No. 31 February 2017


=Foreword=

# International Research Activities at RISH in 2016

Professor Hiroyuki Yano
Chair of the Academic Exchange Committee of RISH, Kyoto University

The Research Institute for Sustainable Humanosphere (RISH) of Kyoto University was established in 2004. RISH defines the “humanosphere” as the spheres that support human activities, including the human living environment, the forest-sphere, the atmosphere and the space environment. We aim to investigate present and future problems of the humanosphere, and to explore innovative technology that will contribute to establishing a sustainable society in harmony with the natural environment.

Before beginning work on the “3rd Midterm Targets and Plans of National Universities” in 2016, RISH reconsidered the roles of its current missions, expanding and reassigning them as: Mission 1: Environmental Diagnosis and Regulation of Circulatory Function; Mission 2: Advanced Development of Science and Technology Towards a Solar Energy Society; Mission 3: Sustainable Space Environments for Humankind; Mission 4: Development and Utilization of Wood-based Sustainable Materials in Harmony with the Human Living Environment; and Mission 5: Quality of the Future Humanosphere, which aims to create healthy and sustainable living environments for society by developing practical applications for research results. In connection to the new missions, we set up a “Humanosphere Asia Research Node” in Indonesia, thereby strengthening the hub functions of international collaborative research, and fostering the work of people who sustain and expand Humanosphere Science to find global-scale solutions.

RISH was approved as a Joint Usage/Research Center to promote humanospheric science with academic activities conducted through both domestic and international collaborative research programs. The Middle and Upper atmosphere radar (MU radar), our largest facility, and the Equatorial Atmosphere Radar (EAR), which was constructed in west Sumatra, Indonesia, have been accepting international applicants for inter-university collaborative programs. In 2015, the IEEE Milestone in Electrical Engineering and Computing was awarded to the MU radar as a state-of-the-art large atmosphere radar with an active phased-array antenna system. A commemorative ceremony was held on May 13, 2015, in Shigaraki and Kyoto. Meanwhile, the EAR celebrated its 15th anniversary in Jakarta on August 4, 2016.

We promote internationalization of other large facilities, such as the Deterioration Organisms Laboratory (DOL) and the Living-Sphere Simulation Field (LSF), to enhance the transfer of technology and higher education. To promote international collaboration, we have produced 22 cooperative Memoranda of Understanding (MOU). In 2016, we added a MOU with the Indian Institute of Geomagnetism, Mumbai, India and extended a MOU with the School of Biological Sciences, Universiti Sains Malaysia, Malaysia. Our counterparts are widely spread over 12 countries in 17 Asian, 3 European, and 2 North American regions.

The academic exchange committee of RISH continues to encourage more productive partnership to strengthen the quality and effectiveness of research on global issues.

=International Activity Report=

# IEEE Milestone awarded to the MU radar

Professor Toshitaka Tsuda,
Professor Mamoru Yamamoto, and Associate Professor Hiroyuki Hashiguchi
RISH, Kyoto University

The IEEE Milestone* in Electrical Engineering and Computing was awarded to the Middle and Upper atmosphere radar (MU radar) as a state-of-the-art large atmospheric radar with an active phased-array antenna system. At the dedication ceremony held on May 13, 2015, at the Shiran-Kaikan of Kyoto University, Dr. Howard E. Michel, President and CEO of IEEE, presented the plaque (see photo) to both Kyoto University and the Mitsubishi Electric Corporation, celebrating their intensive collaboration in developing and constructing the MU radar. Prof. Juichi Yamagiwa, President of Kyoto University, and Mr. Masaki Sakuyama, President and CEO of the Mitsubishi Electric Corporation, represented the two organizations in expressing cordial thanks for the award,.

The award ceremony was followed by a reception at the same venue. Professor Toshitaka Tsuda, Director of RISH, gave the opening address, and four thoughtful congratulatory addresses were presented by Prof. Tomonori Aoyama, Chair of the IEEE Japan Council, Mr. Norifumi Ushio, Director, Scientific Research Institutes Division, Research Promotion Bureau, Ministry of Education, Culture, Sports, Science and Technology (MEXT), Dr. Kazuo Kyuma, Executive member, Council for Science, Technology and Innovation (CSTI), Cabinet Office, and Prof. Susumu Yoshida, past-President, the Institute of Electronics, Information and Communication Engineers (IEICE). A celebratory party was then kicked off with a toast proposed by Prof. Emeritus Susumu Kato, the founder of the MU radar project. A commemorative symposium introduced the key achievements of the MU radar, followed by a tour of the MU radar observatory in Shigaraki, where the IEEE plaque was officially installed.

The design of large-scale atmospheric radars began at Kyoto University in the 1970s. The Incoherent Scatter (IS) radar was initially studied in order to observe the upper atmosphere for the first time in Asia. Studies on radar design showed that radars with specific features were required to observe the middle atmosphere, called “the ignorosphere” in the 1980s. Research was subsequently focused on designing radars for use primarily to observe the middle and part of the upper atmosphere. We decided to develop the active phased-array radar technique for high-speed antenna beam steering and versatile utilization of sub-antennas under intensive collaboration with the Mitsubishi Electric Corporation. After three years of construction, the MU radar was completed in 1984, with an active phased array (a circular array, 103-m diameter) with 475 Yagi antennas and a peak transmitting power of 1 MW.

The MU radar enables real-time observation of the atmosphere up to a height of several hundred kilometers using computer-controlled radar beams scanning at a maximum rate of 400 μs, and it has provided useful results for many scientific fields, including space and atmospheric physics, meteorology, astronomy, electrical and electronic engineering, and astrophysics. In the more than 30 years since 1984, the MU radar has been widely used by both domestic and international collaborative researchers. We celebrated the 25th anniversary of the MU radar on September 2, 2010, at the Uji Obaku Plaza, followed by an international symposium the next day (Tsuda et al., RISH Newsletter, No. 25, 2010). Various new perspectives and insights in meteorology, upper atmosphere dynamics, and astronomical physics have been reported based on collaborative studies using the MU radar, together with the other complementary facilities of the Shigaraki observatory, including satellite data analysis, and numerical model studies.

Following the very successful achievements of the MU radar, the Equatorial Atmosphere Radar (EAR) was constructed in 2001 in west Sumatra, Indonesia. It has been operated jointly by the National Institute of Aeronautics and Space of Indonesia (LAPAN) and RISH. Research activities have been reported elsewhere (Yamamoto, RISH Newsletter, No. 16, 2005). Celebration ceremonies for the 10th and 15th anniversaries of EAR took place in Jakarta on September 22, 2011 (Hashiguchi et al., RISH Newsletter, No. 26, 2012), and August 4, 2016, respectively.

Currently, the active phased-array antenna system is being used in a number of atmospheric radars, such as the MAARSY radar in Germany, the AMISR in the US, and the PANSY radar in Antarctica. Research results from the MU radar have been used in the operational atmospheric radar network, called the Wind Profiler and Data Acquisition System (WINDAS) of the Japan Meteorological Agency. RISH of Kyoto University is continually focused on promoting the establishment of another large radar, named the Equatorial MU radar (EMU), a highly sophisticated and high-performance radar that compiles the MU radar technology in equatorial Indonesia, where the most active cumulus convection occurs because of intense solar radiation.

Related articles in the RISH International Newsletter

No. 16, March 2005, p7, Equatorial Atmosphere Radar (EAR) and research activities in Indonesia, by M. Yamamoto

No. 25, October 2010, p3-4, Ceremony for the 25th Anniversary of the MU Radar, by T. Tsuda, M. Yamamoto, and H. Hashiguchi

No. 26, march 2012, p2-3, Ceremony Celebrating the 10th Anniversary of the Equatorial Atmosphere Radar, by H. Hashiguchi, M. Yamamoto and T. Tsuda


Plaque of the IEEE Milestone awarded to the MU radar

*The IEEE is the world's largest technical professional society, with about 430,000 members in more than 190 countries, and it established the Milestones Program in 1983. Each milestone recognizes a significant technical achievement that occurred at least 25 years ago in an area of technology represented by IEEE. To date, more than 100 Milestones have been approved and dedicated around the world. Japanese Milestones, for example, include the Directive Short Wave Antenna, Mount Fuji Radar System, Tokaido Shinkansen (Bullet Train), etc. The Milestone awarded to the MU radar is the first for both Kyoto University and the Mitsubishi Electric Co.

=Overseas Visiting Scholar=

# Research Activities at RISH on EMIC Waves in the Earth's Magnetosphere

Professor Khan-Hyuk Kim
Kyung Hee University, Korea

The purpose of my research at RISH is to understand electromagnetic ion cyclotron (EMIC) wave properties under quiet geomagnetic conditions. It has been planned for the Japanese science ERG (Energization and Radiation in Geospace) satellite to be launched in December 2016. Since the ERG satellite will be operated during the solar declining phase and near solar minimum of solar cycle 24, it would provide new insights into the dynamics of the inner magnetosphere for the intervals of quiet geomagnetic conditions, which are caused by quiet solar activities. These intervals are not dominated by significant geomagnetic activities (i.e., magnetic storms and/or substorms). While we wait for the ERG mission we can improve our understanding how and where EMIC waves are generated in the magnetosphere during quiet geomagnetic conditions by analyses of existing data during 2007-2011 including a period of solar minimum 23.

During the 6-month stay from March to August 2016, I have focused on three topics. The first is to understand spectral properties of EMIC waves at geosynchronous orbit during steady quiet geomagnetic conditions, which is defined with Kp values ≤ 1 during 12 h, using GOES 10, 11, and 12 magnetometer data for solar minimum year 2007-2008. We found that about 82% of the EMIC wave events were observed in the morning-to-early afternoon sector (0700-1500 MLT) with a maximum occurrence near noon, and their peak frequencies were mostly in the He band. We also found that the occurrence rate of steady quiet-time EMIC waves is higher than that of EMIC waves for all or quiet geomagnetic conditions (Dst > 0 nT or AE < 100 nT) reported in previous studies by a factor of 2 or more. This may be due to the fact that the plasmasphere expanded more frequently to the geosynchronous region under extremely quiet geomagnetic conditions. The amplitude and frequency of He-band EMIC waves for nonlinear wave growth are examined as changing cold plasma density at geosynchronous orbit. We confirm that the spectral properties of observed EMIC waves are in good agreement with the nonlinear theory. This result has been submitted into the Journal of Geophysical Research.

The second topic is to examine EMIC wave occurrence in the outer magnetosphere (L = 6-10) using THEMIS magnetic field data for 2008-2011. In this statistical study we investigate the relationship between EMIC waves identified in H and He bands and plasmaspheric cold density distribution under various geomagnetic conditions. We found that morning-afternoon asymmetry in the H and He band EMIC wave occurrence rates, which is one of interesting and unsolved issues on EMIC waves, is due to the asymmetric distribution of cold plasmaspheric plasma. This result has been submitted into the Journal of Geophysical Research.

The third research topic is the study of EMIC waves excited during strongly disturbed geomagnetic conditions. We have focused on EMIC

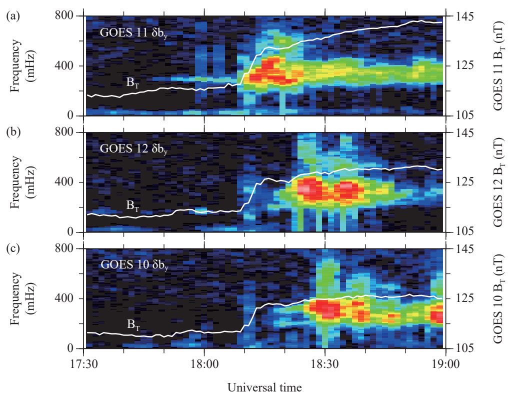



Figure 1

waves observed at three geosynchronous satellites, when GOES 11 was in the morning and GOES 10 and 12 were in the afternoon, during a sudden commencement (SC) on 19 November 2007. In our study we clearly showed that the SC onset was identified nearly simultaneously at the three GOES satellites. GOES 11 detected EMIC wave activity just after the SC onset without a significant time delay. However, EMIC waves occurred ~10-15 min after the SC onset at the GOES satellites in the afternoon sector (Figure 1). This indicates that the source of EMIC waves drifts eastward from morning and afternoon and the magnetospheric compression alone cannot generate EMIC waves. This result will be submitted into the Journal of Geophysical Research.

Finally, I would like to thank all the staff at RISH, Kyoto University for providing a friendly and welcoming atmosphere, and especially my host, Prof. Omura and his secretary for making a pleasant stay. I hope and expect that our collaboration will continue and expand in the future.

**=Overseas Visiting Scholar=**

## My visit and research activities at RISH

Professor Cihat Tascioglu
Duzce University, Turkey

I am a professor in the Department of Forest Industrial Engineering, Faculty of Forestry, Duzce University. I spent 24 weeks from April 1 to September 29, 2016 at RISH, Kyoto University as visiting professor. My host was Professor Yoshimura, the head of Laboratory of Innovative Humano-habitability. I know Prof. Yoshimura and his lab well since I studied there for 24 months between 2007 and 2009 as a JSPS (Japan Society for the Promotion of Science) post doctoral fellow. From my previous experience, I was confident that Yoshimura Lab is well advance in the field of termite and wood decay studies therefore I wanted cooperate with his lab during my sabbatical leave in 2016.

One of my research interests is to develop novel techniques to protect wood-based and wood-plastic composites from termite and fungal attacks. Alkaline copper quat (ACQ) and copper azole (CA) which have been accepted worldwide as alternatives to chromated copper arsenate (CCA), were evaluated as wood preservatives for post-manufacturing treatment of WBC in the present research. Zinc borate (ZnB) and sodium fluoride (NaF) are chosen for their low environmental impact profile and high thermal stability for in-line protection process of particleboard and wood-polymer composites.

Specimens were prepared from five commercially available structural-use wood-based composites: softwood plywood (SWP), hardwood plywood (HWP), medium density fiberboard (MDF) produced from hardwood fibers, aspen oriented strand board (OSB) and particleboard (PB) made of both hardwood and softwood particles. The specimen sizes were 210 mm x 30 mm x thickness and 100 mm x 100 x thickness for laboratory and field tests, respectively. ACQ and CA were tested for their effectiveness at three retentions, respectively K1, K2 and K3 classes as designated by JAS. Zinc borate and sodium fluoride were added at 1,1.5 and 2% and 1, 1.5, 2 and 3% as w/w levels, respectively, during the manufacturing of particleboards. The WPCs are also produced in the same manner (in-line process) but at lower retention levels.

Untreated and treated wood based composite specimens were tested for their changes in mechanical properties due to preservative treatments by the JIS three-point bending method. A previously developed system to simulate performance of sill plates (dodai) in traditional Japanese homes was used in the field tests.

My research activities in recent visit included obtaining field test data from post-treated wood-based and in-process treated wood-plastic composites installed in the RISH's Living Sphere Simulation Field (LSF) located near Hioki City in Kagoshima Prefecture on the south west of Kyushu Island, Japan. I was able to visually observe and rate termite and decay damage on the composites exposed to termite and decay activity under protected above ground conditions for 84 months.

The findings indicate that wood-based composites tested are not dura-

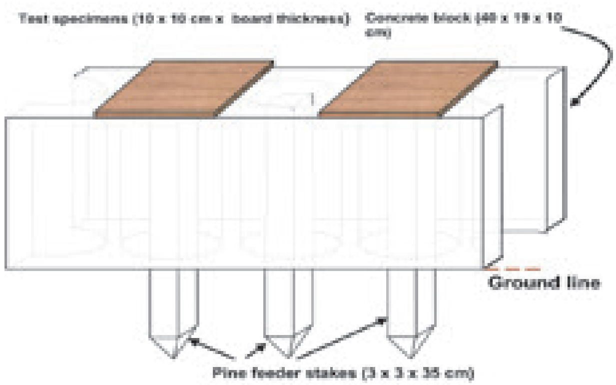



Fig. 1. Installation details of specimens and feeder stakes in the Living Sphere Simulation Field (LSF) of RISH, Kagoshima, Japan.

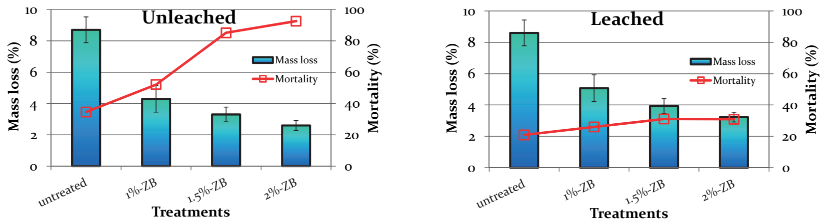



Fig. 2. Mean mass loss (%) and morality (%) of zinc borate –incorporated particle boards after exposure to *Coptotermes formosanus* for 3 weeks in the laboratory conditions.

ble enough, even in protected above ground conditions, if they are used without protective treatment, with the exception of MDF. MDF displayed high natural durability and might be used under less hazardous conditions based on 7-year exposure data. Post treatment with ACQ and CA at the retention levels tested significantly enhanced termite resistance of SWP, HWP, OSB and PB but failed full protection at the end of 84 months period.

While zinc borate incorporation retentions tested in this experiment were successful to protect PBs from decay damage for 84 months, higher than 2% w/w retentions are needed to provide full protection against termite activity under protected above ground conditions in southern Japan.

WPCs used regardless of formulation, wood particle size, surface grooving and zinc borate content shoved greater resistance to decay activity during exposure period with the exception of last 18 months where even the ZnB embedded formulations started to exhibit reducing decay ratings. It is clear that ZnB retentions slow down termite damage even in higher wood content formulations, higher ZnB retentions (above 1% w/w) are required for better protection.

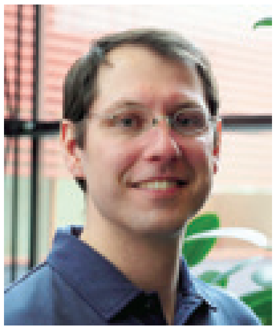
While a visiting professor, I was able to share my research interest on wood preservation and biodeterioration to graduate students from Japan and Indonesia. I gave a seminar before faculty of RISH on September 21, 2016 entitled "Long-term field test performance of treated wood-based and wood-plastic composites (WBCs and WPCs)". After my presentation, I received many interesting questions and input which encourages me to take my study to further stage.

I would like to extend my sincerest thanks to my host Yoshimura-Sensei for his time, interest and very warm hospitality during my stay. I am also thankful to Yanagawa-Sensei, Umemura Sensei, Yang Sensei for interesting discussions and help during my sabbatical term. Finally, I would like to thank all laboratory personnel including staff members Mr. Akio Adachi, Ms. Kaori Sunagawa, Ms. Kyoko Inoue and Mr. Hajime Sorimachi and graduate students Ms. Ono Kazuko, Mr. Sukma Kusuma, Mr. Khoirul Himmi, Ms. Munadian Musalam and Mr. Didi Tarmadi who were always there when I needed help in or out of the lab.

**=Oversears Visiting Scholar=**

## Insights during visit to RISH summer of 2016

Principal Scientist David Sandquist
VTT Technical Research Centre of Finland



To be invited and being able to come as a visiting researcher to RISH and Japan has truly been one of the highlights of my career so far. The width and depth of research covered at RISH and the University of Kyoto is staggering. And in the field of wood science it is truly world class. There are few other scientific centers or clusters in the world that can measure up to the scope of activities spanning wood anatomy, microbiology, material science, chemistry and physics. It is truly humbling to experience.

Japan is also still rich in one of the modern era's scarcest commodities - time. I have experienced a tremendous amount of generosity in scientists of all levels sharing their insights and expertise during my visit. My experience is that this permeates not just academia, but all of Japanese society. Not only is there a feeling of treasuring time, but also of making, keeping and storing time. This together with the breath of interdisciplinary research right across the University of Kyoto is something truly special.

On a global scale, there is a pressing need to replace our oil-based plastics with more environmentally sound options. The plastics that we are currently using contribute significantly to the global carbon dioxide emissions, and break down incredibly slowly in nature, causing problems for life on land and in water. Approximately half of all life in the world oceans has disappeared over the last 40 years (Tanzer et al., 2015), and it is now estimated that by the year 2050 there will be more plastics than fish in the world oceans (Neufeld et al., 2016).

There are alternatives available as replacements, such as biopolymers and natural fiber. Unfortunately, commercial success has so far been hampered by uncompetitive mechanical performance of these materials. This is rapidly changing however, as both nanocellulose and wood fiber composites are now starting to make an entry in the market. However, there is still a need to improve the process and production methods for these materials, and improve their interface performance.

During my time at RISH I have focused on investigating the architecture and interfaces of new cellulose structures, in an effort to improve cellulose biocomposite performance. To characterize these materials, I have focused a lot of my time at RISH on high resolution tomography of different cellulose materials and composite materials (see Figure 1). These tomographic results will be correlated with solid state NMR results and SEM and AFM measurements in an effort to elucidate the interactions at a super molecular and fibrillary level. Tomography can yield the overview, complemented by SEM, AFM and NMR which can give increasing levels of details. Much of my work at RISH has revolved around how to prepare these materials for imaging and analysis, without instruction of artifacts.

A tremendous personal treat was that my wife and daughter were able to join me for part of my time in Japan. During the summer we traveled extensively around the Kinki region of Japan. To be able to experience Japan first hand together with them and finding new favorites almost daily is a treasured experience for all of us. I think that my young daughter summarized it best when she said "Daddy, can we not take Japan with us home to Sweden"?

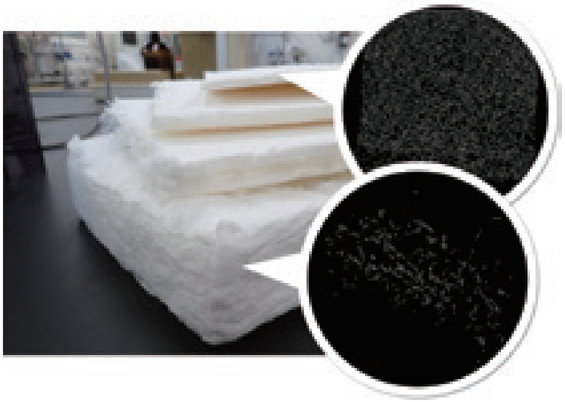


Figure 1. Wood fiber based fiberfoams of decreasing densities, showing two tomography scan (μCT) cross sections. Along with the effects of densities, the influence of different levels of nanocellulose on the architecture and interfaces has also been investigated.

Neufeld, L., Stassen, F., Sheppard, R., Gilman, T., 2016. The New Plastics Economy: Rethinking the Future of Plastics, in: World Economic Forum.

Tanzer, J., Phua, C., Jeffries, B., Lawrence, A., Gonzales, A., Gamblin, P., Roxburgh, T., WWF (Organization), Zoological Society of London, 2015. Living blue planet report species, habitats and human well-being. WWF International, Gland, Switz.

**=RISH Mission Research Fellow=**

## Field measurements to elucidate forest methane dynamics

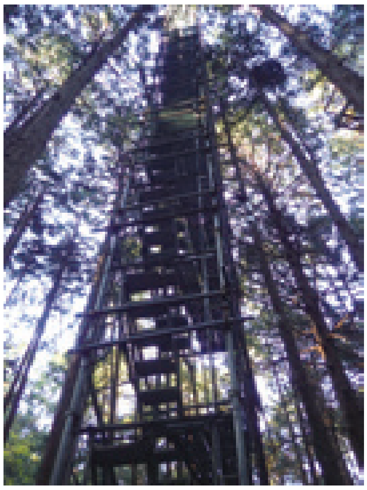
Dr. Ayaka Sakabe

Methane ($CH_4$) is an important greenhouse gas that despite its low atmospheric abundance, accounts for approximately 32% of global radiative forcing, because it has about 30 times the global warming potential of $CO_2$ over a 100-year time horizon (Intergovernmental Panel on Climate Change, 2013). Therefore, sinks and sources of $CH_4$ must be identified and accurately quantified, and we need a better understanding of the processes that control their dynamics.

Soils play important roles as $CH_4$ sources and sinks. $CH_4$ is produced in anoxic environments, including submerged soils such as wetlands and paddy fields, by methanogenic bacteria during the anaerobic digestion of organic matter. On the other hand, $CH_4$ is oxidized by methanotorophic bacteria in water-unsaturated soils. Above all, forest soils are recognized as the most efficient sinks for atmospheric $CH_4$, because of their $CH_4$ oxidation capacity in water-unsaturated soil (Le Mer and Roger, 2001). However, studies have revealed that forest ecosystems, especially in wet climates, are not always $CH_4$ sinks. Wetlands often occur in riparian areas within forests, and some water-unsaturated forest soils could be a $CH_4$ source when soils become water-saturated following precipitation events. The $CH_4$ dynamics in whole-forest ecosystems are still poorly understood because of insufficient $CH_4$ gas exchange (flux) measurements in the field.

The main $CH_4$ flux measurement techniques are the chamber method and the micrometeorological methods. The former is a more traditional method for measuring $CH_4$ flux on small spatial scales (usually less than 1 $m^2$). The chamber technique is useful for examining the influence of environmental conditions on $CH_4$ flux at the local scale, but has poor spatial representation when estimating ecosystem-scale flux in heterogeneous terrain such as $CH_4$ dynamics in a forest. Micrometeorological methods measure net vertical turbulent $CH_4$ fluxes between the atmosphere and surface (vegetation and soil). These fluxes represent the integrated net fluxes from the landscape upwind of the measurement point. Micrometeorological methods have advantages over the chamber method in that they are ideally suited for continuous ecosystem-scale flux measurements integrated over a larger area without artificial disturbance.

We examined the $CH_4$ dynamics in a temperate forest in Shiga Prefecture, which included wet areas along riparian zones within the watershed. In order to reveal the spatiotemporal variations in $CH_4$ fluxes, we combined multipoint plot-scale $CH_4$ flux measurements using chamber methods and ecosystem-scale $CH_4$ flux measurements using a micrometeorological method, the relaxed eddy accumulation (REA) method (Businger and Oncley, 1990). The chamber measurements in both the wet areas and the water-unsaturated forest floor showed that the wet areas had a greater spatial and temporal variability of $CH_4$ fluxes than the forest floor. Hotspots of $CH_4$ emissions were observed during summer and fall, immediately after intensive precipitation in the wet areas. On the other hand, on the forest floor, $CH_4$ absorption increased at some measurement plots in spring before intensive summer rainfall. The watershed-scale $CH_4$ budget estimated from chamber measurements showed that the forest turned into a $CH_4$ source during the summer owing to the high and variable $CH_4$ emissions from the wet areas. The REA ecosystem-scale $CH_4$ flux measurements also revealed that a temperate monsoonal forest switched seasonally between being a sink and source of $CH_4$. $CH_4$ fluxes tended to be a source during summer and fall. The results show that the temperate forest containing a riparian zone acts as a $CH_4$ source seasonally through increased $CH_4$ emission in the wet areas, and/or decreased $CH_4$ absorption on the water-unsaturated forest floor in response to changing soil temperatures and/or the soil water status. Overall, our results indicated that $CH_4$ emissions from small riparian areas are important in controlling forest $CH_4$ dynamics at a watershed scale. We have also started these measurements in tropical and boreal forest to further elucidate forest $CH_4$ dynamics.

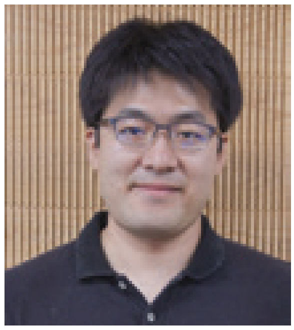


Flux measurement tower 30 m high

=RISH Mission Research Fellow=

## Development of techniques for highly controlled chemical treatment in wood flow forming

Dr. Soichi Tanaka



Recently there has been considerable interest in chemical treatment techniques required for the flow forming of wood. In the wood flow-forming process, bulk wood is processed and compacted, and then flowed into a mold to create a chosen form. To obtain a stable compact, it is necessary to introduce a chemical substance into cell walls in raw wood materials before the forming process. The chemically treated compact (**Fig. 1**), however, can still have color changes and roughness on its surface, and its dimensions may be unstable. This is because there might exist many cells that were not chemically treated (macroscopic irregularity) and large unstable areas in the amorphous region of the cell wall (microscopic irregularity).

Microscopic irregularity has received little attention, even though it has been studied for many years. This problem is in common with most wood and wood-based materials. In the liquid-phase chemical treatment, a chemical solution is impregnated into the wood block, and the solvent is then subsequently evaporated from it. After the impregnation process, it was supposed that microscopic irregularity existed in the amorphous region of cell walls due to solvent remaining there. During solvent evaporation, called the conditioning process, this

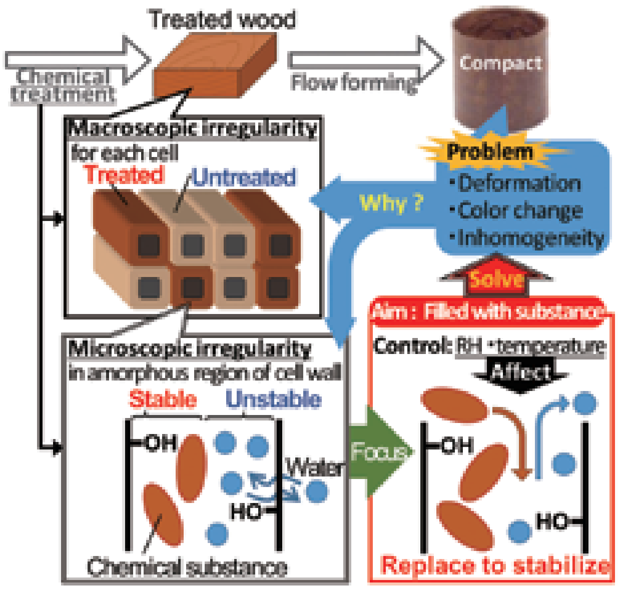



**Fig. 1** Schematic diagram of this research.

irregularity was supposed to decrease as the chemical substance diffused into cell walls to replace the solvent in the unstable area. This diffusion is caused by a higher concentration of chemical substances in cell cavities than in cell walls, which is due to the higher evaporation rate of solvent from the cavities (Stamm 1956). The evaporation rate is related to atmospheric conditions such as relative humidity (RH) and temperature. The decrease in the irregularity, or the diffusion of chemical substance to cell walls, therefore, was expected to be promoted by manipulating the atmospheric state.

In our previous studies (Tanaka et al., 2015 and 2016), we confirmed that the RH affects the amount of chemical substance in cell walls, or the irregularity of the amorphous region, when polyethylene glycol and water were employed as the chemical substance and solvent, respectively. A theoretical approach suggested that the amount of chemical substance diffused into cell walls would be increased by an increase in the difference in concentration of the chemical substance between cell cavities and cell walls, and by increasing the diffusivity of the chemical substance into cell walls. It was also suggested that the amount of chemical substance after impregnation is smaller than that after well-controlled conditioning. These findings indicate that the conditioning process, as well as the impregnation, is quite important to decreasing microscopic irregularity. Further study is necessary to clarify the effect of temperature on the diffusion of chemical substance into cell walls. To apply this study to practical usage in the wider wood and wood-based materials, as well as in flow-formed wood, it will also be necessary to clarify the effect of conditioning when a thermoplastic or thermosetting resin, or inorganic compound, is employed as the chemical substance.


Stamm A.J. Dimensional stabilization of wood with carbonwaxes, *Forest Prod. J.* **6**, 201–204, 1956

Tanaka S., Seki M., Miki T., Shigematsu I., Kanayama K., Solute diffusion into cell walls in solution-impregnated wood under conditioning process I: effect of relative humidity on solute diffusivity, *J. Wood Sci*. **61**, 543–551, 2015

Tanaka S., Seki M., Miki T., Shigematsu I., Kanayama K., Solute diffusion into cell walls in solution-impregnated wood under conditioning process II: effect of solution concentration on solute diffusion, *J. Wood Sci*. **62**, 146-155, 2016


## List of International MOU in FY2016

| No. | Institution | Country |
|---|---|---|
| 1 | Nanjing Forestry University | China |
| 2 | Centre de Recherches sur les Macromolécules Végétales, Centre National de la Recherche Scientifique (CNRS) | France |
| 3 | National Institute of Aeronautics and Space of the Republic of Indonesia (LAPAN) | Indonesia |
| 4 | School of Biological Sciences, Universiti Sains Malaysia | Malaysia |
| 5 | VTT Technical Research Centre of Finland | Finland |
| 6 | Zhejiang Agriculture and Forestry University | China |
| 7 | Centre for Research in Earth and Space Science (CRESS), York University | Canada |
| 8 | College of Atmospheric and Geographic Sciences, University of Oklahoma | USA |
| 9 | National Atmospheric Research Laboratory (NARL), Department of Space, Government of India | India |
| 10 | Institute of Mathematics and Informatics, Bulgarian Academy of Sciences | Bulgaria |
| 11 | Southwest Forestry University | China |
| 12 | College of Planning and Design, National Cheng Kung University | Taiwan |
| 13 | Faculty of Foresty, Tanjungpura University | Indonesia |
| 14 | Research Center for Biomaterials, Indonesian Institute of Sciences (LIPI) | Indonesia |
| 15 | Faculty of Science, Chulalongkorn University | Thailand |
| 16 | University of Riau | Indonesia |
| 17 | College of Forest and Environmental Sciences, Kangwon National University | Korea |
| 18 | Research Institute for Human Settlements, Agency for Research and Development, Ministry of Public Works | Indonesia |
| 19 | Faculty of Civil Engineering and Planning, Islamic University of Indonesia | Indonesia |
| 20 | Material Science and Engeneering College, Northeast Forestry University | China |
| 21 | Faculty of Mathematics and Natural Sciences, Andalas University | Indonesia |
| 22 | Indian Institute of Geomagnetism (IIG) | India |


**The Committee of International Academic Exchange**
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