The Highest Research Laboratory in Japan: Mount Fuji Research Station

Tokyo Office, NPO Mount Fuji Research Station

1. Introduction

Mount Fuji Research Station (MFRS) is maintained by the nonprofit organization 'Mount Fuji Research Station' (NPO Mt. Fuji). The English name of the station was changed in January 2016 from Mt. Fuji Weather Station. The station's main activities are its yearly summer campaigns from July to August, although some battery-powered instruments take automatic measurements year-round. Most of the station is rented from the Japan Meteorological Agency (JMA) under a 5-year contract (2013-2018).

Due to the value of Mt. Fuji's summit and the weather station buildings, the number of researchers in a diverse range of scientific fields has been increasing over the last 10 years (Fig. 1-1, Fig. 1-2). MFRS is now recognized as a new type of scientific institute for interdisciplinary scientific research.

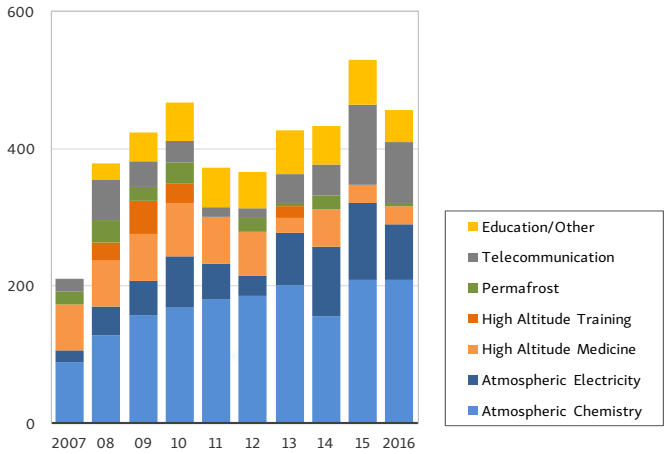


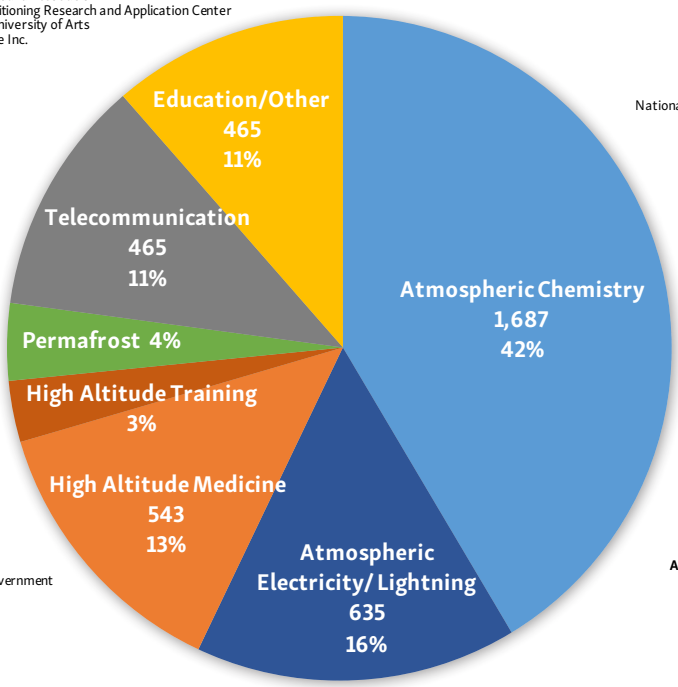
Fig. 1-1: Number of participants by year, 2007–2016

Education/ Other
National Institute of Technology, Ibaraki College
Rikkyo Niiza Junior & Senior High School
Japan Broadcasting Corporation
Japan Spaceguard Association
Satellite Positioning Research and Application Center
Kyoto City University of Arts
MTS Institute Inc.

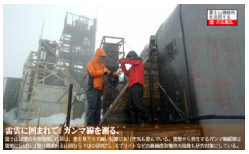
Telecommunication
KDDI Corporation
NTT DOCOMO, INC
Yokohama Amateur Microwave Association

Permafrost
National Institute of Polar Research
University of Tsukuba
Shizuoka University

High Altitude Medicine/ Training
Mount Fuji Research Institute, Yamanashi Prefectural Government
National Institute of Fitness and Sports in Kanoya
Osaka City University
Biwako Seikei Sport College
Tsurumi University
Sakakibara Heart Institute
Tokyo Metropolitan Ohtsuka hospital



Atmospheric Chemistry
National Institute for Environmental Studies
National Institute of Advanced Industrial Science and Technology
Japan Agency for Marine-Earth Science and Technology
Center for Environmental Science in Saitama
National Defense Academy of Japan
Hokkaido University
Tokyo University of Agriculture and Technology
University of Yamanashi
Kanazawa University
Tokushima Unniversity
Kumamoto University
Tokyo Metropolitan University
Ishikawa Prefectural University
The University of Shiga Prefecture
Waseda University
Tokyo University of Science
Teikyo University of Science
National Central University (Taiwan)
Centre national de la recherche scientifique (France)
Leibniz-Institute for Tropospheric Research (Germany)



Atmospheric Electricity/ Lightning/ Cosmic Ray Sciences
National Institute of Radiological Sciences
Japan Atomic Energy Agency
Hirosaki University
The University of Tokyo
Tokyo University of Science
Tokai University
OTOWA Electric Co., Ltd.

Fig. 1-2: Constituent ratio of research fields, 2007–2016

This chapter includes a short history of the former Mt. Fuji Weather Station, the progress over the last 10 years of the NPO, research and education at MFRS, the organization of the summer campaigns, and our funding and financial support.

2. Brief history of the former Mt. Fuji Weather Station

"If changes in weather originate from the upper atmosphere, then observations at the summit of Mt. Fuji should be useful", thought Itaru Nonaka, a young meteorologist, at the end of the 19th century. He decided to take winter meteorological observations at the summit of Mt. Fuji by himself, selling his house in his hometown to build a hut on the highest hill on the summit. He stayed on the summit from October with his wife, Chiyoko, taking observations for 82 days. Their heroic observations led to the development of Mt. Fuji Weather Station. Their story is known nationwide through many novels, such as those by former JMA engineer Jiro Nitta.

From 1932, Mt. Fuji Weather Station was manually operated by JMA. In 1944, electric power cable was laid by the army (described in detail in Chapter 2). After World War II, Mt. Fuji RADAR was established in 1964 to serve as a defense against typhoons, forecasting their arrival much earlier than was previously possible and saving thousands of lives, as well as being a proud symbol for engineers and researchers. However, in the 1990s, its main function was taken over by meteorological satellites, and JMA switched to automatic operation in 2004. Using battery-powered systems, JMA has reported atmospheric pressure, temperature, and humidity since October 2004.

3. NPO Mt. Fuji

Did Mt. Fuji Weather Station become redundant when its meteorological use ended?

The summit of Mt. Fuji is 3776 m above sea level, and remains in the free troposphere throughout the year because of its steep, slender peak standing alone in the middle of Honshu Island. The summit of Mt. Fuji is an ideal observation site for atmospheric chemists, and some atmospheric chemists used the station from the 1990s to 2003. The research performed there was reported in a number of international journals. In November 2003, the researchers were told that manned observation of the station would end the following year because of safety and decreased funding of JMA.

The researchers who wanted to continue using the weather station feared that ending manual operation would mean the loss of precious living knowledge on how to maintain the mountain research stations. Once lost, such knowledge is difficult to recover. To avoid this, we formed the 'Mt. Fuji High Altitude Research Group' in August 2004 to discuss feasible ways to continue using the station.

We tried to raise funds by visiting the offices of JMA, the Ministry of Education, Culture, Sports, Science and Technology (MEXT), and the Ministry of the Environment (MOE); by petitioning members of the National Diet; and by raising awareness by publishing books and organizing lecture meetings for citizens. However, these efforts were fruitless. In 2006, the law concerning government building management was revised to allow private enterprises to rent government buildings, so we decided to change our organization to an NPO and rent the weather station. In November 2005, we established the NPO 'Valid Utilization of Mt. Fuji Weather Station' by reorganizing the Mt. Fuji High Altitude Research Group. MFRS key events covered from 2005 are summarized in Table 1-1.

4. Research and education at MFRS

The station is used in many interdisciplinary fields of research and education. Mt. Fuji serves as a huge observation tower from which representative samples of the upper atmosphere can be taken. The station is a good observation site for cosmic rays and lightning, and for high-altitude medical studies and training. The research fields now extend to space science, new technologies, and development of teaching tools.

Atmospheric chemistry

The summit of Mt. Fuji reaches into the free troposphere, which is the atmosphere between an altitude of 1000 m above sea level and the stratosphere. In this layer, substances travel long distances without being subject to land surface friction. Substances generated on the Eurasian Continent are carried from west to east by westerly winds generated in the mid-latitudes of the

Table 1-1: MFRS key events from 2005 after the NPO was established

Year	Date	Event
2005	11/27	**Establishment of NPO 'Valid Utilization of Mt. Fuji Weather Station'** (reorganization from Mt. Fuji High Altitude Research Group).
2006	3/4-5	**1st International Workshop/Symposium** in Tokyo on International Valid Utilization of Mt. Fuji Weather Station. An appeal declaration was adopted.
	5/26	**1st General Meeting** after official certification as an NPO, including a special lecture by Mr. Shosuke Ito, former chief engineer of Taisei Cooperation, the company that built the new Mt. Fuji Weather Station buildings in 1973.
	1/15	**Mt. Fuji Science School** started (13 sessions during 2006-7).
	11/22-23	2nd International Workshop/Symposium at the University of Tokyo, supported by the MEXT grant for the Mt. Fuji Project for establishing a high mountain observation platform in an extreme environment.
2007	2/4	**Shizuoka office** opened in Mishima.
	7/10-9/5	**1st Summer Campaign** at the Mt. Fuji Weather Station. 212 researchers participated over 58 days.
	7/17	World Eco-Science Network Meeting sponsored by Dentsu Ltd.
2008	1/27	**1st Annual Meeting of the NPO**, reporting the research results of the 2007 summer campaign, Koshiba Hall, University of Tokyo.
	5/x	Electric power cable damage by heavy snow was found near Tarobo, which imposed a major financial burden on the NPO.
	6/19	Negotiation with JMA to double the rented area.
	7/10-9/5	**2nd Summer Campaign** 379 researchers participated over 53 days.
2009	1/25	2nd Annual Meeting of the NPO, reporting the research results of the 2008 summer campaign.
	7/10-8/30	**3rd Summer Campaign** 424 researchers participated over 52 days. National Institute for Environmental Studies (NIES), Japan, started year-round CO_2 monitoring using battery-operated instruments.
2010	1/25	3rd Annual Meeting of the NPO.
	3/24	Another three-year contract was signed with JMA.
	3/20	Lightning damage was found on the electric power cable.
	7/12-8/30	**4th Summer Campaign** 467 researchers participated over 50 days. National Institute of Radiological Science (NIRS), Japan, started year-round observation of cosmic rays. The National Institute of Advanced Industrial Science and Technology (AIST), Japan, and Tokyo Metropolitan University started to use wireless LAN for data communication and nearly real-time data publication on their home page.
2011	1/23	4th Annual Meeting of the NPO.
	3/11	**East Japan Earthquake and Fukushima Daiichi Nuclear Disaster**
	7/12-9/1	**5th Summer Campaign**. 373 researchers participated over 53 days. Radioactivity measurements on the climbing route and live camera pictures of clouds were broadcast by wireless LAN to the NPO members, and affiliated programs at two stations, the summit station and Yokohama station, were performed.
2012	1/29	5th Annual Meeting of the NPO
	6/1	Publication of the book Yomigaere Fujisan Sokkojo (Revival of Mt. Fuji Weather Station) by Seizando Books, authored by 50 NPO researchers
	7/13-8/31	**6th Summer Campaign** 366 researchers participated over 54 days. A new air inlet for Atmospheric Chemistry was established on the third building. Another five-year contract was signed with JMA.
2013	1/27	6th Annual Meeting of the NPO.
	5/26	At the Eighth General Meeting of the NPO, a five-year mid-term plan for 2013-2018 was decided.
	6/22	Mt. Fuji was registered as a World Cultural Heritage by UNESCO. After this, the NPO became very busy.
	7/2-12/24	A weekly column Kamitsubute (Paper Pellets) written by Dr. Y. Dokiya, a director of the NPO, was serialized in the Tokyo Shimbun evening paper.
	7/16-8/30	**7th Summer Campaign** 427 researchers participated over 42 days. PM 2.5 particles were measured. Volcanic gas from Sakurajima was detected by Dr. S. Kato during his observation of SO_2 at the summit.
2014	1/24	7th Annual Meeting of the NPO.
	4/8-6/27	Dr. Y. Dokiya discussed research at Mt. Fuji on the program Culture Radio on NHK, Japan's national public broadcasting organization.
	7/10	Electric power was shared with Oyama town, Shizuoka Prefecture.
	7/1-8/29	**8th Summer Campaign** 434 researchers participated over 60 days. A gigantic jet, which is a type of upper-atmosphere lightning, was observed by Dr. M. Kamogawa and Tokyo Gakugei University group. Live camera pictures were broadcast for the public.
	9/27	Eruption of Kiso-Ontake
2015	3/22	8th Annual Meeting of the NPO.
	6/24	Underground electric cables were destroyed in the vicinity of a shrine near the summit. The 2 weeks needed for repairs delayed the summer campaign by 1 week.
	7/8-8/28	**9th Summer Campaign** 530 researchers participated over 52 days, and 22 projects were performed including a new student project, 'Fuji-Sat'. Real-time SO_2 data, live camera pictures, and virtual tour of the station were published on the home page.
	10/31	A popular NHK TV program, 'Bura Tamori', featured some of the research at the station.
2016	1/8	NPO Valid Utilization of Mt. Fuji Weather Station was accepted as an authorized NPO by the Tokyo Metropolitan Government.
	3/13	9th Annual Meeting of the NPO.
	1/19	The English name of the station was changed to the Mount Fuji Research Station.
	7/1-9/1	**10th Summer Campaign** 456 researchers participated over 63 days. A joint Taiwanese-Japanese project on atmospheric mercury and volatile organic compounds was performed by National Central University, Taiwan, and Tokyo University of Agriculture and Technology, Japan.

northern hemisphere; thus, Mt. Fuji, which is located at the eastern edge of the Eurasian Continent, is an optimum site for these observations.

With the current rapid economic growth in Asia, the importance of the observations and research at the Mt. Fuji station will increase because the station is located directly downwind of some of the largest sources of emission and other atmospheric effluents on Earth. Chemical and physical studies of aerosols, including PM2.5 particles, fog and cloud water, trace gases, such as carbon dioxide, ozone, carbon monoxide, and sulfur dioxide, and organic gases, have been studied intensively for the last 10 years. An International Symposium on Atmospheric Chemistry and Physics at Mountain Sites (ACPM 2017) will be held in Japan, led by this group (chairperson: Prof. S. Hatakeyama; vice chairpersons: Prof. H. Okochi and K. Miura).

Atmospheric electricity, lightning, and cosmic ray studies

The top of Mt. Fuji is often covered by thunder clouds and is therefore an ideal observation site for lightning, especially summer lightning, which usually occurs at a cloud height greater than 4000 m. Atmospheric electricity measurements are performed on the roof of the station using field mills and other instruments to elucidate the relationship between electric fields and the behavior of radioactivity.

As the altitude increases, the intensity of cosmic rays increases as well, because the atmospheric layer thins with altitude. This has raised concerns about the effects of cosmic rays on the health of aircraft crews. For real-time, accurate dosimetry of cosmic ray exposure at aviation altitudes, a system for cosmic ray measurements with advanced instruments has been constructed at MFRS.

Permafrost/ecology

Permafrost can be found at the summit of Mt. Fuji. Research on special moss and lichens that depend on permafrost for water will help clarify the effect of global warming on the distribution of permafrost. A second research group has been investigating permafrost since 2010 by boring holes as deep as 10 m near the summit.

High-altitude mountain medicine and training

Mt. Fuji attracts about 300,000 climbers every year, and several die of cardiac failure or other causes. One of the major causes of death at high altitudes is acute mountain sickness, the group of symptoms caused by low oxygen levels. At a height of more than 3000 m, the lower atmospheric pressure reduces the amount of oxygen in the blood to 60% of that at sea level.

Space science education

The Fuji-Sat Challenge Team is a team organized by voluntary students. They produce a simulated satellite for their study. They also help with environmental conservation by cleaning up litter.

Study tools

New and unique study tools for junior high school and high school students are being developed using the Mt. Fuji environment. Low pressure, severe wind and rain, sunshine, high UV light, and natural radioactivity are utilized as new study tools that help students learn using all of their senses.

5. Organization of the summer campaigns

For the last 10 years, we have established a method for supporting researchers at the summit of Mt. Fuji, learning from the experience of JMA ex-engineers and researchers at other mountain stations. MFRS is in a very harsh environment meteorologically, geographically, and even in terms of human relationships. The atmospheric temperature is often below 0 °C with high wind speeds, low humidity, and low atmospheric pressure. In addition, to MFRS being on the highest peak of the mountain, as many as 300,000 climbers a year visit during the summer, especially since the registration of Mt. Fuji as a World Heritage Site in 2013. We now use the following processes each year.

January-March

Choosing the projects for the summer campaign in the Academic Committee of the NPO Mt. Fuji from the applications made via our home page. The decisions are made based on scientific value and safety through peer review and a committee meeting.

March-May

Submission of documents for authorization to MOE, Agency for Cultural Affairs (ACA), and JMA, about

the installation of instruments for research around the MFRS. This process is required because MFRS is in a national park.

May

Between 7 and 10 mountain crews are hired, consisting of professional climbers, and lead by 2 ex-part time workers at Mt. Fuji Weather Station, when it was manually operated by JMA. The crews check the snow piles on the climbing route and the overhead electric power cable.

June

Setting up Gotemba Base. An apartment is rented for the 3 months of the summer campaign, so that the mountain crews can start the maintenance of the electric power supply and the station buildings, which have been vacant from the previous September to June. The bulldozer operator is contacted with the details of the schedule for transporting essential supplies for research and living to the summit. Bulldozers are used because helicopters cannot be practically used on Mt. Fuji.

July

The summer campaign is started after the power supply is switched on. In 2015, the summer campaign was delayed by 1 week because the power supply was damaged by an accident during construction at a shrine near the summit. Researchers climb to MFRS on foot or travel by bulldozer to start their research according to the schedule set out by the Tokyo office. They usually stay at the station for 1-3 days, or in some cases, a week or more with the help of the mountain crews (at least 3 crews, with at most 13 researchers a day). The busiest time in the summer campaign is from the last week of July to the second week of August.

End of August

The summer campaign finishes and instruments are carried down by bulldozer, taking care to avoid typhoons;

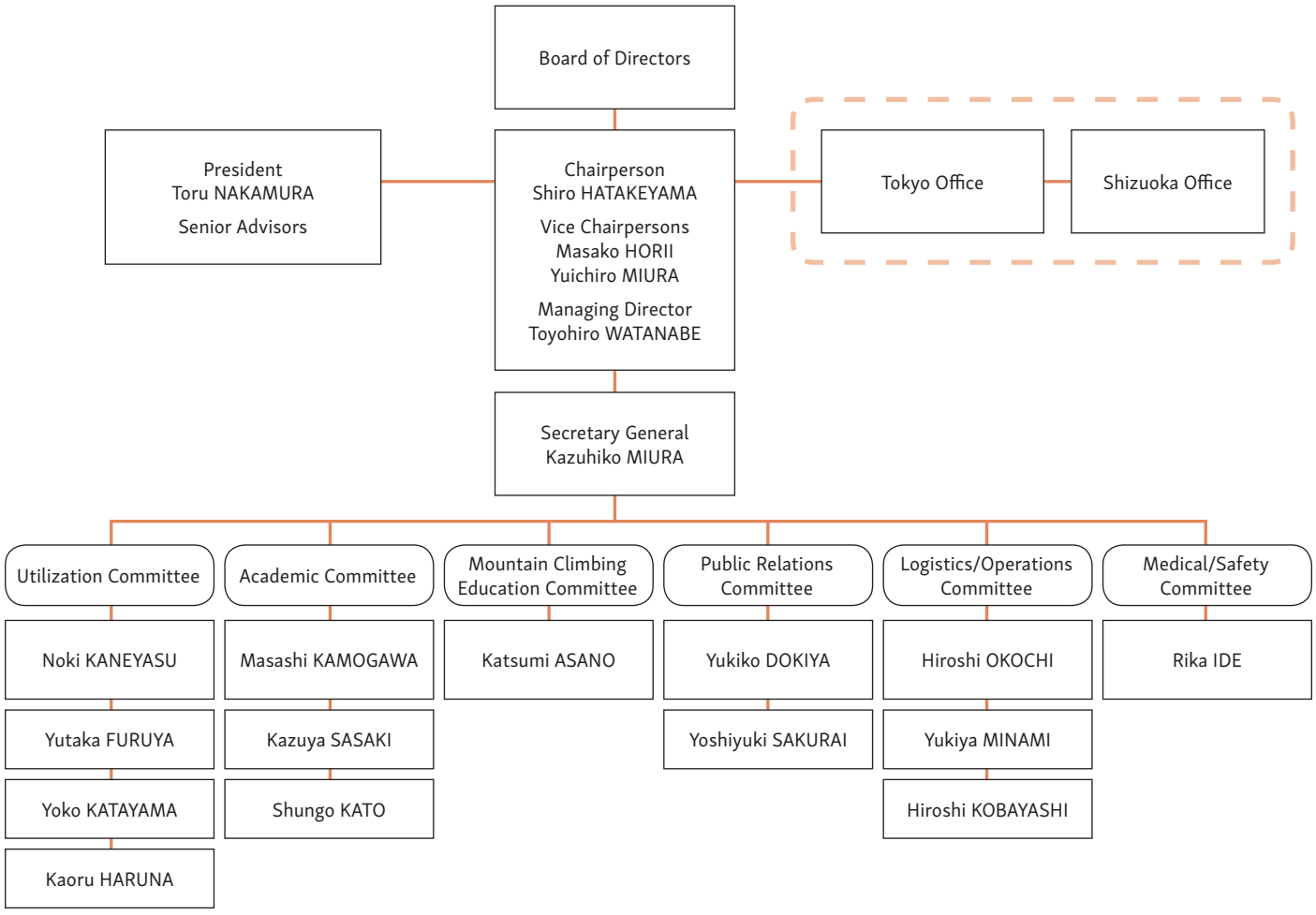


Fig. 1-3: Organizational Chart of the NPO Mount Fuji Research Station

typhoons frequently arrive in the last week of August. NPO staff update the schedules with the bulldozer operator frequently during the summer campaign, especially during the last stage. After the researchers are gone, the mountain crews cut the commercial power supply with JMA engineers, check that the battery-powered instruments will work through the winter, close the station, and climb down the mountain.

Early September-December

NPO staff cancel the apartment contract and close the Gotemba Base. At the Tokyo office, documents are sent to MOE, ACA, and JMA, and reports are written in order to secure funding. Researchers also write quick reports about the campaign for the home page of the NPO, and write up their research for publication and presentation at scientific meetings in their own fields.

6. Costs and financial support

The annual expenses of the NPO Mt. Fuji are approximately 30 million yen, the majority of which is the cost of the 2-month summer campaign. This does not include the cost of individual research, although it does include the costs of bulldozer transportation, the mountain crew and office workers, electricity maintenance, and rental of the facility.

Because the NPO Mt. Fuji is not supported by JMA or other governmental organization, the costs must be covered by members' fees, donations, and general scientific grants and trusts. The main support for the first 5 years was from collaboration with the Japan Agency for Marine-Earth Science and Technology (JAMSTEC), but from 2010, Mitsui & Co., Ltd. Environment Foundation has played a key role. Funding sources for the last 10 years are shown in Table 1-2.

Table 1-2: Funding sources for the last 10 years

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
JAMSTEC (collaboration)												
NIES (outsoucing)												
Watanabe Memorial Foundation for the Advancement of New Technology												
Mitsui & Co., Ltd. Environmental Foundation												
Japan Post												
The Awai Hidero Environment Foundation												
Environmental Restoration and Conservation Agency (ERCA)												
The Hitachi Global Foundation												
Mobile Communication Fund (MCF)												
The Toyota Foundation												
Taisei Corporation Natural and Historic Environment Fund												