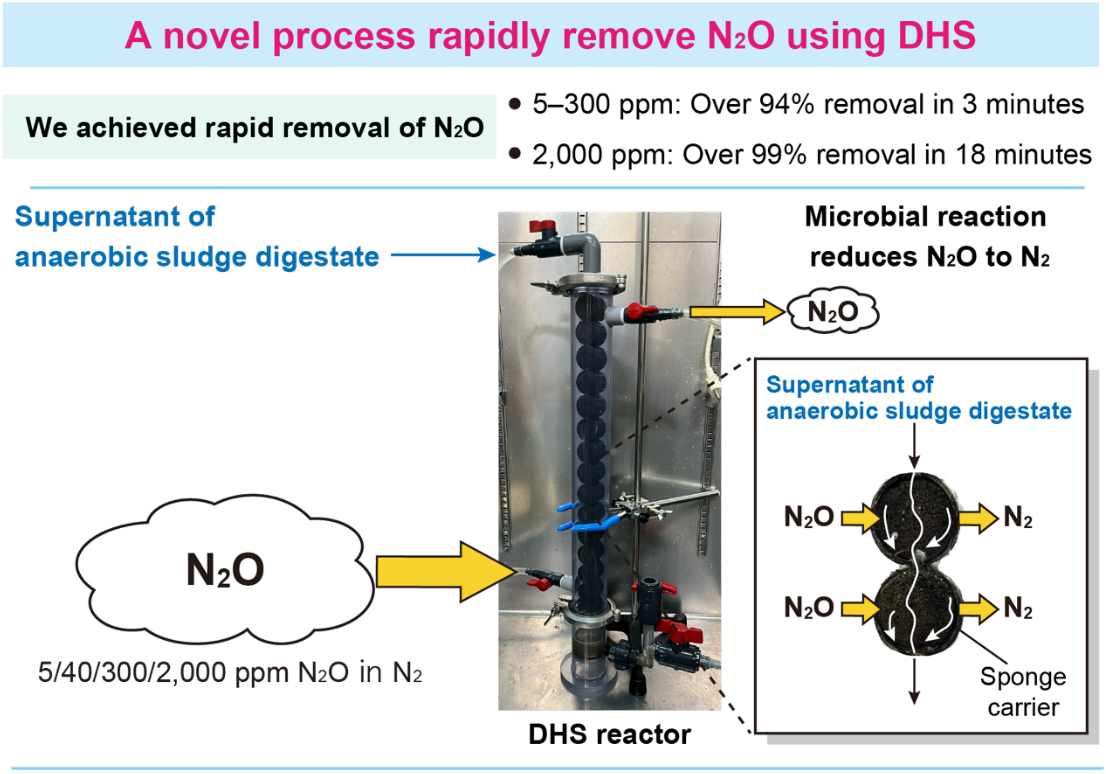

Fig. 1 Overview of this study

Theme: (2)

Volcanic Research for Sustainable Development

Taisei Ukita

In 2015, all UN Member States adopted the 2030 Agenda for Sustainable Development, widely known as the 17 Sustainable Development Goals (SDGs). The SDGs provide a universal, integrated blueprint spanning social, economic, and environmental dimensions. Within this framework, I consider how volcanological research can contribute to SDG 1 (No Poverty) and SDG 11 (Sustainable Cities and Communities).

Globally, some cities are located alongside highly active volcanoes. Kagoshima, Japan (with Mt. Sakurajima), and Catania, Italy (with Mt. Etna), are emblematic examples. Despite frequent eruptions, hundreds of thousands of residents continue to live in areas exposed to volcanic hazards. The difference lies not in proximity but in capability: decades of sustained monitoring, transparent alert protocols, and science–policy linkages that translate observations into timely decisions. Where such measures are incomplete or absent, exposure remains high; in some places, communities may not even realize that they inhabit hazardous zones. In this context, volcanological research can be viewed as a form of lifesaving infrastructure. However, capability is uneven across regions. The 2014 eruption of Mt. Ontake illustrates how rapidly conditions can shift and why preparedness and clear communication are essential.

On September 27, 2014, Mt. Ontake in central Japan experienced a sudden phreatic eruption around midday when many hikers were near the summit. Ballistic blocks and ash struck popular trails, and 63 people lost their lives (Sano et al., 2015), marking Japan's deadliest volcanic disaster in decades. Precursory signals were present but subtle and did not prompt the Japan Meteorological Agency to raise the eruption alert level. As a result, hikers received no timely official warning before the eruption. A post-eruption survey by Shinano Mainichi Shimbun found that 39% of respondents were unaware that Mt. Ontake is an active volcano, and that 91% of bereaved families and 76% of climbers did not pay attention to the eruption risk. The lesson is not only technical but also institutional: multi-parameter monitoring must be coupled with conservative access policies near craters, clear and timely public messaging, and routine preparedness measures (such as signage, drills, and shelter plans) for high-use areas.

Despite decades of advances in volcanic research, including monitoring and modeling, accurately predicting eruptions remains beyond our current capabilities. However, the field of volcanology continues to progress by building a multi-method view of pre-eruptive magma behavior. Field observations, geophysical and geochemical monitoring (seismicity, deformation, gas, thermal), remote sensing, laboratory experiments, numerical modeling, and petrological analyses of erupted materials work together to constrain the processes and timescales. In my work, I concentrated on subtle variations in the chemical composition recorded in minerals and glass within erupted rocks. These compositions provide insight into the conditions the materials experienced prior to the eruption and can be analyzed using diffusion chronometry and related techniques. By employing these methods, I quantified the hours-to-days records of the host magma's evolution prior to eruption. When considered alongside direct observations, this materials science approach advances our understanding of volcanic activity and aids in translating petrological evidence into more informative interpretations of monitoring data.

Volcanic research also serves as a public touchpoint, raising awareness about eruption-related hazards. Unlike earthquakes or extreme rainfall, large life-threatening eruptions have a low frequency but high impact. Research programs can include outreach, which helps residents locate themselves relative to hazard zones, understand plausible impacts, and learn about evacuation routes and trigger conditions. Thus, volcanology contributes to SDG 1 (No Poverty) by reducing disproportionate losses among vulnerable groups, and SDG 11 (Sustainable Cities and Communities) by informing risk-aware urban planning and preparedness.

Scientific analysis clarifies the nature of volcanic activity, whereas institutions and communities use this knowledge to take action for preparedness. When petrological insights are paired with multi-parameter monitoring and fit-for-purpose governance (including alert thresholds, access management near craters, and practiced communication), warnings can be issued earlier, policies can be calibrated to the actual risk, and responses can be rehearsed in advance. The result is not certain and remains unattainable, but rather a narrower uncertainty that can be turned into practical decisions that protect lives and livelihoods.

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Theme: (2)

A Sustainable Future with Zero-Emission Energy Sources Can Be Realized by Developing New Materials

Toshiki Saito

I am Toshiki Saito, a PhD student at the Graduate School of Engineering, Tohoku University. Since 2021, I have been developing Cu alloys that exhibit high strength and ductility under harsh conditions. Modification of the material microstructure is key to enhancing material performance. Our research group is currently developing oxide-dispersion-strengthened Cu alloys (ODS-Cu). ODS-Cu is a type of Cu alloy whose microstructure is altered from that of pure Cu metals by dispersing nanosized oxide particles. ODS-Cu can exhibit outstanding material properties through this type of microstructural modification. Currently, my mission is to fabricate a Cu material that demonstrates high strength and to reveal the mechanism behind the improvement in material strength using microstructure observation methods such as electron microscopy and X-rays.

How can my research and new material development contribute to realizing sustainable society? To answer this question, I must explain the goal of the material on which I have been working.

My research topic, the oxide dispersion strengthened Cu alloys (ODS-Cu), is a material that has been studied based on the demand for **fusion reactor development**. Fusion reactor, or fusion energy is a new energy source that produces enormous amounts of energy with almost no greenhouse gas (GHG) emissions.

Currently, most electricity is produced by burning fossil fuels, such as coal, oil, and natural gas. These energy sources generate large amounts of electricity. In addition, the electricity produced by burning these fuels cannot be influenced by human-uncontrollable factors, unlike renewable energy sources. However, burning these fuels emits large amounts of GHG. Since the industrial revolution, human prosperity has been achieved by burning fossil fuels, exposing the Earth to the risk of global warming and climate change. Currently, a movement against such developments is spreading, especially in Western countries. To save our planet, we must perhaps stop using fossil fuels as soon as possible and cease emitting GHG into the environment.

However, we cannot give up all the efficiency and convenience of everyday life achieved through the use of a large amount of electricity. Furthermore, there are still many people in the world who suffer from hunger, poor hygiene, and poverty. If we were to stop all civil activities in the world that rely on electricity, many individuals enduring such circumstances would be at risk of survival. We cannot sacrifice these people, even for the sake of environmental protection.

What if the energy source were beneficial for both the environment and humanity? This is the concept of fusion energy. Nuclear fusion reactions produce enormous amounts of energy. When two nuclei meet and fuse into the nuclei of different atoms, a significant amount of energy is released. This energy can be harnessed for electricity production in fusion reactors. Fusion reactors are capable of generating substantial amounts of energy, and their output can be controlled by humans. They do not emit GHG during electricity generation. Fusion energy is expected to be an energy source that supports a sustainable future for both Earth and humanity.

However, in reality, the fusion reactor is a technology that is currently under research, and many barriers must be overcome for its realization. One of these issues is the lack of materials that can effectively remove the heat generated by the fusion reaction under harsh conditions. A large amount of heat, almost equivalent to the heat of the nozzle of a launching space rocket engine, along with highly energized neutrons and other highly energized ions, is produced by the reaction. A fusion reactor that harnesses the fusion reaction and generates electricity must be composed of materials that can withstand thermal loads and energetic particle bombardment. Current commercial materials struggle to endure these conditions for long periods. If these materials are used, the components of the reactor will need to be frequently exchanged to maintain the system's health. Therefore, new materials with excellent properties and high toughness against thermal loads and energetic particles are required. Additionally, as mentioned previously, the ability to effectively remove heat is necessary for the new material; thus, ODS-Cu is expected to be a promising candidate for future fusion reactors. ODS-Cu is expected to have higher strength in high-temperature environments and greater tolerance to the bombardment of energetic particles. The alloy also exhibits comparable heat transfer capabilities. We must produce ODS-Cu, which possesses outstanding properties that no other copper materials have previously shown.

There is still a long way to go to convert ODS-Cu into commercially available and ready-to-use materials for fusion reactors, but I believe that the development of ODS-Cu will contribute to the realization of fusion reactors and this research contributes to the future of both humanity and our planet.

Theme：（Number）

Sustainable Societies and the Role of Research on Stress Corrosion Cracking in Carbon Steel Overpacks for Geological Disposal of High-Level Radioactive Waste

Tomohiro Takita

The pursuit of a sustainable society requires a careful balance between fulfilling the energy demands of modern civilization and protecting the environment for future generations. One of the most pressing challenges in this endeavor is the safe and long-term management of high-level radioactive waste (HLW) generated from nuclear power plants. Although nuclear energy offers a low-carbon alternative to fossil fuels and contributes significantly to reduction of greenhouse gas emissions, the waste it produces remains hazardous for tens of thousands of years. Therefore, ensuring its safe isolation from the biosphere is critical to sustainable development. My research focuses on one of the key technical aspects of this issue—: the potential for stress corrosion cracking (SCC) in carbon steel overpacks used for the geological disposal of HLW—and explores how this work contributes to the realization of a sustainable society.

Geological disposal is widely recognized as the most feasible and ethically responsible method for managing HLW. In this approach, the waste is solidified, sealed in robust metallic containers (overpacks), and buried hundreds of meters underground in stable geological formations. Overpacks play a crucial role in maintaining their integrity for thousands of years to prevent the release of radionuclides into the surrounding environment. Among the various candidate materials, carbon steel is considered promising due to its mechanical strength, availability, and cost-effectiveness. However, its long-term corrosion behavior under repository conditions remains a subject of active research. One potential threat to its integrity is stress corrosion cracking—, a localized form of corrosion that can lead to sudden failure even under relatively low applied stress.

This study investigated the conditions under which SCC may initiate and propagate in carbon steel overpacks, particularly in the presence of groundwater containing chloride ions and under the reducing chemical environments expected in deep geological repositories. Through a series of laboratory experiments, the key environmental and mechanical parameters governing the likelihood of SCC were identified. Understanding these mechanisms is essential for developing reliable models that predict the long-term performance of overpacked materials. Finally, this study provides scientific evidence to support the design of safer and more durable disposal systems.

The connection between this study and the concept of sustainability extends beyond the realm of materials science. Sustainable development is defined as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs.” In the context of nuclear waste management, this means minimizing environmental risks and ensuring intergenerational fairness. By improving the safety and reliability of geological disposal systems, this research helps alleviate the burden placed on future generations, who would otherwise have to monitor or remediate waste repositories for centuries. Therefore, studying SCC in overpacked materials directly contributes to environmental stewardship and long-term societal responsibility.

Furthermore, this study will play a crucial role in maintaining public trust in nuclear energy—, which is a key element in many countries’ sustainable energy strategies. Despite its potential to mitigate climate change, nuclear energy faces strong opposition due to concerns about accidents, waste, and long-term safety. Transparent, evidence-based research on the integrity of disposal systems is essential to address these concerns. By providing quantitative data and a mechanistic understanding, this study demonstrates that nuclear waste can be safely and ethically managed. This, in turn, supports informed policymaking and contributes to public acceptance of nuclear power as part of a diversified, sustainable energy mix.

In conclusion, the study of stress corrosion cracking in carbon steel overpacks for the geological disposal of high-level radioactive waste is not merely an isolated technical problem. It is part of a larger ethical and environmental commitment to building a sustainable society. By advancing our understanding of corrosion mechanisms, improving material performance, and enhancing the credibility of nuclear waste disposal strategies, this study contributes to the safe utilization of nuclear energy and the protection of future generations. In this context, this research serves as a bridge between the precision of materials science and the broader vision of a sustainable human future.

Theme：**(2)**

From Agricultural Waste to Bioenergy: Anaerobic Digestion of Rice Straw

ZENG QINGKANG

As demand for energy continues to increase around the world with the depletion of fossil fuel reserves, responding to global calls for renewable and low-carbon energy systems is critical to achieve a sustainable society. Moreover, the accumulation and improper disposal of agricultural biomass residues have serious impacts on the environment and waste considerable resources. Among these residues, rice straw is one of the most abundant forms of dry plant matter byproducts worldwide, with annual production reaching billions of tons. However, managing rice straw resources remains a pressing environmental issue. Of note, rice straw is highly resistant to microbial degradation given its high lignocellulosic content, crystalline cellulose structure, and rigid physical characteristics. Consequently, open field burning is still commonly used as a prevalent method of disposal in many regions. This releases a great deal of CO_2, CH_4, and particulate matter, and thus contributes to global warming, air pollution, and loss of soil nutrients.

As a representative lignocellulosic biomass, rice straw has therefore attracted increasing attention as a potential substrate for bioenergy production using environmentally friendly bioconversion technologies. Among these methods, anaerobic digestion (AD) is recognized as a promising biological process that can decompose organic matter into biogas (mainly CH_4 and CO_2) under oxygen-free conditions while simultaneously recycling nutrients and processing waste sustainably. However, anaerobic digestion of rice straw faces several technical challenges. Its low biodegradability and structural recalcitrance often result in incomplete hydrolysis, excessive accumulation of volatile fatty acid (VFA) compounds, and subsequent process instability, which leads to reduced methane yield and low efficiency in terms of energy recovery. These limitations highlight the need for further optimization of process parameters and a deeper understanding of the mechanics of microbial interactions that govern substrate conversion and system performance.

In recent years, various strategies have been developed to enhance the efficiency of anaerobic digestion of lignocellulosic materials. Process-level approaches have focused on optimizing operating conditions such as temperature regimes, inoculum sources, substrate-to-inoculum ratios, and retention times to enhance microbial adaptability and substrate accessibility. From a biological perspective, research efforts have increasingly emphasized the regulation of microbial community structures and syntrophic cooperation to maintain a balanced relationship between hydrolytic, acidogenic, and methanogenic populations. Building on this foundation, in this study, we optimized the anaerobic digestion performance of rice straw through integrated process engineering and analyses of the microbial ecology. Our investigation combined systematic experimentation with kinetic modeling to elucidate the relationships between operational factors, degradation kinetics, and microbial community dynamics to establish a scientific basis for stable and energy-efficient anaerobic systems.

Beyond the technical scope, the optimization of anaerobic digestion of rice straw involves some significant social and environmental implications. This approach provides a sustainable solution for agricultural waste management and renewable energy generation and contributes to the reduction of carbon emissions and air pollution. The produced biogas can be used for rural electricity or heating, whereas the digestate and effluent can be recycled as organic fertilizers to enrich soil nutrients. This agricultural waste processing cycle exemplifies the principles of a circular economy and aligns closely with several Sustainable Development Goals (SDGs), including Goal 7, affordable and clean energy, Goal 12, responsible consumption and production, and Goal 13, climate action.

In summary, as shown in Fig. 1, enhancing the performance of anaerobic digestion of rice straw improves the efficiency of renewable energy production and contributes to a broader vision of a sustainable society. By integrating process optimization with an understanding of microbial ecology, our findings support the transition toward a low-carbon, sustainable, and environmentally harmonious future.

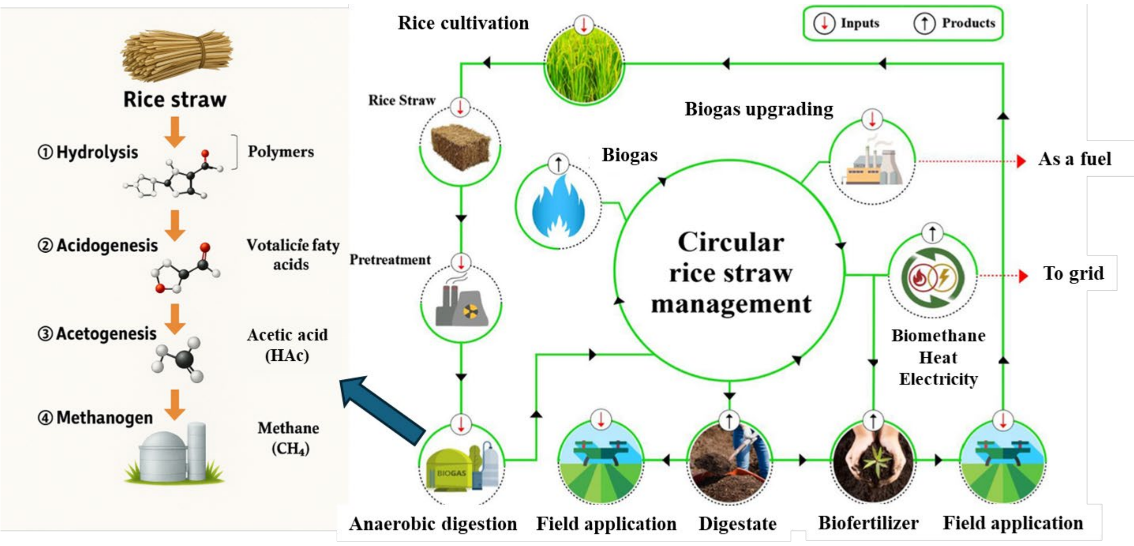

Fig. 1. Conceptual framework of circular rice straw management integrated with anaerobic digestion process.

Theme: (2)

Numerical Approach for Sustainable Transmission Systems

Yuto Yamano
Department of Civil and Environmental Engineering

Numerical Approach for the Collapse of Transmission Towers

With severe climate change, existing infrastructure is sometimes damaged by unexpected natural disasters [1]. My research target, transmission towers, has also experienced collapse. I propose the example of a tower collapse. In September 2019, transmission towers collapsed due to Typhoon No. 15 in Chiba Prefecture. This collapse caused severe supply disruption, with almost 640,000 households reporting blackouts.

In the following section, the current situation is explained. In Japan, many transmission towers were constructed during the rapid economic growth following World War II (from approximately 1955 to 1973). The expected lifetime of these towers was assumed to be approximately 50 years. However, many of them still play a role in the electric power supply. This implies that we must establish maintenance technology for old transmission towers.

I think that my research contributes to this field. The failure behavior of transmission towers is usually studied using numerical simulations [2]. A numerical simulation is a research method used to create a computer program to solve this equation.

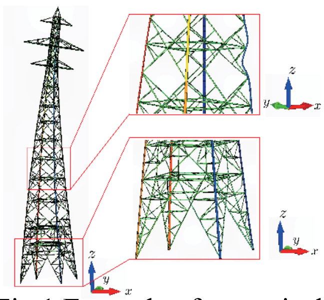

Fig.1 Example of numerical simulation result

In this case, you should imagine the equilibrium equation if you studied physics in high school. Can you explain the "advantages" of numerical simulation? If asked, I would answer that you could easily perform several experiments. Please remember your experience in science class. You can prepare many chemicals and equipment. However, these methods can be costly. Moreover, if the required experiments differ, the necessary equipment will also vary. You must also maintain funding. Therefore, it is difficult to compare various experimental results. Fig. 1 shows an example of the simulation results.

However, numerical simulations only require computers and programming skills. It may be difficult to set up the computational system and write the programming code; however, once it is established, various experiments can be performed by changing the initial setting values. On the other hand, please keep in mind that not all phenomena can be simulated by computer. Therefore, appropriate methods should be selected. My research applies numerical simulation instead of break experiments because I will evaluate various damage failures of transmission towers.

The relationship of my research to a sustainable society

Additionally, the repair effect on the damaged transmission towers was evaluated. This will aid in the effective management of existing transmission towers. In current engineering practices, the judgment on repair or reconstruction is determined according to the state and degree of damage. Repair can be done by member replacement and is usually based on qualitative damage assessments such as "large, medium, or small." Moreover, this judgment depends on the skill and experience of the inspector.

What is the problem? Please imagine that you have to carry out actual inspection work. Unfortunately, I cannot make an appropriate judgment about the damaged transmission towers, and I am sure you feel the same. Experienced engineers may make ideal decisions, whereas beginners may not. Hence, damaged transmission towers are repaired based on individual judgment, which can vary from person to person.

Let us now confirm another issue. As you checked for unclear repair criteria, the repair effect of member replacement is not necessarily clear. Visually, the damaged members are replaced by straight members. However, it is not possible to evaluate repaired transmission towers quantitatively. Therefore, it is unclear whether repaired transmission towers will easily break during the next disaster.

My research also attempted to standardize tower strength. It is difficult to determine the strength of the damaged towers. However, the collapse must be addressed. I attempt to evaluate this by observing the member damage. Strength degradation can be assessed during daily inspections.

In view of the above situation, this research, damage assessment, and repair methods are expected to be in high demand for the effective management of transmission towers. Damaged transmission towers can be maintained even after severe disasters. One may accurately assess tower strength, appropriately select the replaced member, and efficiently achieve strength recovery after hazards. This means that we need not fear a severe breakdown of the electric power supply, significant disruption to daily life, and socioeconomic stagnation.

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Theme: (2)

The Jupiter System as a Multidisciplinary Gateway to Sustainability

Natsuko Matsushita

Earth and planetary science studies seek to understand the structure and phenomena of planets. Research topics on Earth, such as volcanoes, the atmosphere, the ocean, and the magnetosphere, play a direct role in addressing natural disasters and environmental issues. By contrast, studying planets beyond Earth seems less directly connected to our daily lives. However, to determine whether the phenomena we observe on and around Earth are universal, we must compare them with observations on diverse planets and moons and study both their similarities and differences. This essay suggests connections between the study of Jupiter's moons and a sustainable society.

Jupiter, the largest planet in the solar system, has a radius approximately 11 times that of Earth and a magnetic field intensity approximately 20,000 times greater. It is scientifically interesting for several reasons: it represents a key body for investigating the formation and evolution of the solar system; its icy moons may host subsurface oceans capable of supporting life; and its powerful magnetic field produces a plasma environment fundamentally different from that near Earth.

The innermost Galilean moon, Io, located at 5.9 R_J (where 1 R_J = 71,492 km is Jupiter's radius), is the most volcanically active object in the solar system. Volcanic SO_2 gases released from its atmosphere are ionized, generating heavy ions (S^+, S^{2+}, S^{3+}, O^+, O^{2+}) at a rate of approximately 1 ton per second in the inner magnetosphere. These ions are incorporated into Jupiter's rapidly rotating magnetic field, forming the Io plasma torus, a dense and doughnut-shaped plasma structure surrounding the planet.

At greater radial distances, magnetic field lines are stretched by centrifugal forces and reconnect, releasing stored magnetic energy to charged particles and producing hot electrons. In the inner magnetosphere, while hot electrons (with energies of several hundred electron volts) represent only a small percentage of the total electron population, their fraction increases with radial distance. This distribution can be explained by the instability driven by centrifugal force; as dense and heavy ions are transported outward, light and high-energy electrons move inward.

Europa, located at 9.4 R_J, is believed to harbor a salty subsurface ocean beneath its icy crust, likely in contact with the rocky mantle, as indicated by Galileo magnetometer observations. Europa also contributes oxygen and hydrogen ions to Jupiter's magnetosphere through interactions between its icy surface, tenuous atmosphere, and the surrounding plasma. At the same time, plasma originating from Io supplies energy to Europa, which may help sustain a potentially habitable environment. For these reasons, the investigation of Europa's plasma environment is significant not only for elucidating the mechanisms of mass and energy transport in Jupiter's magnetosphere but also for assessing Europa's prospects for habitability.

In our research, we used extreme ultraviolet spectra obtained by the Hisaki space telescope and derived the electron density, temperature, and the ion composition from Io's to Europa's orbit. Hisaki could observe a wide field of view for an extended period, enabling it to acquire simultaneous data spanning from Io's orbit to Europa's orbit for the first time. Both the estimated hot electron fraction and charge state of the sulfur ion increased with increasing distance from Jupiter, which is consistent with previous studies. We investigate variations in plasma properties in Europa's orbit during Io's volcanically quiet and active periods.

The appeal of planetary science lies in comparing phenomena with those on Earth. Investigating the interactions between Jupiter's magnetosphere and its moons requires a multidisciplinary approach that integrates knowledge from physics, chemistry, and life sciences. By sharing insights about planetary environments with students and the public, we can not only develop a comprehensive perspective on Earth and its place in the universe but also demonstrate the necessity of studying a wide range of natural science fields. This broader understanding can serve as a gateway for supporting efforts to build a more sustainable society.

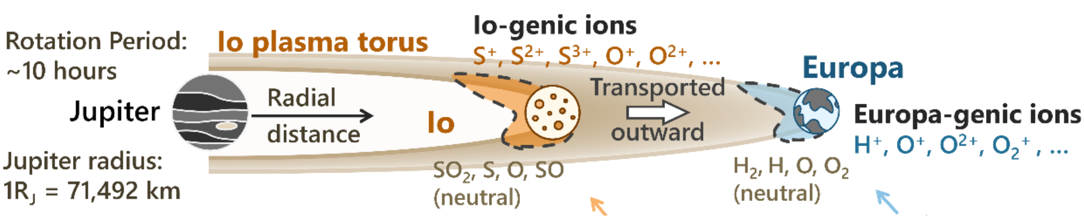


Figure 1. The schematic of Jupiter's magnetosphere and its moons, Io and Europa.

Theme: (2)

Safe Water in a Warming World: Understanding the Hidden Risks of Toxic Algae

Shoya Tanaka

Recently, the word "sustainability" has become increasingly important to societies worldwide. It is not just about protecting forests or reducing carbon emissions, but also about ensuring that basic necessities, such as safe drinking water, are available for future generations. In many countries, water is taken for granted; people can simply turn on the tap to obtain clean water. However, this does not imply that the system is robust. It is fragile and threatened by climate change. My research examines one aspect of this problem: ensuring that we have clean water in a warming world. I am especially interested in the risks posed by toxic algae, which may become more common with climate change.

When most people think about climate change, they imagine melting ice caps, rising sea levels, and intense heat waves. However, few consider that climate change could affect the water in their glass. There is a strong connection. Climate change alters rainfall patterns, increases water temperatures, and disrupts the delicate ecological balance of rivers, lakes, and reservoirs. These changes create new opportunities for certain types of tiny organisms, particularly a type called cyanobacteria, also known as blue-green algae, to thrive. Occasionally, these algae can grow in large numbers, turning the water a very green color, which can be unappealing to anyone using it. Not all cyanobacteria are harmful; however, some species produce toxins known as cyanotoxins. These toxins can damage the liver and nervous system and can even be fatal at high doses. This is not only an environmental issue but also a direct threat to human health.

This problem is exacerbated by climate change, which makes these harmful blooms more common. Warmer weather allows toxic algae to grow more easily. Storms also wash more nutrients, such as nitrogen and phosphorus, into lakes and rivers, causing the algae to proliferate further. Longer droughts indicate that these harmful organisms are less diluted. Scientists already know that cyanobacteria blooms are occurring more frequently all over the world. However, they do not understand how these toxins are likely to be produced as a result of climate change. If there were more algae, there would have been more toxins. Alternatively, changes in the competition between toxic and nontoxic strains may lead to different outcomes. This study attempted to answer these questions.

To address this issue, experiments were conducted in a laboratory. The growth of toxic and non-toxic cyanobacteria was compared. By growing them in a laboratory, researchers can observe how they compete for resources, how they react to changes in temperature, and how environmental stress affects their survival. These data form the basis for creating mathematical models that simulate competition between the two groups. When the models were ready, computer tests were conducted using different climate scenarios, such as warmer average temperatures, varying amounts of rain, and extreme weather conditions. This will help predict whether cyanobacteria bloom more often and whether toxic strains will become more common in ecosystems that supply drinking water.

This type of research might sound technical, but it has a significant impact on people. Consider a community receiving drinking water from a nearby reservoir. Currently, water treatment plants can handle occasional algal blooms. However, if toxic blooms occur more frequently or are stronger, treatment systems may not be able to keep up with them. The consequences can range from unpleasant tastes and smells to more serious health risks. This research attempts to identify these risks before they occur. This will give society a chance to prepare, for example, by improving monitoring practices, developing better treatment technologies, or managing water sources more effectively. This means that the work is not just about algae and models, but also about protecting one of the most important elements of life.

Access to safe water is a basic requirement for humans. The United Nations Sustainable Development Goal 6 (SDG 6) focuses on ensuring that everyone has access to clean water and sanitation. They recognize that if people cannot rely on clean water, then countries cannot make progress in health, education, and economic stability. However, climate change can complicate this because it creates new uncertainties in water quality. This research helps protect the environment by highlighting hidden risks that could affect water security if ignored. If we look to and plan for the future, we can strengthen the system and protect people who might be in danger.

I believe that this work is a link between science and society. Models and simulations may seem abstract, but they can help us make informed decisions about how to manage water, educate our communities about it, and even use it in our daily lives. By sharing these risks in a way that everyone can understand, I hope to contribute as both a researcher and a citizen who cares about others. Sustainability is not achieved in laboratories alone; it requires everyone to be aware and take action.

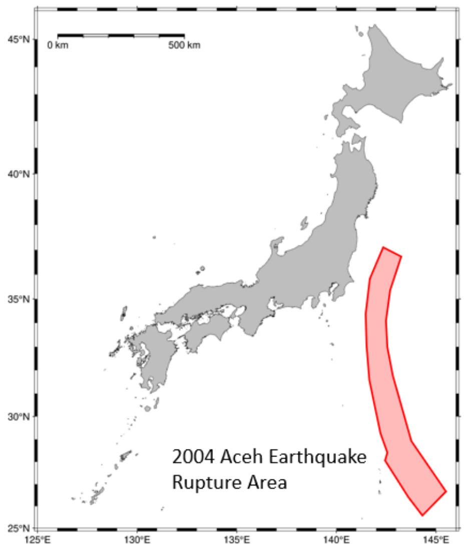
Thus, ensuring clean water in a changing climate is both important and challenging. This is accomplished by conducting experiments in the laboratory, using models, and running simulations. This has helped me understand how toxic and non-toxic algae respond to future environmental conditions. This understanding will help highlight any potential dangers to water safety and support the sustainable management of this vital resource. Clean water is more than just a nice thing to have; it is essential for living a dignified and healthy life. Protecting it from climate change is both a scientific and moral responsibility. If we want the world to be a good place for future generations, we must ensure that everyone has access to clean water.

Theme: (2). The relationship of my research to a sustainable society

Hidden Movements Beneath Sumatra: Understanding Earth for a Safer Future

Fermiro Faza Haribowo

When considering sustainability, we often imagine clean energy or the protection of forests. However, for countries like Indonesia and Japan, sustainability also means surviving nature's most powerful forces: earthquakes and tsunamis. Earthquakes are among the most powerful and unpredictable forces on Earth. In only a few seconds, they can reshape coastlines, destroy cities, and change the course of communities for generations. However, their causes begin in the quietest places, deep beneath our feet, where the Earth's crust slowly bends, slips, and stores energy for decades or centuries.



Geodetic research reveals that the 2004 earthquake has a rupture area almost as large as Japan

In Indonesia, the 2004 Sumatra-Andaman earthquake remains one of the clearest lessons from Earth's power. With a magnitude of 9.1, it triggered tsunami waves of more than 30 meters in height, claiming over 200,000 lives. For many Indonesians, it became clear that natural disasters are not "acts of fate," but the result of living in dynamic environments where risk must be managed, not ignored.

Since then, Indonesia has made great progress in monitoring systems and community awareness; however, the Earth continues to move quietly, invisibly, and constantly. Scientists studying these processes, such as myself, use tools such as global navigation satellite systems (GNSS) and seismometers to measure how the ground deforms over time and to detect the earthquakes it produces. With these data, we can not only understand the explanations of past earthquakes that occurred, but also try to prevent the loss of life and destruction from future earthquakes.

Understanding the Earth is the first step toward a disaster-resilient society. What we do with this understanding defines sustainability. Scientific knowledge must be translated into policy, planning, and education. Bridging science and policy is one of the greatest challenges of disaster management. Researchers may develop accurate models of how stress accumulates on faults; however, these models must reach the desks of those who design buildings, plan cities, and allocate resources. Communication between scientists and policymakers should not happen only after a disaster, but also continuously as part of a feedback system that keeps society prepared.

Preparedness is not only about technology; it is also about building a culture of awareness. Communities that understand their environment can react and recover more quickly. Policymakers who value and invest in long-term scientific monitoring contribute directly to the sustainability of a nation. Every earthquake that occurs provides lessons, but these lessons are meaningful only if they are shared, institutionalized, and remembered.

Keeping these things in mind, it is important for us to remember that an earthquake is not something that we, as a society, can escape from, but rather a phenomenon that we must embrace and prepare for. By investing in long-term observation networks, supporting local research, and encouraging education that connects students to Earth science, we can build not only knowledge but also resilience. For policymakers, this means recognizing that disaster mitigation is not a cost; it is an investment in the nation’s stability and safety for future generations. For students, this means seeing science not as something distant but as a language that explains the world in which they live.

Beneath the calm sea surface near Sumatra, the Earth continues its slow, invisible dance. Every millimeter of movement carries a message about the planet’s history and our collective future. If we listen carefully to science, education, and wise policies, these messages can guide us toward a safer and more sustainable society. Understanding the hidden movements of the Earth is, ultimately, understanding how to live responsibly on it.

Theme：2

The Relationship of My Research to A Sustainable Society

Nasaai bin Masngut

When a big and complicated issue hits the news, such as the release of treated water from the Fukushima Daiichi Nuclear Power Plant, people respond with questions, worries, and opinions. My research asks the following simple but powerful question: How do official messages and media stories shape how the public feels about and responds to these moments? To study this, I focus on the Japanese government and related organizational communication about the Fukushima treated water release and analyze how news articles present those messages.

I use two main tools. First, I apply **Image Repair Theory (IRT)** which is a framework from communication studies that explains the communication strategies used to protect trust and reputation. Examples include providing evidence, taking corrective action, and expressing concern. Second, I use **Natural Language Processing (NLP)** which is a computer technique that help us "read" and classify large amounts of text. With NLP, I can automatically label news articles for which IRT strategies appear and measure the **sentiment** (positive, neutral, or negative) of the coverage and public reactions. By combining theory and technology, I aim to understand the types of messages that reduce anxiety, strengthen trust, and support informed public discussion.

The Relationship of My Research to a Sustainable Society

A sustainable society requires more than clean energy, healthy oceans, or smart cities. It also depends fundamentally on **trust**. Even the best environmental plans can fail if people do not trust scientific information or public institutions. My research supports sustainability by examining the **communicative** processes that connect science, policy, and everyday life.

My arguments are as follow:

1. **Environmental Decisions Need Public Understanding.** When communities understand how safety standards work, how monitoring is performed, and what risks imply in practical terms, they can participate in decisions with confidence. Participation stabilizes policies over time, which is an essential part of sustainability.
2. **Resilience Depends on Credible Information.** During disasters or high-uncertainty events, clear, timely, and culturally sensitive messages can help people act safely. Good crisis communication reduces confusion, prevents harmful rumors, and helps communities bounce back.

3. **Justice and Inclusion Strengthen Long-Term Outcomes.** Sustainable development requires that all voices, especially those of local workers, such as fishers, small businesses, and youth, be heard. My research highlights whether messages address real concerns, use accessible language, and show respect for people whose livelihoods or identities may be affected.

I chose this research for three reasons:

First, it matters today. We live in an age of information overload, which may lead to what experts call an infodemic. A single headline or viral post can sway public opinion within minutes, even on complex scientific topics. I aim to help foster a healthier information environment that empowers people to make thoughtful choices instead of reacting to fear.

Second, it bridges my interests. I enjoy both words and numbers, how stories persuade us and how data reveal patterns. This project allows me to combine **theory** (Image Repair Theory), **technology** (NLP and statistics), and **real-world impact** (public understanding of environmental risk). The opportunity to translate abstract ideas into tools that can guide communication is particularly compelling to me.

Third, it supports a future I believe in. Sustainable development is not only about technology but also about **trust between people and institutions**. Communities can weigh trade-offs, support science-based policies, and hold leaders accountable when communication is honest, inclusive, and clear. I want my work to contribute to a future in which facts are explained well, concerns are respected, and solutions are built together.

My research analyzes how official messages and news coverage of the Fukushima water release shaped public sentiment and trust. By combining communication theory, data science, and the environmental context, and by centering on fairness and accessibility, I aim to design practical recommendations for clearer, kinder, and more credible public communication. This study supports a sustainable society by strengthening the bridge between scientific knowledge and decision-making, ensuring that progress is not only technically sound but also socially just.

Theme: (3)

Experimental Reproduction of the Earth's Crust: An Interdisciplinary Approach to Understanding Inland Earthquakes

D2 Yukiko Kita

My research goal is to elucidate the generation process of inland earthquakes. Inland earthquakes are among the most destructive natural disasters; however, their triggering mechanisms remain unclear. The occurrence of earthquakes depends directly on the strength and rheological properties of the Earth's crust, which is the area of the Earth's surface where inland earthquakes occur. In particular, plagioclase is a major constituent mineral of the crust and is abundant in seismogenic zones, making it essential to experimentally investigate and evaluate its physical and chemical properties. Geological surveys of the fault zones have revealed that the deeper parts of these zones are composed of fine plagioclase. Therefore, it is necessary to study the physicochemical properties of fine plagioclase experimentally and to understand how they affect crustal strength. However, the use of natural rocks as experimental samples is extremely complicated because their compositions and microstructures are complex and heterogeneous. To overcome this limitation, I actively incorporated knowledge from materials science and ceramic engineering, creating artificial rocks composed of plagioclase as experimental samples to simulate the crust. Thus, my research advances from an interdisciplinary perspective that transcends conventional academic boundaries. The aim of this research is to artificially synthesize crustal analog samples with controlled compositions and structures and to experimentally investigate their physicochemical properties. I focused on the concept that rocks can be regarded as ceramics in a broad sense. By applying ceramic sintering techniques, I succeeded in synthesizing dense and homogeneous plagioclase aggregates with a natural composition. This approach enables the reproduction of crustal materials in the laboratory.

Most of my experimental methods rely heavily on ceramic processing techniques. Natural plagioclase single crystals are milled under wet conditions using a planetary ball mill, and by employing CAS freezing and freeze-drying, agglomeration is suppressed, resulting in powders suitable for sintering. Through this process, I was able to produce ultra-fine powders with controlled degrees of aggregation, enabling precise control of the initial microstructure. Subsequently, the powders were formed into pellets by slip casting. Slip casting, a technique developed for industrial ceramics, is indispensable for the uniform molding of samples with complex compositions. The resulting green bodies were densified by hot-press sintering, yielding artificial plagioclase rocks (crustal analogs) that replicated natural microstructures. This sequence of powder preparation, slip casting, and sintering constitutes the core of this research, representing the application of industrial ceramic processing methods in geoscience. In the future, I plan to use these crustal analogs to conduct deformation experiments under temperature and pressure conditions corresponding to the lower crust, thereby evaluating their physicochemical properties.

My research has been conducted in close collaboration with researchers at the Research Institute of Eathquake and Volcano Geology, the Geological Survey of Japan, and the Multi-Material Research Institute of the National Institute of Advanced Industrial Science and Technology (AIST). With their advanced expertise in ceramic synthesis and material processing, and through over three years of trial and error, I successfully synthesized artificial crustal rocks. This collaboration has not only provided access to cutting-edge equipment and methods but has also greatly expanded the scope of my research by allowing me to approach the same phenomena from the dual perspectives of industrial and crustal materials. At the same time, conducting joint research with scientists from different backgrounds poses challenges, particularly in sharing knowledge and engaging in discussions, owing to differences in technical terminology and disciplinary expertise. Moreover, because many individuals are involved, it is essential to develop well-structured research plans, enhance communication, and ensure strong project coordination. Establishing and maintaining shared goals and mutual trust are important challenges. Nonetheless, these difficulties embody the essence of interdisciplinary research and provide invaluable learning opportunities.

Looking ahead, I aim to further integrate knowledge from materials science, geoscience, and industrial research to generate innovative insights beyond traditional disciplinary boundaries. Reproducing the Earth’s interior in the laboratory using industrial techniques such as slip casting and sintering carries not only academic significance but also societal importance. Collaborating with researchers from diverse fields, sharing methodologies, and reconciling different perspectives have enriched my research and fostered my growth as a scientist. By embracing diverse scientific cultures and combining their respective strengths, I aspire to open new possibilities for earthquake research and contribute to building an academic foundation that advances disaster prevention and mitigation.

Theme: (3)

Interdisciplinary Research on Past Tsunamis

Hidetoshi Masuda

Main text

Tsunamis are the most destructive hazard to coastal communities. There are a wide variety of approaches for investigating and mitigating tsunamis, such as seismology, coastal engineering, geology, and social science, because tsunamis can affect various aspects of society. For example, understanding the generation mechanism of tsunamis is generally regarded as part of seismology, as most tsunamis are generated by seafloor deformation caused by earthquakes. Seismologists often use tsunami observations to reveal earthquake mechanisms. The behavior of tsunamis around the coastline and during run-up has been investigated by coastal engineers to assess and reduce their impact on coastal infrastructure. Geologists work to reveal past occurrences of tsunamis from coastal geology, while social science approaches are crucial for mitigating human losses. Diverse disciplines are involved in the science and engineering of tsunamis.

My current research topic is the reconstruction of tsunami events using geological records. Tsunami deposits are sedimentary deposits transported and left behind by tsunamis, serving as crucial geological traces of past tsunami inundations. Researchers have attempted to estimate the local behavior and/or tectonic sources of past tsunamis from these deposits. Geological investigations of tsunami deposits begin by obtaining geological samples of coastal strata. We usually dig small pits or drill sediment cores in the coastal lowlands. Subsequently, we analyze the sediment grain size, age, and geochemical and paleontological features to determine whether the candidates for tsunami deposits were truly deposited by the tsunami. As tsunamis are energetic waves, tsunami deposits often retain evidence of transportation under powerful currents. Marine microfossils and biomarkers are occasionally found in tsunami deposits. The age of the deposits is used to check the consistency of the historical record of tsunamis and estimate the recurrence pattern of tsunamis. Although this kind of work is essential and I sometimes engage in it, searching for tsunami deposits is not a central focus of my research.

My primary interest lies in the tectonic sources of tsunamis in the geological past. By estimating tectonic tsunami sources, paleotsunami studies can be placed into seismological contexts, particularly to understand long-term seismic cycles. Tsunami source characterization is generally performed through an inverse analysis of tsunami observations, specifically tsunami waveforms at tide-gauge stations. Seismologists seek tectonic sources that can explain observations using numerical models of tsunamis and the inversion method. The inversion method is a systematic inverse analysis based on the least-squares approach and has been fundamental in seismic source studies. Although numerical models of tsunamis have primarily been developed by coastal engineers, they are widely used in tsunami seismology. In this study, instrumental tsunami observations were replaced with tsunami deposits. Therefore, the goal of this study was to infer the seismic characteristics of past tsunamis using engineering tools and geological tsunami records.

However, a simple combination of disciplines is challenging in this case. The inversion method generally assumes linear relationships between unknown parameters and observations. However, for tsunamis, this linear relationship is violated when they reach the shoreline, including run-up on land. Not surprisingly, tsunami deposits are affected in a complex manner by the nonlinear behavior of tsunami run-up; therefore, the measurable quantities of tsunami deposits (e.g., deposit thickness) are nonlinear with respect to the tectonic source parameters (e.g., fault slip amount). For nonlinear systems, the inversion method is still available in a different form, that is, nonlinear inversion, based on systematic trial-and-error of forward numerical analysis. Since the forward computation of tsunamis takes a long time (at least several hours for each case), even when using very powerful computers, attempts at the nonlinear inversion of tsunamis have been hindered by their excessively high computational costs. Therefore, efforts to reduce the computational cost of each forward computation are essential for achieving the nonlinear inversion of tsunamis in realistic timeframes.

A similar concern has arisen regarding the real-time forecasting of tsunamis using numerical tsunami models. To address this problem, a research group in computational mechanics proposed the use of a surrogate model to estimate the inundation depth. The surrogate model serves as an alternative for forward computation and provides quick results based on the regression of vast precalculated forward simulations. Recently, we applied this surrogate-based approach to the nonlinear inversion of a tsunami and successfully inverted the source of the 2024 Noto Peninsula tsunami in Japan. The application of the surrogate model drastically reduces the computational cost by several orders of magnitude. Although we used tsunami trace heights in this study, I plan to expand it to tsunami deposit-based nonlinear inversion in the near future. This enhances the importance of tsunami deposit research for a long-term assessment of seismicity. Tsunami research has always been interdisciplinary, but the addition of new approaches has resolved longstanding challenges. Collaborations with other scientific and engineering fields will continue to advance tsunami research in the future.

Theme: (3)

Advancing Geotechnical Engineering through Interdisciplinary Collaboration

Taiga Saito

The construction industry is entering an era of rapid change, driven by digital technologies and data-centric approaches. However, beneath every project lies the ground itself, soils and rocks, whose properties are variable, uncertain, and difficult to predict. Engineers have traditionally relied on experience and intuition to navigate these uncertainties. However, as projects become more complex, intuition alone is insufficient. To address this challenge, this research focuses on developing data-driven geotechnical engineering methods through collaboration between civil engineering and statistical science. This interdisciplinary effort has fundamentally reshaped our approach to ground variability, decision-making, and automation in construction.

However, uncertainty is inevitable in geotechnical engineering. The strength or stiffness of the soil can differ dramatically even within the same site. If an engineer underestimates this variability, the result may be an unsafe structure; if the engineer overestimates it, the design may become unnecessarily costly. Historically, resolving these uncertainties has heavily influenced the judgment of seasoned engineers. Although valuable, this judgment is subjective and inconsistent. By incorporating statistical science, we develop objective data-driven tools that quantify uncertainty and provide evidence-based recommendations. Instead of relying solely on intuition, engineers can now rely on predictive models that analyze past data, anticipate potential risks, and flag unusual soil behavior during construction. This shift from intuition to evidence-based decision-making has already proven vital for enhancing both safety and reliability.

The cornerstone of this transformation was my collaboration with the researchers at the Institute of Statistical Mathematics. This partnership has introduced advanced tools from modern statistics into the geotechnical domain. Two models proved particularly transformative: the hierarchical Bayesian model and the Minimum Information Dependence Model. Hierarchical Bayesian models provide predictions using probabilities rather than single values. This probabilistic perspective captures uncertainty with greater transparency, thereby enabling safer design decisions. The Minimum Information Dependence Model complements this by revealing complex nonlinear relationships among soil properties, such as water content, grain size, and strength. It uncovers hidden patterns without imposing rigid assumptions, thereby providing interpretable and trustworthy insights. These methods, which were introduced in collaboration with statisticians, did not emerge from civil engineering alone.

The fusion of civil engineering knowledge with statistical science has produced tangible breakthroughs in construction practices. If a model predicts a safe range for soil strength and field measurements fall outside that range, it acts as an early warning system. Project managers can respond promptly by adjusting their methods or reinforcing the ground before small issues escalate. Tasks that once required manual interpretation can now be completed in minutes using models trained on large datasets to produce consistent and reproducible results. Because these models are interpretable, engineers understand the reasoning behind the predictions, fostering trust between humans and AI tools. These benefits extend to sustainability. Accurate predictions allow leaner designs when the soils are strong, thereby reducing the unnecessary use of concrete and steel. This not only reduces costs but also lowers the carbon footprint of projects. Conversely, when soils are weak, reinforcement is applied precisely where required, preventing costly rework.

Thus, these models support both economic and environmental sustainability. They also help address workforce challenges. By embedding expert knowledge into statistical models, younger engineers can be effectively guided, thereby reducing their dependence on retired experts. Furthermore, automation enhances safety by minimizing the need for workers to perform hazardous inspections. The overall quality of construction improves as machines and data undergo the same rigorous checks without fatigue or bias.

This study clearly demonstrates how interdisciplinary collaboration can drive innovation in solving complex real-world problems. Civil engineering has addressed the pressing challenges of soil variability and construction quality, whereas statistical science offers novel frameworks for in-depth analysis. Together, these disciplines have produced models that are both technically advanced and practically applicable, bridging the gap between theory and field practice. More broadly, this experience reflects a deeper truth: many of today's societal challenges are too multifaceted for any single discipline. Different perspectives and skillsets enable a more holistic understanding of problems and foster innovative solutions. In our case, the intersection of statistical science and geotechnical engineering not only advanced construction technology but also created tools that will prepare the industry for the future. This collaborative approach is valuable not only in engineering but also in fields such as climate change, public health, and sustainable development. Crossing disciplinary boundaries often sparks the breakthroughs that society needs. The success of our project is a testament to the idea that when experts unite their strengths, they can collectively achieve outcomes far beyond what can be accomplished alone. The future of geotechnical engineering and many other disciplines will be shaped by interdisciplinary efforts, driving progress and innovation for the benefit of all.

Theme: (3)

Dust in Natural Phenomena

Akinori Hasebe

Mars, the red planet next to Earth, is my primary research target. Many questions remain regarding Mars: What determined the present Martian climate? What is the cause of the massive sandstorm ("dust storm")? How did Mars obtain its moons, Phobos and Deimos? Among these, I focus on the dust particles that surround the Martian environment. This dust includes interplanetary dust originating from the outer solar system, cometary dust, small fragments ejected from Phobos and Deimos by meteoric impacts, and dust uplifted from the Martian surface by dust storms; however, the details of the dust environment remain unclear. Cosmic dust causes many changes in the planetary environment.

An example of a natural phenomenon is the formation of noctilucent clouds, a type of cloud found at extremely high altitudes (~80 km). When a cloud ice droplet forms, impurities such as dust in the atmosphere become the core of the droplet, promoting its growth. The formation of noctilucent clouds on Earth has been linked to climate change. The first noctilucent clouds were observed after the Industrial Revolution, and their formation reflected climate change, including atmospheric temperature fluctuations and the impact of anthropogenic gases. Beyond Earth, noctilucent clouds have also been observed on Mars, as evidenced by current observations (Fig 1). This finding is remarkable considering the arid environment of Mars. Research on Mars will help us understand how noctilucent clouds form and what they signify as climatic phenomena. One key point is the difference between the dust environments of the two planets. For example, although cosmic dust falls on both planets, its composition may vary. Furthermore, large dust storms lift dry dust into the Martian upper atmosphere but not as strongly on Earth. By comparing these differences, we will gain insight into the type of dust crucial for forming noctilucent clouds and will be able to apply this knowledge to estimate the future impacts of climate change.

Another example of cosmic dust in natural phenomena is that it may retain the history of a massive event, such as a meteor impact on the planet. It is well known that there have been considerable extinction events in Earth's history, but the causes of these events remain unknown. A recent study of the Ordovician–Silurian boundary proposed that the massive extinction that occurred approximately 450 million years ago was caused by a Saturn-like ring composed of broken asteroids, which led to global cooling on Earth. One piece of evidence supporting this theory is the small meteorites preserved on terrestrial ground. If a ring were formed around the Earth, the number of meteoroids would be sporadically enhanced while the ring was intact, causing an increase in micrometeorites during a specific geological epoch. Therefore, I believe that by collaborating with geologists, biologists, and geoscientists, we can gain insights into what caused the extinction, particularly whether meteoric impacts were responsible for the catastrophe.

My current research interest is the interaction between small meteoroids and the Martian atmosphere; therefore, I have not conducted specific research on noctilucent clouds, micrometeorites linked to massive extinctions, or other interdisciplinary topics. However, I always keep in mind that my research can be relevant to various fields by considering "dust" in a broad sense.

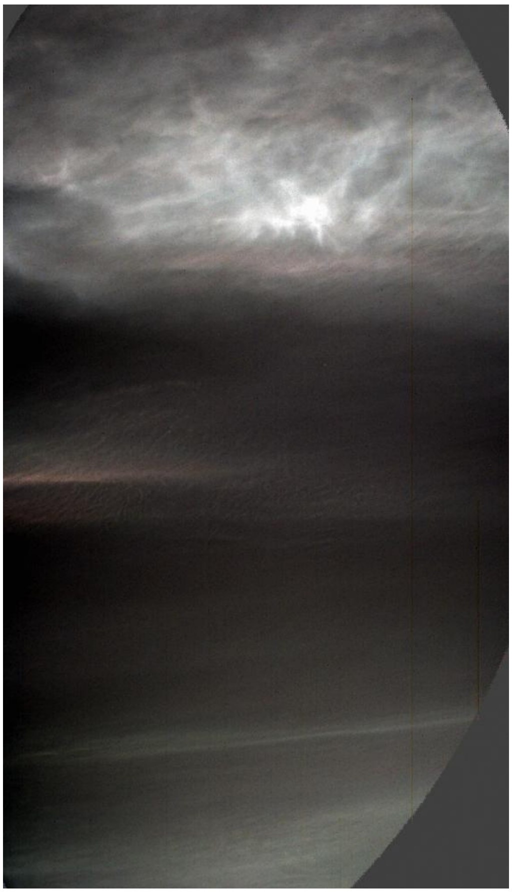


Fig 1. Noctilucent cloud on Mars captured by NASA's Curiosity rover.
©NASA

Theme: (3)

From Sediment Disasters to Broader Applications: Expanding the Potential of Numerical Simulation

Riichi Sugai

In this document, I discuss how my research can be enhanced through integration with other fields. First, I will present the content of my research and explain the social issues that need to be addressed. I will then describe how my work can extend beyond the framework of computational mechanics in civil engineering, my field of expertise, collaborate with other disciplines, and create new value.
My research focuses on developing numerical simulation methods that can reproduce the damage caused by sediment-related disasters and clarify their mechanisms. The types of sediment disasters I study include three distinct categories: slope collapses, downhill debris flows, and the evaluation of damage caused by debris that eventually reaches urban areas and collides with structures. In many parts of Japan, slope failures occur annually, resulting in debris flows that damage houses and other buildings. There are three main reasons why these disasters continue to cause harm: (1) it is difficult to predict when, where, and how much of a slope will collapse; (2) it is uncertain whether the debris will be stopped by protective structures; and (3) it is challenging to predict whether the debris will destroy these structures and gain even more momentum.

Although numerical simulations are considered highly effective for understanding these processes, no method has been established that can consistently represent slope collapse, debris flow, collisions with structures, and subsequent structural failure within a single simulation framework. However, there are technologies that can reproduce slope collapse and flow behavior to some extent, as well as technologies that can simulate structural failure. My research aims to integrate these two separate areas of development and establish a foundation for numerical simulations that can reproduce the complete sequence of debris flows and structural failures. If such a simulation method is realized, it may become possible to replicate the overall dynamics of a sediment disaster without relying on assumptions regarding the location or volume of the collapsed debris. This technology would not only be useful for post-disaster assessments but could also be applied to risk evaluations in advance. As the reliability of the method improves, it can contribute to strengthening disaster prevention and mitigation policies at the municipal level.

Thus far, I have described how the numerical simulation method I am developing aims to reproduce sediment-related disasters. However, the potential applications of these methods are not limited to this field. Because they are based on the framework of equations of motion, they can also be applied to simulate the deformation behavior of solids in general, not just sediment flows. With this in mind, I hope to extend the application of my simulation tool to problems outside civil engineering. A promising example is the study of rock fracture phenomena in geosciences. Although numerical simulations are not yet a primary research tool in this domain, combining experiments with computational methods would broaden perspectives and provide deeper insights into the mechanisms of these phenomena. Understanding such mechanisms could, in turn, help reduce the risk of earthquake damage and rockfall hazards, thereby offering significant engineering value.

From the perspective of implementing numerical simulation technologies in society, two promising directions exist: integration with digital transformation (DX) and advancement of visualization techniques for disaster prevention. Japan is currently promoting DX nationwide by digitizing design drawings and inspection records as part of its efforts to improve efficiency in response to population decline. Digital data collected in this manner can be converted into input data for numerical simulations. If structural inspections and durability assessments using such simulations can be conducted simultaneously, the effectiveness of inspections can be enhanced while improving efficiency. This would enable safer infrastructure management with fewer resources.

Regarding the second direction, I believe that visualizing simulation results can play an important role in disaster prevention. Individual preparedness is crucial for disaster mitigation, and the ability to visualize potential damage is essential for encouraging appropriate evacuation behavior. As simulations can virtually reproduce all conceivable scenarios, they can help individuals envision situations they might encounter during a disaster. I believe that this act of visualization can encourage people to take appropriate action in times of crisis.

The above section outlines my current research activities and the potential for interdisciplinary collaboration. I hope to continue advancing my work to realize these possibilities.

SyDE
WISE Program for Sustainability in the Dynamic Earth

Theme：④

Ethical Awareness Required in the Conduct and Application of My Research

Kaho Suzuki

Main text

As a researcher investigating the psychological mechanisms of fatigue, I recognize that the ethical dimension of my work extends far beyond simple adherence to procedural norms. The study of fatigue—particularly subjective fatigue—inevitably involves the human body, mind, and behavior. Therefore, my primary ethical responsibility lies in protecting the dignity, well-being, and autonomy of all participants, while ensuring that the knowledge derived from my work contributes meaningfully to human welfare.

First, I am committed to the principle of non-maleficence—the obligation to avoid causing harm. Research on fatigue often requires participants to engage in mentally or physically demanding tasks that are designed to induce fatigue. Although necessary for scientific validity, this procedure carries the inherent risk of physical or psychological discomfort. To mitigate such risks, it is important to design experimental protocols that maintain a balance between scientific rigor and participant safety. This includes continuous monitoring of participants' states, establishing clear withdrawal criteria, and providing sufficient debriefing and recovery time. I believe that ethical research is not achieved by merely satisfying institutional guidelines but by embodying an attitude of genuine care toward individuals who make scientific discovery possible.

The principle of respect for autonomy is closely related to the concept. Fatigue research involves subjective experiences that cannot be verified externally. Therefore, participants' self-reports are not only data points, but also expressions of personal experience. I consider it ethically imperative to treat such reports with respect and avoid reducing participants from mere sources of measurement. In practice, this implies ensuring informed consent, guaranteeing confidentiality, and fostering a research environment in which participants feel safe expressing their experiences honestly. In this context, respect for autonomy also extends to acknowledging the diversity of individual experiences—cultural, physical, and psychological—which shape how fatigue is perceived and reported.

I am mindful of the potential societal implications of this study. Fatigue is not merely a private experience; it is a social phenomenon that is deeply connected to issues such as overwork, mental health, and productivity. In Japan, where chronic fatigue and overwork-related deaths remain pressing social issues, the dissemination of research findings must be handled with caution. My ethical responsibility includes preventing the misuse or misinterpretation of research outcomes—for example, avoiding the reduction of complex human experiences to simplistic performance metrics or justifications for increased labor demands. Instead, I aim to communicate the findings in a manner that promotes an understanding of fatigue as a protective and adaptive process that safeguards both individual health and collective well-being.

Another ethical concern relates to scientific integrity. Fatigue is a multidimensional and interdisciplinary topic that invites various methods and interpretations, from physiological measurements to subjective assessments. Although this diversity is a strength, it also requires intellectual humility. It is considered unethical to privilege one methodological approach over another without critical reflection. In my own research, which focuses on subjective fatigue, I strive to clearly acknowledge the limitations of self-reporting methods while emphasizing their unique value in capturing lived experiences. Transparency, replicability, and honest reporting of negative or ambiguous results are essential ethical commitments that sustain the credibility of science as a collective endeavor.

Finally, I believe that ethical research entails a sense of social responsibility. Fatigue research has the potential to inform not only academic understanding but also public health policies, workplace design, and education. Therefore, I view dissemination as an ethical act. Findings should not remain confined to academic journals but should be translated into forms accessible to the broader public. In this process, researchers must avoid deterministic or pathologizing narratives, instead promoting empathy for individuals struggling with fatigue. My goal is to ensure that the fruits of this research are used to enhance, rather than exploit, the human capacity for recovery, balance, and sustainable engagement in life.

In summary, my ethical awareness as a researcher relies on four interconnected principles: non-maleficence, respect for autonomy, scientific integrity, and social responsibility. These principles guide not only how I design and conduct experiments but also how I interpret and communicate findings. Fatigue is the signal that urges an organism to rest and restore itself. In the same way, I believe that ethical reflection functions as a form of "intellectual homeostasis," reminding researchers to pause, reconsider, and realign their actions toward the preservation of human dignity. Therefore, to study fatigue ethically is to practice the lesson that fatigue itself teaches us to respect the limits that sustain life and to use knowledge for the protection, not exhaustion, of human beings.

Theme:(4)

Integrating Multiple Perspectives for Precise Understanding

Shuhei Hotta

Main text

My research focuses on volcanology. In particular, my research aims to understand the mechanisms of volcanic eruptions — why they start, stop, and repeat these cycles. To achieve this, I consistently strive to consider phenomena from multiple perspectives.

Volcanology primarily relies on three approaches: natural observation, laboratory experiment, and numerical simulation. The method I usually employ is natural observation of volcanic products. The textures and structures of these products record the processes experienced during magma ascent. We cannot directly observe what happens beneath the volcanoes; however, the products allow us to infer these processes. The strength of this approach lies in the fact that the data directly reflect what actually occurred before the eruption. However, natural systems often record many overlapping processes, making it difficult to draw simple or definitive conclusion. If we become trapped by complexity, we may lose sight of essential understanding.

In contrast, experimental and theoretical approaches make phenomena simple. In these methods, parameters can be controlled to meet specific objectives, making them powerful tools for identifying the essential factors governing phenomena. However, these methods inevitably simplify natural systems, and their results cannot be directly applied to reality.

These contrasting approaches — natural observations versus experimental and theoretical methods — complement each other. Therefore, acknowledging their limitations and combining them is, in my view, an important strategy.

I hope to develop my ability to integrate multiple approaches and comprehensively reveal volcanic processes.

Theme: (5)

Europa and Jupiter as Natural Laboratories of Plasma Physics

Shinnosuke Satoh

Europa is a moon of Jupiter that is covered by a thick ice shell, and deep inside is a liquid-water ocean. It has been one of the most anticipated moons in the solar system because observations have identified three essentials for life: liquid water, organic materials, and energy to sustain chemical reactions, suggesting it may be habitable.

The two spacecraft missions are being carried out to determine its potential habitability, with many instruments on board to measure the plasma environment around Europa. Europa does not possess an internal thermal or energy source to heat its environment. However, high-energy charged particles (electrons and ions) in Jupiter's magnetosphere provide Europa with energy through collisions between particles. The energy drives physical and chemical reactions in the atmosphere and on the surface. For instance, Europa's atmosphere is mostly generated through the plasma sputtering on the water ice surfaces. Therefore, it is important to investigate the entire process of interaction between Europa and the Jovian magnetospheric plasma because it leads to a better understanding of Europa's environment.

My research project aims to fully understand the energy transfer from Jupiter's magnetosphere to Europa to find the answer to the potential habitability of Europa. One of the key paremeters to do so is the density and temperature of the magnetospheric charged particles around Europa. Previous spacecraft missions have measured those parameters around Europa on several occasions, but monitoring by remote observations has not been established. Our research (Satoh et al., 2024) developed a new method to measure the plasma parameters around Europa using remote observations of ultraviolet aurorae in Jupiter's atmosphere. This enables a long-term monitoring of the plasma parameters around Europa without operating a large spacecraft close to the moon. The goal of this research project was to understand the spatiotemporal variability of the plasma parameters around Europa.

Pursuing my research goal has been challenging, but at the same time, studying Europa and Jupiter gives me a sense of exploring a natural and vast laboratory of plasma physics. I enjoy the thrill of studying something so distant and unreachable like Europa and Jupiter, using remote observations and data. In addition, I find great joy in working on a science project as a part of a large international spacecraft mission such as Juno and JUICE, where collaborative efforts will provide us with clues to understand the potential habitability of Europa.

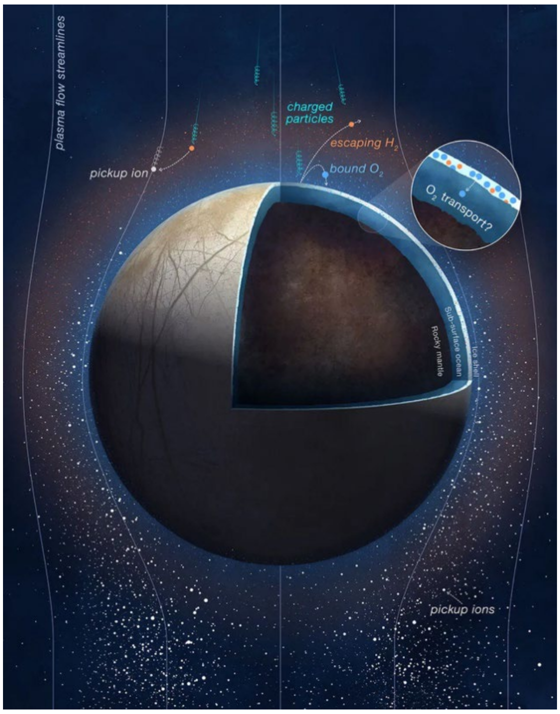


Figure: Charged particles are the source of energy in Europa’s environment (NASA/JPL-Caltech/SwRI/PU).

Reference
Satoh, S., Tsuchiya, F., Sakai, S., Kasaba, Y., Nichols, J. D., Kimura, T., Yasuda, R., & Hue, V. (2024). Changes in the plasma sheet conditions at Europa's orbit retrieved from lead angle of the satellite auroral footprints. Geophysical Research Letters, 51, e2024GL110079. https://doi.org/10.1029/2024GL110079

Theme: (5)

Reasons for Choosing My Research on Religion and Public Health

Gong Xiyan

The reason for choosing my current research topic can be traced back to my first encounter with the social contributions of religion. This occurred when I was a first-year high school student in 2010. On May 12, the second anniversary of the Wenchuan earthquake, my school screened a documentary on disasters. Among the many scenes, one episode at the Shifang Luohan Temple left a profound impression on me. After the earthquake, the local maternal and child health hospital collapsed, leaving many pregnant women without a safe place to stay. The temple opened its doors as an emergency shelter for 108 infants. To ensure that the mothers received sufficient nutrition, the monks permitted the breaking of monastic precepts by allowing killing within the temple grounds. At that moment, I realized that religion is not merely a matter of spiritual belief. In times of disaster, it can mobilize resources and assume a powerful social role, offering both psychological comfort and practical assistance. This experience planted the seeds of my long-term interest in the relationship between religion and society, particularly the ways in which religion contributes to social resilience in times of crisis.

Later, the global COVID-19 outbreak further sharpened my awareness of the relevance of religion to public health. The pandemic has been one of the greatest disasters faced by humanity in recent decades. In the absence of effective vaccines during the early stages, fear of the unknown is inevitable. In such moments, the power of faith becomes especially important. During my Master's program, I had the opportunity to visit several temples in Japan and interview religious practitioners. Religious communities provide psychological support and tangible resources. This reinforced my conviction that religion should not be viewed separately from public health; rather, it is deeply connected to the ways in which societies respond to crises. Based on these experiences, my broad interest in "religion and society" has evolved into a more specific focus on the relationship between religion and public health.

Based on these experiences, I decided to focus on this subject in my doctoral research. My dissertation examines the relationship between religion and public health in modern Japan, with particular attention to the cholera epidemics of the Meiji era. On the one hand, the Meiji government was engaged in building a modern public health system grounded in Western science and medicine. On the other hand, religious institutions significantly influenced everyday community life. I am interested in how these institutions may have contributed to the dissemination of hygiene practices and the cultivation of communal resilience. In other words, I seek to analyze how religion functioned as a supplementary force on the periphery of the formal public health system and how this dynamic shaped the broader process of nation building.

I believe that this line of inquiry holds significance not only for historical scholarship but also for contemporary society. Even today, when facing pandemics or large-scale disasters, government institutions and medical systems alone cannot fully address these problems. Cooperation between various social actors is essential. Religious organizations remain an important component of this cooperative framework. By studying how religion functioned in the context of public health during Japan’s modernization, we can gain insights into how religious resources may be mobilized in contemporary crises. Therefore, this historical perspective can inform present-day discussions about building resilient and sustainable societies.

Through this research, I hope not only to deepen the scholarly understanding of the social contributions of religion but also to provide insights that are relevant to contemporary challenges. If religion could have played a meaningful role in times of epidemics in the past, it is worth considering how religious institutions might continue to make positive contributions in the present and future. This conviction was the fundamental reason for choosing this research path.

SyDE
WISE Program for Sustainability in the Dynamic Earth

Theme: (5)

Why I Chose to Study Nanocarbon Materials: Hidden Potential in Black Powder

Xia Tian

At first glance, nanocarbon materials appear to be just black powders; their appearance shows nothing of their remarkable properties. However, this simple appearance conceals a highly ordered nanoscale structure, offering an internal surface area, tunable porosity, and remarkable physical behavior (e.g., mechanical flexibility). Because of these properties, nanocarbon materials are attractive for applications in catalysis, adsorption, molecular separation, and electrochemical systems. They represent a platform through which materials science can transform ordinary substances into advanced environmental, energy, and technological solutions.

Nanocarbon materials are composed of carbon atoms arranged in nanoscale frameworks and are typically based on graphene, which is a two-dimensional carbon sheet with a hexagonal structure. When these sheets assemble into porous networks, the three-dimensional network structure provides considerable specific surface area and porosity. Therefore, several key parameters should be emphasized: 1) High specific surface area and porosity. Even small samples possess large internal surface areas and volumes that enable efficient molecular interactions. 2) Surface chemistry. Carbon materials are generally hydrophobic; however, surface functional group modifications can be used to control their hydrophilicity and selectivity. 3)Mechanical flexibility. Some porous carbon frameworks and sponges can deform and recover their structures under pressure. These properties enable them to achieve performances unattainable with conventional porous materials, such as polymers and porous silica.

One of the most fascinating aspects of nanocarbon materials is the behavior of fluids within their pores. Typically, liquid-to-gas transitions (e.g., evaporation and condensation) follow well-known patterns. However, at the nanoscale, these transitions deviate from classical expectations. Narrow pores that are only a few nanometers wide change the balance of molecular interactions, creating phenomena that cannot be observed in macroscopic containers. Interestingly, when certain nanoporous carbon sponges are mechanically compressed, the confined liquid within their pores can be forced into a vapor-like state, and when the pressure is released, it condenses back into a liquid (Fig. 1). Importantly, this transition is reversible and occurs under conditions in which no phase change is expected in the bulk. This behavior is not only a scientific curiosity but also a technological opportunity. By harnessing force-induced phase transitions, it is possible to design new types of mechanical heat pumps and cooling systems that do not rely solely on traditional refrigerants.

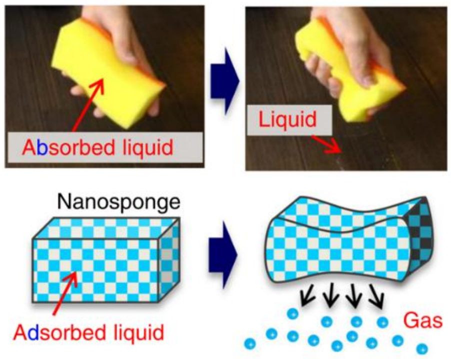


Fig. 1 Compression of normal sponges and nanosponges.

Despite the advantages of flexible porous carbons, their flexibility is rare. Most conventional activated carbons are mechanically stiff and brittle. In contrast, graphene-based carbon sponges exhibit compressibility and resilience, properties that arise from their finely tuned internal structure. To guide the synthesis of flexible porous carbon materials, my recent work investigated the origins of this flexibility by examining the relationship between structural parameters and bulk mechanical properties to predict and design porous carbon with specific flexibility. The ability to design nanocarbon sponges with controllable properties provides opportunities in various fields, including environmental treatment, adsorption of volatile organic compounds from polluted air, selective absorption of oil for water purification; clean energy and sustainability; catalytic supports with high surface areas and tunable pore structures; separation and purification technologies; flexible conductive frameworks for sensors and soft electronics. Fortunately, we have actively developed applications to improve society using nanocarbon materials.

To me, nanocarbon materials represent the culmination of nanotechnology and embody the central idea of materials science; by controlling nanostructures, we can design matter to serve humanity in entirely new ways.

Theme: (5)

Why Do People Blame the Victims?

Yu Hachiya

I studied victim blaming in the context of sexual crimes. Victim blaming refers to people criticizing or blaming the victim instead of the offender. I was shocked when I first saw such comments on social media platforms. I could not understand why people wrote things that hurt the victims. Victims were already suffering, but they received harsh words from strangers. This made me feel both sad and curious. Why do people behave this way? Why do people blame someone who has done nothing wrong? These questions became the starting points for my research. In this essay, I explain why I chose this topic, what I focused on, and how I hope my work will help society.

The first strong motivation came from the realization that victim blaming is a form of "secondary harm." It is similar to adding another injury to someone who has already been hurt. Imagine a person with a broken bone being pushed down again. This is how I think of secondary harm. Seeing how cruel this is, I want to study it in depth. At the same time, I became interested in the human mind. Why do people blame innocent victims? Is there something wrong or distorted in the way people think? I want to understand the darker aspects of human nature. In my view, studying these negative aspects is just as important as studying the positive ones. By understanding human weaknesses, we can build a kinder and more supportive society.

Victim blaming has been studied by many researchers; however, many questions remain unanswered. Studies have shown that people with traditional gender beliefs are more likely to blame victims. Others have found that individuals may blame victims in order to protect their own sense of safety, as thinking "it was the victim's fault" makes the world seem less dangerous. These explanations are valuable, but I believe that emotions may also play an important role, with special attention paid to disgust. Disgust is the feeling we experience when something seems dirty, impure, or unpleasant. I believe that disgust may be strongly connected to victim blaming, even though people may not be aware of it. There is a psychological concept called the "misattribution of arousal," which is often explained with the famous "suspension bridge effect." People who feel excited while standing on a shaky bridge may mistake the feeling of romantic attraction for the person they meet. Similarly, I wonder whether individuals sometimes feel disgusted and wrongly connect that emotion to the victim. If this is true, blaming the victim may not stem from rational judgment, but from misplaced emotions. This motivated me to continue studying the relationship between emotions and unfair judgments.

When I present my work at academic meetings, I notice that many people are interested in it. This encourages me and makes me feel as though I have chosen the correct path. Personally, I find it exciting to reveal hidden distortions in human thinking. Humans are imperfect, and their minds sometimes take shortcuts that lead to unfair or harmful outcomes. To me, it is fascinating to uncover these flaws and make them more visible. At the same time, I feel a sense of responsibility. Victim blaming is not only a psychological phenomenon but also a serious social problem that hurts people who have already experienced trauma. That is why I think, “Someone has to study this.” And then I realize, “That someone can be me.” This feeling gives me the energy to continue, even when research is difficult.

Looking ahead, I believe that my research will contribute to society in several ways. Victim blaming often occurs when men blame women. This creates conflicts between the genders and makes mutual trust more difficult. If blame decreases, the relationship between men and women may improve. On a larger scale, this could even help with significant social challenges such as the declining birthrate, which is partly caused by gender inequality and mistrust. Of course, this is a long-term vision, but I believe that small steps matter. Another important point is that my research is not about creating something new but about removing something harmful. Although this may seem less exciting, it is essential. By reducing the harm caused by unfair blame, we can make the world better for everyone. My goal is not to achieve a perfect society but to make progress toward a more just and compassionate one.

In summary, I chose to study victim blaming because I was deeply moved by the cruelty I saw in real life and because I wanted to understand why people think in such harmful ways. By focusing on emotions such as disgust, I hope to uncover hidden causes of unfair judgments. Through my research, I want to reduce the suffering of victims and help society develop fairness and empathy. The world will never be perfect, but if my work can make it “just a little bit better,” then I believe it is worth doing. I chose this research because I wanted to make the world a slightly better place.

Theme: (5)

Why I Choose to Study the Moon

Keitaro Kanda

I am studying lunar surface history. The Moon maintains an ancient surface environment and evolutionary history because it has no atmosphere, water, or large tectonic activity that alters or hides ancient features. Therefore, by exploring the surface of the Moon, we can obtain basic knowledge about the planet and the solar system.

My first encounter with Moon exploration was in elementary school when I read the Japanese comic book "Space Brothers." Space Brothers is the story of astronaut brothers Hibito and his older brother Mutta, who aspire to become astronauts. In this story, Hibito is the first Japanese moonwalker. When I saw a scene in which Hibito took his first step on the lunar surface, I became fascinated by astronauts and the Moon. Subsequently, I read many books and watched movies about American lunar exploration during the Apollo missions. Fortunately, my father was also a space enthusiast, and our house was full of books and videos that satisfied my interests. These items further increased my fascination with the Moon.

As time passed, when I was a second-year high school student, I had to choose a university to take the entrance exam. At that time, I decided to study something related to planetary science, especially the Moon. Therefore, I investigated the websites of many related laboratories to see if I could study the Moon. Finally, I found Tohoku University's Space and Terrestrial Plasma Physics (STPP) Laboratory. The STPP participated in the development of the Japanese lunar exploration satellite KAGUYA and developed a radio-wave observation instrument called the Lunar Radar Sounder (LRS). Thus, I decided to aim for Tohoku University and the STPP Laboratory.

After entering the STPP, I began to acquire basic knowledge and learn about recent studies and exploration missions on the Moon. Because the STPP excels at radio wave observations, as exemplified by the development of the LRS, I decided to make lunar radio wave observations my research theme. Ground-penetrating radar (GPR) measures subsurface structures using radio waves, and my research theme involves simulating and analyzing lunar GPR observations. In GPR observations, radio waves are transmitted from an antenna on the surface, and these radio waves are reflected by subsurface structures. By receiving these reflected waves, GPR can measure the subsurface structure. GPR is often used in lunar and planetary explorations. China's lunar exploration program conducts GPR observations during several missions, which have been used to investigate the structures and physical properties of the lunar subsurface, such as dielectric permittivity. GPR is a powerful method for exploring the lunar subsurface, and I have studied different topics using GPR.

When I began my research, I focused on GPR observations of lunar subsurface caves known as lava tubes. A lava tube is a subsurface structure formed after a lava flow. Lunar lava tubes are gaining attention as potential shelters against the harsh conditions of the lunar surface, similar to the effects of meteorite impacts, temperature variations, and cosmic rays. Furthermore, the presence of lava tubes indicates ancient volcanic activity on the lunar surface, making them significant. While reading several papers related to lunar science and exploration, I learned that the LRS developed by the STPP for KAGUYA had observed lunar lava tubes. This sparked my interest in lava tube observations using GPR, leading me to choose simulations as my first research topic. Through these simulation studies, I developed the foundational skills and knowledge related to GPR observations and simulations.

Although the initial research theme was intriguing, I became increasingly interested in performing GPR data analysis. Consequently, I focused on subsurface rocks as targets. The lunar surface has been subjected to meteorite impacts for billions of years, resulting in its destruction and coverage by rock and fine soil. The relationship between rock size and quantity reflects the duration of surface exposure to meteorite impacts and is considered an important area of research for investigating lunar surface evolution. While these surface rocks have been studied using camera observations, the size and distribution of subsurface rocks remain unknown, as camera observations are limited to the surface. I am currently investigating the size and distribution of subsurface rocks using GPR observation data obtained from China's lunar rover (Fig. 1).

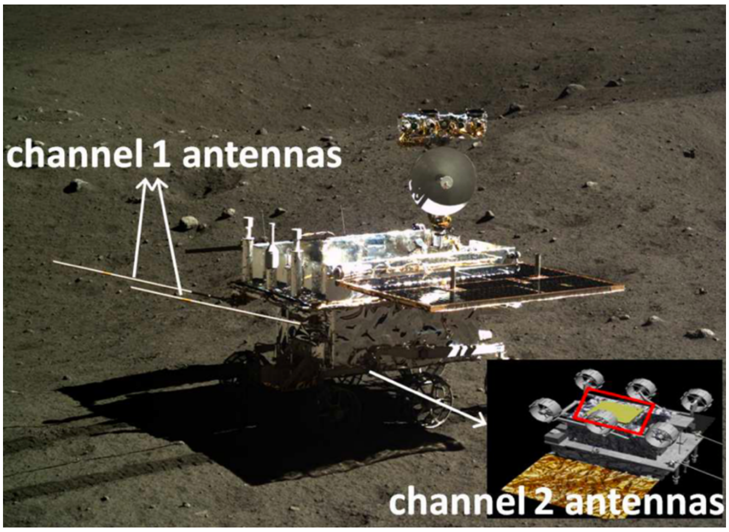


Fig. 1. China's Chang'E-3 rover and its GPR antennas. [From Su et al. (2014)]

Reasons for selecting this study:(5)

Development of a landslide forecasting model using regional ensemble prediction system for extreme rainfall due to senjo-kosuitai in Niigata

Kosei Osamura

1. My personal experience with atmospheric disasters

Recently, the frequency of landslides and floods caused by extreme rainfall has increased. For example, in the latter stage of the Baiu season, the western part of Japan including the Kyushu area experiences accumulated rainfall of over 150 mm in 3 hours. A "senjo-kosuitai" is the extreme heavy rainfall with a width of 20-50 km and a length of 100-300 km, produced by successively formed and developed convective cells that pass and stagnate in almost the same place for a few hours. Senjo-kosuitai often cause large-scale disasters. In 2020, multiple flood disasters occurred around the Kuma River in the southern Kumamoto, resulting in more than 70 deaths and emergency heavy rainfall warnings were issued in southern of Kumamoto, Kagoshima, Fukuoka, and other areas.

In July 2018, the extreme rainfall occurred over the western part of Japan and caused more than 220 deaths, which I experienced while living in Osaka. Railways and roads were cut off for one month. I wondered, "Why did the damages from senjo-kousuitai become so extensive?" In fact, I visited the disaster memorial museum in Hiroshima which experienced an extreme rainfall disaster in August 2014 after the 2018 disaster because I was looking for an answer to this question. I learned that it is very difficult to forecast the location and precipitation amount of senjo-kousuitai because meso-scale (atmospheric scale 2-2000 km) events including senjo-kosuitai have an associated with the degree of chaos, i.e. nonlinearity. For this reason, unlike typhoons and low pressures, the meso-scale is sensitive to initial conditions and long-term unpredictability. Thus, initial errors increase as the forecast time extends. Therefore, evacuation emergencies for Hiroshima City during extreme rainfall due to senjo-kousuitai often occurred at the night making it difficult for people to evacuate to the shelters. I thought that if we could predict the landslide risk due to extreme rainfall, the damage would decrease because we could predict the landslide risk earlier than at night.

In July 2021, extreme rainfall in Atami, Shizuoka caused the landslide. While I was on the Shinkansen, I witnessed the landslides disaster in Atami directly. After experienced landslides disaster, my motivation to study the prediction of landslides risk become stronger.

2. Motivation of this study

In 2009, the Japan Meteorological Agency (JMA) implemented soil water index (SWI) for to determine when issue the heavy rainfall warnings and to assess landslide risk. The SWI has a horizontal resolution of 1 km and is forecasted after 6 hours using 1 hour of precipitation data examined every 10 minutes. However, short-term forecasting is not possible for Senjo-kosuitai, which exhibit rapidly increasing hazard risk.

Since 2019, the JMA has operated an ensemble prediction system, which is a method for calculating precipitation scenarios that considers the sensitivity to initial conditions due to atmospheric chaos by creating multiple initial conditions. Ensemble predictions are useful when addressing chaos a meso-scale level. However, the SWI uses only deterministic predictions and cannot accurately forecast landslide risk for extreme rainfall. In this study, we developed a long-term landslide hazard risk forecasting system using regional ensemble predictions for heavy rainfall events caused by senjo-kosuitai in Niigata in 1998.

3. Future goals and significance

This study showed that a long-term hazard risk forecasting system for landslides using ensemble predictions that could issue warnings more than 72 hours in advance could facilitate evacuation, thereby resucing the number of deaths and hazard risk. The results of this study are expected to improve the efficiency of evacuation, train services (transportation) before during natural disasters, and to reduce the damage caused by weather-related natural disasters. This study used horizontal resolution of 5 km for ensemble prediction. Therefore, higher horizontal resolution will be employed in the future.

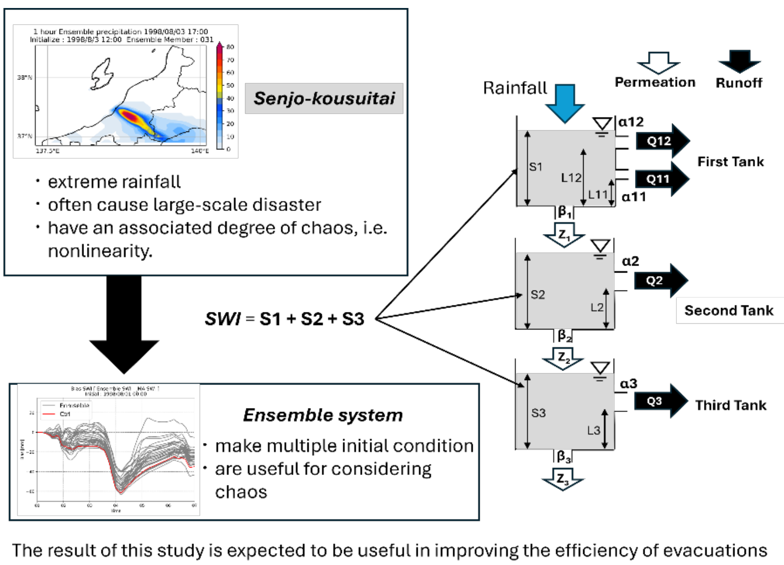


Figure 1 : Outline of this study

Theme : (5)

Why Do I Study The Universe ?

Daichi Kashizaki

I study how heat is produced in plasma disks that orbit black holes and how that heat is partitioned between electrons and ions. A key element is the Event Horizon Telescope (EHT), which is a global radio telescope network. By operating radio telescopes worldwide as a single Earth-sized array, the EHT images the region around black holes[1]. The light observed here was primarily emitted by electrons. This means that unless we know how strongly the electrons are heated, we cannot correctly interpret why the EHT images have the same brightness and shape. Therefore, I aim to clarify how energy is partitioned between electrons and ions using a physically grounded method and to provide reliable estimates of the electron temperature that feed directly into the interpretation of EHT images.

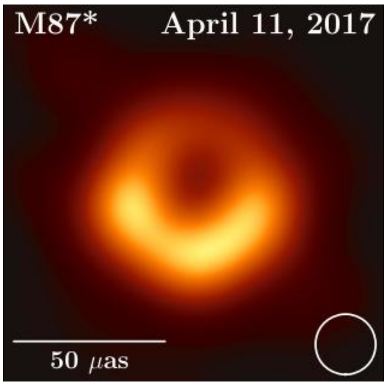


Fig. 1. M87 [1]

Traditionally, the ion-electron temperature ratio has been specified via empirical prescriptions. While convenient, their physical underpinnings are weak, limiting confidence in their predictive accuracy. Based on this background, physically motivated models of turbulent heating have been proposed in recent years. My work advances this line by incorporating more realistic conditions from the outset and systematically reconnecting the character of turbulent fluctuations with where the heat ultimately goes.

The reasons I chose this topic, and more broadly, why I set out to study the universe, are quite simple. I have loved the night sky since I was a child and used to look at Saturn's rings through a telescope. What proved decisive was learning that the starlight we see now was emitted long ago. Gazing at distant space is, in a sense, looking at the past. This realization moved me deeply and made me want to understand the cosmos more fully. In 2019, when the EHT captured the first image of a black hole's shadow, it felt as though the wonder I felt as a child had taken a real image before my eyes.

When I began full-fledged research at the university, I joined a laboratory that included researchers specializing in black hole astrophysics. Through many discussions, I came to focus on the idea that if we estimate electron temperatures not by empirical tuning but by tying them to the physical character of turbulent fluctuations, we can provide a stronger basis for explaining why EHT images look the way they do. Specifically, I incorporate the vertical stratification due to gravity from the outset, classify representative types of turbulent fluctuations, and examine how each channel contributes to the heating of electrons and ions. The work is unglamorous and incremental, but with each step I feel we are sketching, little by little, a map of "invisible heating."

Looking back, what led me to this research was my fascination with the starry sky, the amazement that we are seeing the ancient light in the present, and fortunate encounters with mentors and colleagues. To make the invisible gradually visible, I hope to keep tracing, carefully and concretely, how turbulence "stirs" the disk and where the heat ultimately goes, building explanations that tie naturally to what we observe.

References

[1] The Event Horizon Telescope Collaboration, "First M87 Event Horizon Telescope Results. I. The Shadow of the Supermassive Black Hole," ApJL, 2019, 875, L1.

Theme: (5)

Reasons for My Interest in Space Weather and Solar Physics

Naoto Kinno
Department of Geophysics, Graduate School of Science M2

My main research topic is space weather and solar physics. First, I will introduce my research briefly.

The Sun emits plasma composed of charged particles, such as electrons and protons. The space environment surrounding Earth is constantly exposed to ultraviolet radiation and high-energy particles originating from the solar surface. The intensity and quantity of these emissions fluctuate with changes in solar activity and can significantly impact communication satellites, technological systems, and human health in space. These physical phenomena around the Earth and their effects on our social infrastructure, which depends on solar activity, are collectively referred to as "space weather." Space weather describes the variations in the interconnected state of the space environment influenced by both solar and terrestrial atmospheric changes. These fluctuations can affect the performance and reliability of space- and ground-based technological systems, potentially posing direct and indirect threats to human well-being. For modern civilization to continue advancing and for humanity to expand its presence in space, it is crucial to accurately understand and predict space weather events. By doing so, we can reduce the damage to both our technological infrastructure and human lives from the hazardous effects of space weather.

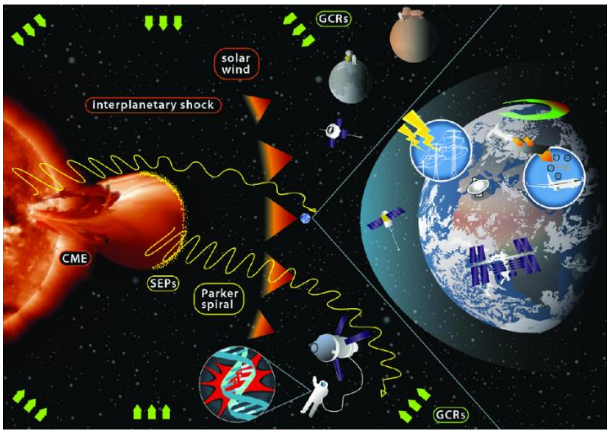


Fig. 1. Space weather phenomena and their impact on society. [Guo et al. (2023)]

Since kindergarten, I have been interested in science, especially astronomy and Earth science. My father graduated from a science-related department and enjoys science. He took me to science museums and astronomical observatories in the Tohoku region several times. This experience was my first motivation to enter the science faculty of Tohoku University.

When I was in high school, I was interested in astrophysics and earth science; therefore, I wanted to study these fields. Although I found these research areas intriguing, studying astrophysical phenomena such as black holes, galaxies, and the origin of the solar system evoked a sense of ambiguity. They are so distant from Earth and possess elusive qualities that they are difficult to visualize. Additionally, Earth sciences, such as geology, earthquakes, and ocean physics, are crucial for preventing natural disasters. However, I believed that this research field was very popular, and almost everyone was interested in it. I wanted to explore lesser-known topics that are essential to our daily lives. In a special class designed to help us think about our future careers, we searched online for what we wanted to learn. For these reasons, I wanted to study both research fields but felt uncertain. I wondered what would happen if I combined astronomy and the with phenomena related to the Earth. Then, I discovered "space weather," which refers to how solar activity affects the space environment around the Earth and our social infrastructure systems. From that time on, I became fascinated by weather in space. My research topic is Solar Physics. This was because I wanted to directly study the origin of space weather phenomena rather than the social effects of space weather. Furthermore, it is challenging to measure these phenomena directly with an in-situ spacecraft due to the high density and temperature near the solar surface. If we understand the physical phenomena and environment surrounding the sun, space weather forecasts could improve and become more accurate.

In my current laboratory, many students research the physical phenomena of the space environment around Earth, such as the disappearance of the radiation belt, the elementary processes of plasma particles, and applications for other planets. Therefore, I joined the laboratory at Tohoku University.

Theme: (5)

Why I Study Fuel Debris:
My Contribution to 1F Decommissioning through Chemical Research

Toshiki Iwahara

The Great East Japan Earthquake and Tsunami of 2011 caused some of the most complex engineering problems faced by humanity. My study of nuclear engineering, specifically the fundamental chemistry of nuclear waste, is motivated by the social imperative to manage and dispose of the waste generated by this accident. Regardless of the global debate surrounding nuclear energy, there is an obligation to properly assess, manage, and drastically reduce the risks associated with existing waste. The belief that resolving this challenge is essential for future generations to live securely has led me to focus my research on contributing to the comprehensive decommissioning of the Fukushima Daiichi Nuclear Power Plant (1F), specifically, the safe management of fuel debris.

I vividly recall images broadcast in 2011 that showcased the helplessness of technology against the forces of nature. For my generation, who were children at the time of the accident, this event was not distant history but a deep, life-shaping memory. While we are not yet adults, let alone researchers, we are perhaps the last generation to carry this direct, visceral impact, which separates us from those who will know it only through textbooks. This generational perspective instilled a deep conviction in me: regardless of how society's energy policy or public opinion might evolve, the safe decommissioning of 1F is an unquestionable necessity that must be completed to prevent the indefinite deferral of risk to the future. This daunting challenge has fueled my academic journey. I realized that the path to fulfilling this commitment lies in dedicated fundamental science. I was particularly drawn to the rare opportunity offered by my institution: the chance to conduct experiments using actual nuclear fuel materials, such as uranium, a capability that is highly restricted in domestic research environments. This hands-on experimental work provides a means to address an unparalleled engineering challenge.

My specific area of focus is the fuel debris generated inside 1F. This substance is a complex and highly radioactive material resulting from the melting of reactor cores containing nuclear fuel, zircaloy cladding (fuel cladding), carbon steel (reactor pressure vessel), stainless steel (structural material), concrete, and other materials. This challenge is critical because, until this material is fully understood and managed, it represents a long-term risk. Our ultimate mission is to bring the debris completely under human management to permanently reduce future hazards. It involves a four-stage process: retrieval, long-term storage, stabilization treatment, and final disposal. To complete this historical task, we must first accurately determine the precise physical and chemical states of the debris before attempting the first step of retrieval. Addressing this challenge is the most crucial step in completing the decommissioning of 1F, enabling regional recovery and restoring hope. The scientific findings and knowledge we establish will provide invaluable lessons for managing the aftermath of future nuclear incidents.

To fulfill my commitment to securing the future, my research focuses on an experimental approach to understanding debris. Because the exact conditions during the core meltdown are unknown, given the dynamic progression of the accident and the immediate emergency response phases, it is essential to meticulously determine the fundamental behavior of fuel debris across the full range of possible conditions. While the U-Zr-O system (the reaction between nuclear fuel and zircaloy cladding) has been well studied to understand debris characteristics, the fundamental behavior of the U-Fe-O system (the reaction between nuclear fuel and steel) is equally essential. Unlike the well-studied U-Zr-O system, the U-Fe-O system is far more complex due to its susceptibility to phase changes governed by the oxygen potential, a challenge compounded by a lack of prior comprehensive research. My work involved experiments conducted under controlled oxygen potential to obtain two essential sets of data. First, thermal analysis was performed to determine the exact temperatures at which the uranium and iron components reacted. Second, a solid-phase analysis was carried out to evaluate the generated chemical products. We analyzed the resulting simulated debris by integrating information across multiple scales. This involved leveraging advanced tools, including transmission electron microscopy (TEM) and synchrotron radiation analysis, to examine the material, from the overall structure down to tiny features on the micrometer and nanometer scales. This multiscale analysis allowed us to precisely determine the chemical states and morphologies of the products. This comprehensive chemical picture is a crucial part of the puzzle linking pure science to the four practical phases of decommissioning: guiding the retrieval strategy, assessing storage stability, and determining the safest treatment and disposal methods. My unique contribution provides the highly specific, fundamental data required to enable the safe and controlled execution of this complex engineering project.

My decision to pursue fuel debris research was driven by scientific curiosity, primarily through a profound sense of generational responsibility. The work I do, gathering data and gaining a deep understanding of the U-Fe-O system, is a direct link to fulfilling our generation's promise of bringing manmade waste under human management and preventing the deferral of risk to our children and grandchildren. By pioneering safe retrieval, storage, treatment, and disposal of this complex material, valuable knowledge for future decommissioning and accident responses can be generated. Ultimately, the advancement of decommissioning science ensures that society learns from its challenges, paving the way for a safer and more responsible energy future.

Theme: (5)

Why I Chose My Research: From Childhood Wonder to Studying Meteorites

Seima Ishida

From the time I was young, I have been impressed by the mystery of the universe. The night sky is always full of questions. Rather than being discouraged by how little I understood it, I felt excited. The more unknowns there were, the more magical the universe seemed. I remember looking up at the stars and feeling that each was like a secret waiting to be uncovered. This sense of wonder has become one of the strongest motivations in my life.

As a child, I often visited science museums and planetariums. I enjoyed watching exhibitions on planets, galaxies, and the births of stars. I also loved looking through telescopes. These moments were not merely fun; they provided me with a sense of direct connection to something far beyond Earth. Touching a meteorite on display or watching a simulation of the solar system was enough to spark my imagination. I began dreaming of becoming someone who could unlock some of these secrets one day.

Among the various aspects of space that fascinated me, I was especially drawn to meteorites. Unlike stars or galaxies, which can only be seen from a distance, meteorites are pieces of the universe that we can hold in our hands. They are physical samples of materials older than the Earth itself and contain clues about the early days of the solar system. The idea that I could touch something that had traveled through space for billions of years felt almost surreal to me as a child. Meteorites make the universe feel closer and more tangible.

My strongest childhood memory is of the Hayabusa mission conducted by JAXA. Between 2003 and 2010, when I was three to ten years old, JAXA launched a spacecraft to an asteroid and brought back samples. This was not just a scientific mission; it was a story full of drama and inspiration. The spacecraft encountered multiple problems, including engine failures and communication loss, yet it managed to return to Earth, carrying precious rock grains from asteroids. I remember reading books about this mission and feeling overwhelmed. This was the first time in human history that material was directly collected from an asteroid. Even though I was still a child, I sensed how historic and important this achievement was.

Hayabusa's story is also deeply emotional. It was not a smooth success but a mission that faced many difficulties. Engineers and scientists worked tirelessly to address these challenges. When the spacecraft finally returned, it was described almost as a "miracle." This human element, persistence, passion, and refusal to give up, made me more open to science. This mission planted a seed in my heart, and eventually, I wanted to be part of research that involved real samples from space.

As I grew older and began thinking about my future, I realized that I wanted to dedicate myself to studying meteorite and asteroid samples. The question was, where and how could I do this? I learned that Professor Tomoki Nakamura, who played a leading role in the analysis of the Hayabusa samples, was at Tohoku University. He guided some of the world's first studies on materials brought directly back from asteroids. Knowing this, I made a clear decision: I wanted to study in his laboratory, where I could join the frontlines of this groundbreaking work. It felt like the most natural step for me after years of inspiration from the Hayabusa story.

Now, as a graduate student in the laboratory, I work on actual return samples. My research focuses on understanding how the solar system formed and evolved by studying the materials collected from asteroids. These samples are very valuable because they have remained almost unchanged since the birth of the Solar System. By analyzing them, we can reconstruct events that occurred more than four and a half billion years ago. Each piece of data helps us see a bigger picture of how planets were born, how water was delivered to Earth, and how the conditions for life might have emerged.

This research is scientifically exciting and emotionally powerful. Every time I handle a sample, I feel a deep sense of connection with both the past and the future. On one hand, I am holding something older than our planet, a witness to the early days of the solar system. On the other hand, the knowledge we gain may help answer questions about the origins of Earth's water and life. These questions affect not only scientists but also humanity. To be even a small part of seeking answers to such a grand mystery gives me an unshakable sense of purpose.

However, this study is challenging. Sample analysis requires patience, precision, and creativity. There were times when the results were unclear or when the experiments did not proceed as planned. However, I remember Hayabusa's story. Success is not about avoiding problems but about continuing to move forward despite them. This mindset keeps me motivated and makes every small discovery feel rewarding. When I finally see a clear result, it feels like a conversation with the universe, a whisper from the past telling us something new.

The curiosity of a child staring at stars, the excitement of touching meteorites in museums, the inspiration for the Hayabusa mission, and the admiration for scientists who never gave up, all these experiences have guided me to where I am today. My choice of research is not only about science but also about following a dream that has grown with me since childhood. It is about honoring the stories that inspired me and adding my own chapter to human exploration.

SyDE
WISE Program for Sustainability in the Dynamic Earth

Theme: (5)

Why Should We Inspect Machine Learning Models?

Kotaro Asano

Introduction: The Potential of Machine Learning in Civil Engineering

The convergence of advanced computational power and sophisticated algorithmic innovation has fueled a revolution in the field of machine learning. By training on vast datasets, these algorithms perform complex computations at unprecedented speeds, surpassing conventional methods. This paradigm shift enables the quantitative analysis of unstructured data, such as images and audio, a task that was previously intractable. My civil engineering field is not insulated from these global trends. Japan faces an acute labor shortage driven by demographic shifts, making the need for innovation urgent. Consequently, machine learning is viewed with immense expectations not merely as a tool for incremental improvement but as a transformative solution. It holds promise for automating routine inspections, optimizing structural designs, and enhancing disaster simulation accuracy, thereby fundamentally reshaping how we build and maintain infrastructure.

A Dilemma in a Life-Saving Field: Reliability and the Black Box Problem

However, the path to adopting these powerful technologies is fraught with significant barriers, including trust. Civil engineering infrastructures such as bridges, dams, and buildings form the backbone of modern society. Their primary role is to safeguard human lives and property from natural disasters, which means that the calculations underpinning their design, construction, and maintenance demand unwavering reliability. Traditional engineering methods based on physical laws offer this certainty. Their equations provide a transparent and interpretable link between an input and an output, such as a clear relationship between the applied force and the resulting structural displacement. This transparency exhibits the highest strength.

In contrast, many machine learning models, particularly deep neural networks, operate as "black boxes." Their complex, multilayered internal structures make it difficult for engineers to intuitively grasp their decision-making processes. This opacity is a potentially fatal flaw in a field where a single miscalculation can have catastrophic consequences. If a model predicts an incorrect stress distribution in a bridge or fails to anticipate a building's response to an earthquake, the inability to diagnose the root cause of the error precludes reliability in future crises. This lack of interpretability creates an unacceptable level of risk, preventing the widespread adoption of otherwise promising technologies.

The Origin of My Research: Pursuing Technology That Can Answer "Why"

This dilemma motivated my current research path. As an engineer, I am captivated by the innovative potential of machine learning; however, I am also aware of the immense social responsibility inherent in my major. I sought to reconcile these two imperatives: to harness the power of artificial intelligence without compromising the safety and trust that are the cornerstones of civil engineering. To overcome this apparent contradiction, I conclude that we need a technology capable of explaining why a model arrives at a particular conclusion. The goal cannot simply be to obtain the right answer; we must also understand the reasoning behind it. This conviction led me to focus my research on a central challenge in modern AI: demystifying the internal architecture of machine learning models and rendering their behavior both understandable and trustworthy.

Conclusion: The Quest for Explainable AI by Fusing with Physical Models

This background guided my specific research topic: "Seismic Response Analysis using Recurrent Neural Networks based on Dynamic Mode Decomposition." This approach fundamentally connects two methods: the data-driven power of machine learning and the time-tested principles of the physical sciences. My methodology leverages established knowledge from physics and statistics, which are the cornerstones of engineering analyses. Specifically, it involves integrating known physical models directly into a machine learning framework. These models serve not only as core components that constrain the learning process but also as powerful guides for interpreting the results.

We believe that by combining these two approaches, we can create a hybrid system that is greater than the sum of its parts. This fusion allows us to explain the model's internal processes in physically meaningful terms, connecting its abstract calculations back to real-world phenomena while harnessing the immense computational power and expressive capability of machine learning. Through this research, I hope to build a robust foundation for the safe, effective, and responsible adoption of machine learning in civil engineering. My goal is to develop tools that engineers can trust, ensuring that as we embrace future technologies, we continue to uphold our most profound responsibility: the protection of human life.

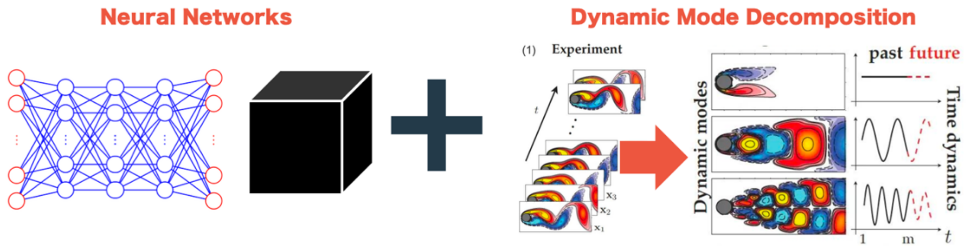


Fig. 1: Integration between Neural Networks and Dynamic Mode Decomposition

Theme : (5)

Revealing Earthquakes Mechanisms in Subduction Zones Through Rock Deformation Experiments

—Atsunari Suga

Japan is known globally for its frequent earthquakes. There are various types of earthquakes,; my research aims to reveal the mechanisms of earthquakes occurring in subduction zones such as the Japan Trench. In subduction zones, strain energy accumulates as the oceanic plate subducts under continental plates, triggering earthquake events when this energy is released. The 2011 earthquake off the Pacific Coast of Tohoku is a prime example of this type of earthquake. The Tohoku earthquake caused extensive damage throughout eastern Japan, not only because of the massive shaking with a magnitude of 9.0 and a maximum seismic intensity of 7 but also because it was accompanied by a tsunami. My experience of this earthquake sparked my interest in earthquake mechanisms from the perspective of structural geology.

What are the factors that cause earthquakes in subduction zones? A key term for understanding this matter is "asperity." An asperity is a patch-like structure on the oceanic plate that bonds continental and oceanic plates together, acting as a region that releases strong seismic waves during an earthquake (Fig. 1). Geological surveys and mineralogical analyses have investigated the mechanism of asperity formation. Previous studies have suggested that the formation of asperities is influenced by uneven topography, such as seamounts originating from hotspots and phase transitions in silica minerals (Kameda et al., 2012). The latter is referred to as silica diagenesis (Opal-A: amorphous → Opal-CT → Quartz) . Amorphous silica is supplied to subduction zones, where it crystallizes through diagenesis as oceanic plates subduct, forming hard patches. It is believed that the asperities are created from siliceous subduction zone sediments. However, it is impossible to observe seafloor conditions and the structure of the oceanic plate surface during an earthquake with the naked eye in real time.

How can the process of silica diagenesis be directly observed? Almost all the natural rocks -have already undergone silica diagenesis. Therefore, in this study, silica diagenesis in subduction zones was simulated by conducting rock deformation experiments on siliceous mudstone (or diatomaceous earth). It was observed that microfracture energy signals (AE: acoustic emission) were released during the experiments compared to natural earthquakes. This enables the evaluation of the temperature and pressure at which siliceous rock failure occurs, as well as the microfracturing activity. No studies have experimentally investigated whether silica diagenesis is actually a factor in asperity formation. For this reason, my research is novel. However, it is difficult to set the experimental conditions to reproduce silica diagenesis in the laboratory because conducting experiments under the same natural temperature and pressure conditions is time-consuming. As a first step in this research, it is important to investigate the temperature-pressure dependence of silica diagenesis and set conditions higher than natural values to account for the time required.

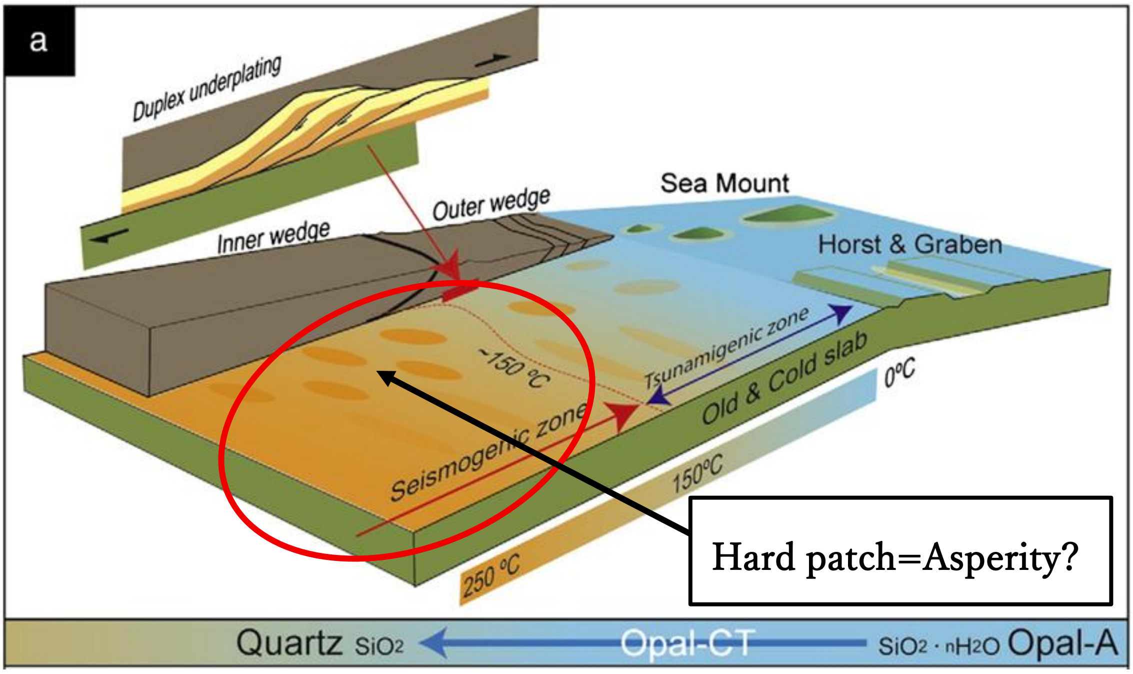


Fig.1 Added annotations to the subduction zone schematic illustration (Kameda et al., 2012). As temperature increases, silica diagenesis progresses and completes at approximately 220°C. Earthquakes occur in the temperature range where the patch hardens.