Tokyo Prince Hotel:
Tokyo, Japan, June 8-10, 2015

MuOGRaPhers

MUON-OPTICS-GEONEUTRINO-RADAR-PHOTONICS for Earth Studies

x nature café

Program & Abstracts

tokyo japan

Program Overview

Pre-Conference　開会シンポジウム

Monday June 8, 2015 (2015 年 6 月 8 日)@Hungarian Embassy Tokyo (駐日ハンガリー大使館), 2-17-14 Mita, Minato, Tokyo 108-0073

9:30	***Registration*（ご登録）**
10:00-10:15	***Greetings*（ご挨拶）** - Dr. István Szerdahelyi, Ambassador of Hungary to Japan - Mr. Makoto Katsura, Ambassador for S&T Cooperation of MOFA - Dr. Leonidas Karapiperis, Minister-Counsellor, Head of S&T Section at the Delegation of the EU to Japan (TBC) - Prof. Hiroaki Aihara, Vice President of The University of Tokyo
10:15-11:15	***Plenary*（基調講演）** - R&D Funding in Hungary and in the EU, Horizon 2020 (TBC) Ms. Szonja Csuzdi, head of department, Department for International Affairs, National Research, Development and Innovation Office of Hungary (NRDIO) (20 min.) - Wigner RCP and our Activity in HORIZON2020 Prof. Peter Josef Levai, Director General of the MTA WIGNER Research Centre for Physics Budapest, Hungary (20 min.) - Particle Physics and Earth Sciences Prof. Hiroyuki Tanaka, Professor of High Energy Particle Geophysics at The University of Tokyo(20 min.)
11:15-11:30	***Signing Ceremony*（調印式）** (University of Tokyo ERI - MTA WIGNER Research Centre for Physics) -Prof. Peter Josef Levai, Director General of the MTA WIGNER Research Centre for Physics -Prof. Kazushige Obara, Director General of the Earthquake Research Institute, The University of Tokyo
11:30-12:30	***Reception*（レセプション）**

Main Symposium　シンポジウム

Tuesday June 9, 2015 (2015 年 6 月 9 日)@Tokyo Prince Hotel (Hou-ou-no-ma 鳳凰の間), 3-3-1 Shibakoen, Minato, Tokyo 105-8560

9:00-	***Registration***（ご登録）
10:00-10:30	***Greetings***（ご挨拶） -Prof. Kazuo Hotate, Executive Vice President of The University of Tokyo -Mr. Norifumi Ushio, Director of Scientific Research Institutes Division, MEXT -Prof. Hiroo Fukuda, Dean of School of Science, The University of Tokyo -Prof. Kazushige Obara, Director General of Earthquake Research Institute, The University of Tokyo
10:30 -12:30	***Plenary***（基調講演） -Scientific Visualization and Telemetry with a HEP Flavour from Hungary Prof. Peter Josef Levai (30 min.) -Muon Tomography - Monitoring Carbon Storage Prof. Jon Gluyas (30 min.) -The World Visualized by Electromagnetic Waves（電波で見る世界） Dr. Toshio Iguchi (30 min.) -Development of Microwave Sensors onboard UAV and Microsatellites for Visualization of Earth Environmental and Its Applications Prof. Josaphat Tetuko Sri Sumantyo (30 min.)
12:30-13:30	***Lunch Break***
13:30-14:45	***Public Lecture***　（竹内薫講演会） - Reason why we can Look through a Volcano with Muons （ミュオンで火山が透視できるワケ） Dr. Kaoru Takeuchi (75 min.)
14:45-15:00	***Coffee Break***
15:00-18:00 15:00-15:15 15:15-15:25 15:25-15:35 15:35-15:45 15:45-15:55 15:55-16:40 16:40-17:00	***Nature Café*** Opening -Looking through a Volcano（火山を透視する）Prof. Hiroyuki Tanaka -Geoneutrinos to Visualize the Earth（地球ニュートリノ観察による地球の可視化）Prof. Kunio Inoue -Phased Array Radar to Vizualize Thunderstorms（積乱雲を可視化するフェーズドアレイレーダ） Prof. Tomoo Ushio -Looking through the Fukushima Daiichi Nuclear Power Plant（福島第一原発の透視） Prof. Mitsuhiro Nakamura -Panel Discussion Part1 -Coffee Break -Panel Discussion Part2 Closing Remarks

17:00-17:45 17:45-18:00	
18:00-20:00	***Poster*（ポスター）**

Workshop　ワークショップ

Wednesday June 10, 2015（2015 年 6 月 10 日）@Tokyo Prince Hotel (Suehiro 末広), 3-3-1 Shibakoen, Minato, Tokyo 105-8560

9:30-10:00	Registration
(10:00-12:00) 10:00-10:20 10:20-10:40 10:40-11:00	Session I-Land-based Remote Sensing - Visualizing Lightning by Dr. Michael Stock - Field Observation of Lifecycle of Cumulonimbus Clouds in the Tokyo Metropolitan Area (LCbEX) by Dr. Koyuru Iwanami - Performance of Adaptive Digital Beamforming with MMSE Technique for Polarimetric Phased Array Weather Radar by Dr. Hiroshi Kikuchi
11:00-11:20	Coffee Break
11:20-11:40 11:40-12:00	- Multi-parameter weather radar observation and direct measurement for precipitation （偏波レーダーによる降水観測と直接観測）by Dr. Katsuhiro Nakagawa - Development of X-band Active Phased Array Weather Radar by Dr. Satoshi Kida
12:00-13:00	Lunch Break
(13:00-14:00) 13:00-13:20 13:20-13:40 13:40-14:00	Session-II-Satellite and Airborne Remote Sensing - Global Precipitation Measurement (GPM): More Accurate and More Frequent Space-Borne Precipitation Observations by Dr. Takuji Kubota - Realtime Monitoring of Active Volcanoes using Infrared Images from Satellites and Analyses of Eruption Sequences by Dr. Takayuki Kaneko -Aeromagnetic Survey by Using Unmanned Helicopter by Dr. Takao Koyama
14:00-14:20	Coffee Break
(14:20-16:40) 14:20-14:40 14:40-15:00 15:20-15:40 15:40-16:00 16:00-16:20 16:20-16:40	Session-III-Muography - Gaseous Detectors for Cosmic Muography Measurements by Dr. Dezső Varga - Data Acquisition System for Portable Detectors by Dr. Gergő Hamer - Application of Portable Tracking Detectors for Muography by Dr. Oláh László - Muography of the Shallow Part of Stromboli (Italy) by using Nuclear Emulsion Detector by Dr. Seigo Miyamoto - Nuclear Emulsion Technologies for Muography by Dr. Kunihiro Morishima - Muography of Volcanoes with Nuclear Emulsions by Dr. Ryuichi Nishiyama
(16:40-17:00) 16:40-17:00	Session-IV-Geoneutrino Technology -Geo-neutrino Technology by Dr. Hiroko Watanabe

Scientific visualization and telemetry with a HEP flavour from Hungary

Peter Levai
MTA Wigner Research Centre for Physics, Budapest, Hungary

In my talk I will give an overview on the activities of the research groups at Wigner RCP, related to particle physics, gravitation, fusion research, space science, and geophysics, focusing on visualization and telemetry. Our institute is one of the largest research center of the Hungarian Academy of Sciences and we participate in many international collaborations, including CERN in high energy physics, EGO VIRGO in gravitational wave research, ITER in fusion research, ESA in space science. In parallel we have started special collaboration in seismology to contribute to the Einstein Telescope project in its site-selection activity and in geology to contribute to different studies in the exploration of geological structures. In most of the above cases high energy physicists are working together with the experts of the given fields to accomplish an interesting and cutting-edge research plan.

Visualization and telemetry can not be performed without the application of latest developments in information technology, data collection, data transfer, and data mining. CERN projects demand the continuous improvement of recent protocols; in parallel we can apply these latest results successfully on other fields, also. Space science also ignites lots of development, because the long fly-by period of the robotic space crafts and the large distance from their landing activity really request the application of cutting-edge technologies at their construction. The Wigner RCP participated in the very successful Rosetta mission of ESA, which has served already lots of surprising results, however it displayed the recent limits of emerging technologies, also. In my talk I will comment these results and the difficulties from the point of view of a high energy physicist.

Muon tomography - monitoring carbon storage

Jon Gluyas[2], Lee Thompson[1], Dave Allen[3], Chris Benton[4], Paula Chadwick[3], Sam Clark[2], Max Coleman[5], Joel Klinger[1], Vitaly Kudryavtsev[1], Cathryn Mitchell[4], Sam Nolan[3], Sumanta Pal[1], Sean Paling[6], Neil Spooner[1], David Woodward[1]

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[6]*Boulby Underground Science Facility, Boulby Mine, Loftus, Cleveland, TS13 4UZ, UK*

Humankind must reduce emissions of greenhouse gases if we are to slow climate change. However, fossil fuels are the mainstay energy source for the world's economy. Their replacement by renewable energy sources will not happen quickly and therefore in the interim we need to capture emitted carbon dioxide and store it deep beneath the earth in porous rocks.

Monitoring such carbon storage sites to ensure the distribution of injected carbon dioxide is known will form a critical part of the storage process. As of today the main methods available require active signal generation and are episodic. Muon tomography offers the opportunity of continuous passive monitoring. Signal generation is also free in muon tomography but expensive with other technologies.

Muon transport simulation has delivered results which indicated that injected carbon dioxide could be tracked at typical storage depths by placing detectors beneath storage sites. This requires that instruments be deployed in deep horizontal boreholes beneath injection sites where pore fluids may be at temperatures of around 70deg C and highly saline.

We have built prototype detectors which could be deployed in such boreholes and are currently testing them within boreholes drilled into salt in the Boulby Deep Mine, Palmer Lab facility some 1km below the surface at Boulby in NE England. Successful deployment, detection of muons and retrieval here will lead to testing in a deep onshore borehole and ultimately an offshore setting in a true storage environment.

Demonstrated success could save the embryonic carbon capture and storage industry billions of dollars in monitoring costs around the globe.

電波で見る世界

Toshio Iguchi

National Inatitute of Information and Communication Technology

情報通信研究機構の電磁波計測研究所では電波を使っていろいろなものの様子や中身を調べる研究を行っています。とくに、自然環境の重要な要素である雨、雲、風などを広範囲にわたって観測する手法や、大気中の微量成分を測定する技術など、リモートセンシングにかかわる研究に力を入れています。また、より高い周波数の電波を用いて、例えば、絵画の下絵や塗装の下の腐食などを、そのものに触れることなく中の様子を調べる非破壊センシング装置の開発も行っています。これらの技術は、電波と対象物との相互作用の結果として得られる電波を測定して対象物の存在や性質を調べるものですが、測定された電波に含まれる情報を可視化することにより、その技術が利用しやすくなり、一般に広く受け入れられることにつながります。本講演では、こうした技術で得られた情報の可視化を実例を示して紹介します。

地球環境可視化用マイクロ波センサ搭載無人航空機と小型衛星の開発とその応用

Development of Microwave Sensors onboard UAV and Microsatellites for Visualization of Earth Environmental and Its Applications

Josaphat Tetuko Sri Sumantyo

Center for Environmental Remote Sensing, Chiba University

Recently, Chiba University develops two microsatellites called GAIA-I (50 kg class) and GAIA-II (100 kg class). GAIA-I payload is GNSS Radio Occultation (GPS-RO) sensor and Electron Density - Temperature Probe (EDTP) for Ionosphere monitoring, and GAIA-II payload is Circularly Polarized Synthetic Aperture Radar (CP-SAR) for global land deformation monitoring to visualization of Earth environment. This talk will introduce the progress of its development, research networking and applications for visualization of Earth environment.

現在、千葉大学が地球環境の可視化を目的として、電離層の物理現象観測用の掩蔽GPS（GNSS-RO）及び電子密度・温度測定器（EDTP）搭載のGAIA-I小型衛星（50kgクラス）と、グローバル地殻変動観測用の円偏波合成開口レーダ（CP-SAR）搭載のGAIA-II小型衛星（100kgクラス）を開発している。また、様々なセンサの地上実証実験のために、無人航空機JXシリーズの開発も行っている。本講演では、この研究開発の進捗状況、研究ネットワーキング、地球環境の可視化への応用等を紹介する。

ミュオンで火山が透視できるワケ

Kaoru Takeuchi

そもそもミュオンって何だろう？　素粒子の一種？　そんな小難しいものが火山と何の関係がある？

この講演では、そんな素朴 な疑問を出発点に、素粒子としてのミュオンに馴染んでもらい、ミュオンで火山や建造物などを「透視」する仕組みである「ミュオグ ラフィ」が X 線レントゲン写真撮影の限界を超える夢の技術になり得たわけを誰にもわかりやすく説明します。

近年、御嶽山の噴火による被害などを受け、日本の火山の観測体制の見直しが叫ばれています。ミュオグラフィがすぐに火山の噴 火「予知」や警報発令に使えるわけではありませんが、将来的に、ミュオグラフィが人命を救うために活用される可能性にも触れる予 定です。

火山を透視する

Hiroyuki Tanaka

Earthquake Research Institute, The University of Tokyo

ミュオグラフィは 2006 年、火山の透視に世界で初めて成功して以来、X 線が撮影できるサイズの限界を超える夢の技術として世界中の注目を集めてきました。 しかし、そこには解決すべき問題も残されていました。

従来は望遠鏡の感度が低く、1 枚の透視像を得るのにひと月以上かかっていたのです。以来、東京大 学はこの問題に取り組み続け、2013 年、背景雑音を大幅に低減したミュオグラフィ望遠鏡の開発に成功しました。その後、鹿児島県の薩摩硫黄島を対象に 行われたテスト観測では、噴火に連動した、火山内部のマグマの動きを３日に１枚の透視スナップショット画像として捉えることに成功しました。

3 日の時 間分解能で火山浅部のダイナミクスを透視可視化したのは世界で初めてのことです。

地球ニュートリノ観測による地球の可視化

Kunio Inoue

Research Center for Neutrino Science, Tohoku University

ニュートリノは天体すら容易に通り抜けることができます。

地球内部では地熱の生成に付随して大量のニュートリノが作り出されており、この地球ニュー トリノの最大の観測装置が東北大学のカムランドであり、1000 トンの液体シンチレータを用いています。

等方的な発光特性をもつ液体シンチレータではニュー トリノの到来方向がわからず、単独の装置での地球の『可視化』は不可能と考えられていましたが、高感度撮像装置と特殊な液体シンチレータの組み合わせ で地球ニュートリノの方向を再構成できることが見出され、その開発が精力的に行われています。

積乱雲を可視化するフェーズドアレイレーダ

Tomoo Ushio

School of Engineering, Osaka University

夏季の夕方に、突然の大雨、ゲリラ豪雨に遭遇されたことのある方も多いのではないでしょうか。

　このゲリラ豪雨は、河川の氾濫，鉄砲水などをもたらし、都市の機能を麻痺させ，時には人命にも関わります。こうしたゲリラ豪雨を生む積乱雲を高速に３次元可視化するレーダリモートセンシングについて本講演 では取り上げます。特に、大阪大、東芝、NICT が共同で開発を行った世界最高性能のフェーズドアレイ気象レーダを中心として、その背景、観測されたデー タなどを通じて、災害に強い、安心安全な未来の社会像を紹介したいと思います。

福島第一原発の透視

Mitsuhiro Nakamura

Graduate School of Science, Nagoya University

The situation of the visualization of the inner state of Fukushima Daiichi by muon will be reported. Mainly I will report about the trials for reactor No.2 using Nuclear Emulsions.

名古屋大学の原子核乾板技術を応用した、ミュオグラフィを東京電力福島第一原子力発電所２号機の原子炉に適用して、内部を透視しました。これにより、２号機の透視画像の炉心領域の物質量は、健全な燃料が現在も炉内に存在する５号機よりも少ないことが判明しました。その結果、シミュレーションで示唆されてきた炉心溶融が実際に起こっていることが裏付けられました。

Muographic Imaging of Tropospheric Dynamics

Taro Kusagaya[1,*], Hiroyuki K. M. Tanaka[2]

[1] *Dept. of Earth and Planetary Science, The University of Tokyo*

[2] *Earthquake Research Institute, The University of Tokyo*

Muography has been mainly applied to volcanoes for imaging their internal density structure so far. However, the intensity of cosmic ray muon is affected not only by the density structure of the target such as a volcano but also by the density of atmosphere. When atmosphere becomes lighter, the intensity of cosmic ray muon becomes higher because the low-energy muons do not lose their energy so much that they can reach the ground without decay. Therefore, measuring the intensity of cosmic ray muons directly arriving from sky might be useful for understanding tropospheric dynamics.

In this work, we performed a time sequential muography of atmosphere in southwestern Kagoshima, Japan. The muographic images showed the correlation with air temperature variation. We found that our muographic data were correlated with the near-ground surface temperature data published by JMA (Japan Meteorological Agency).

Based on these results, we compared our data with high altitude temperature data. We show that muogprahy has a potential to monitor atmospheric dynamics that might be useful for the short-term weather forecasting.

Very Long Range Muography for Hazardous Volcanoes

Taro Kusagaya [1,*], Hiroyuki K. M. Tanaka[2]

[1] *Dept. of Earth and Planetary Science, The University of Tokyo*

[2] *Earthquake Research Institute, The University of Tokyo*

Muography gives us a tool to remotely observe a hazardous erupting volcano. However, practical muography of a distant volcano is difficult due to background noises such as electromagnetic particles. Therefore conventional muography has been performed in the vicinity of a volcano crater (~1 km) to reduce background noises and improve the muographic imaging by using volcano as a shield of electromagnetic particles. Here, we created a muographic image right beneath the crater floor of the Shinmoe-dake volcano, Japan by the up-to-date muography telescope that was located at 5 km from the peak. The Shinmoe-dake volcano commenced to erupt on January 19, 2011, and the emitted lava almost completely filled inside the crater. After that, the topography inside the crater completely changed. The resultant muographic image showed a low-density region beneath the newly formed crater floor that indicates the existence of a void. We anticipate that our novel muography will be a practical tool for remote monitoring and predicting an eruption sequence in the future.

Stroboscopic Muography of Sakura-jima Volcano

Taro Kusagaya[1,*], Hiroyuki K. M. Tanaka[2], Takao Ohminato[2]

[1] *Dept. of Earth and Planetary Science, The University of Tokyo*

[2] *Earthquake Research Institute, The University of Tokyo*

Sakura-jima volcano is one the most active volcanoes in Japan and has been activated since 2009. The recent eruptions count one thousand times per year. We performed stroboscopic muography in Sakura-jima in order to take an integrated image of the moment of eruptions. The detector was placed 2.8 km SSW from the peak of the volcano, and the muon events have been recorded for 6 months. During the observation period, we counted 600 eruption events at the Showa crater of the volcano. We will report a preliminary result of the measurements.

Tomographic modeling of muographic data with the Radon transform technique

Shogo Nagahara [1,*], Taro Kusagaya [1], Hiroyuki K. M. Tanaka[2]

[1] *Dept. of Earth and Planetary Science, The University of Tokyo*

[2] *Earthquake Research Institute, The University of Tokyo*

Muography offers us an inner density structure of an object by using cosmic ray muons. In general, the longer time we observe, the more accurate structure we can obtain. In previous research, the 3-dimensional density structure was obtained by using muography. However, in that study, some foresight information was required such as the object's geometry, bulk density and heterogeneity. So we considered utilizing the Radon transform for muography. Radon transform is used for X-ray CT (Computed Tomography) in the medical field. It offers us the 3-dimensional image without foresight information while it was required for the conventional muography. In this method, many stations are required to obtain the high-resolution result of 3-dimensional image. But there are only several muography telescopes and the finite observation period. Therefore, there is a trade-off between the number of station and the period per one observation. So we developed the quantitative evaluating method to optimize an observation plan.

In the present work, we assumed that we had only one telescope and the observation period was one year in total. And we simulated Radon transform for various combinations of stations. We compared the RMS (root mean square) value of the residuals between the original structure and the reconstructed structure to grasp the overall trends of structure.

As a result of the quantitative evaluation, RMS value took a minimum when the number of station was 64. The reconstructed structure with 64 stations was the best visual comparison with the other 3-dimensional images. So it is considered that RMS value is useful to grasp the overall trends.

However, we cannot evaluate the shape of the reconstructed structure and the smallest resolvable structure by RMS value because the value involves all the data points of the reconstructed structure. In the future, we will develop the method to evaluate the geometry of reconstructed structure and resolution by putting small structures in the original structure.

Muography using nuclear emulsion detector

Akira Nishio, Kunihiro Morishima, Masaki Moto, Toshiyuki Nakano, Mitsuhiro Nakamura
Nagoya University

Muography using nuclear emulsion detector has advantages of flexibility to adapt to various environments. The emulsion films, which is a kind of photographic film, are lightweight, compact and need not electrical power supply. This is the reason to be used our detector in volcanoes, nuclear reactors and so on.

In Nagoya University, we launched nuclear emulsion manufacturing equipment at 2010. It has become possible to flexible development of our detector. Recent development of nuclear emulsion detector and its applications will be presented.

Development for Anti-Neutrino Directional Measurement Ⅰ,Ⅱ

Y.Shirahata, T.Takai, S.Ishio, K.Inoue, T.Mitsui,
H.Watanabe, K.Ishidoshiro, H.Ikeda
RCNS, Tohoku Univ.

Liquid scintillator (LS) detectors have a good sensitivity to low energy anti-neutrinos. On the other hand, unlike water Cherenkov detectors, LS detectors are not sensitive to direction of anti-neutrinos. Directional sensitive LS detector has possibility that it can reveal information that cannot be seen with other methods. For example, it will contribute to the better understanding of the Earth's interior using geo-neutrino flux measurement in kton scale detector, and there is possibility of application to reactor monitoring system in small size detector.

Anti-neutrinos are detected by inverse beta decay reaction and tagged by the delayed coincidence method (prompt signal is positron and delayed signal is neutron capture event) that provides a powerful tool to suppress backgrounds. Although the emitted neutron retains the directional information of the incoming anti-neutrino, current LS cannot identify the neutron capture point before it loses the information. Li-loaded LS has the ability to shorten the neutron capture range because of large neutron capture cross section (940barn cf. ^{1}H 0.3 barn) of ^{6}Li. To separate prompt and delayed points clearly, the optical discrimination of energy deposit point by high resolution imaging devices is also required. There are two types of imaging device candidates; lens array and reflection mirror.

The status of Li-loaded LS development and the design of lens array will be presented (I), and experimental study of proto type reflection mirror will be also reported (Ⅱ).

Visualizing Lightning

Michael Stock

Rairan Pte. Lte, Osaka University Lightning Research Group

Lightning is both a health hazard, and a valuable tool for monitoring and predicting the short term behavior of thunderstorms. Each lightning flash produces copious amounts of radio frequency radiation, which can be detected very far from the lightning flash. There are several techniques available which can determine where the lightning occurred if the radiation is recorded at a number of physically separated antennas. However, visualizing lightning offers many challenges because it spans many spatial and temporal length scales. A single lightning flash has a total duration of about 0.5 seconds, but processes within a flash can have durations as short as 1 µs. Flash rates in an electrically active storm can vary from 1 per minute to as high as several per second. A lightning flash is made up of channels which are highly branched. Each channel is approximately 1 cm in diameter, but will frequently extend 10-20 km from the flash origin. Further, different instruments sample different length scales of the lightning flash. Very low frequency measurements are effective at very large distances from a flash, but cannot detect the fine branching structure or time evolution of a flash. Very high frequency measurements are limited by line of sight, but can map out the branching structure and time evolution of a flash.

In this presentation, visualization techniques will be presented for short and medium range lightning mapping systems. Some of the visualizations are intended for scientists who are trying to understand the underlying physics of the lightning flash, and some for forecasters trying to ascertain the near term safety of a particular region.

Field Observation of Lifecycle of Cumulonimbus Clouds in the Tokyo Metropolitan Area (LCbEX)

Koyuru IWANAMI

National Research Institute for Earth Science and Disaster Prevention (NIED), JAPAN

Disasters caused by local heavy rainfall, tornadoes, hail, and lightning are serious social problems especially in urban areas in Japan. It is known that these phenomena are associated with developed cumulonimbus clouds (Cb). The understanding of development mechanism and development of prediction methods are needed for the reduction of these disasters.

National Research Institute for Earth Science and Disaster Prevention (NIED), Japan started field observation of lifecycle of Cb (Lifecycle of Cb Experiment: LCbEx I) in the Tokyo Metropolitan Area from 2011 using a Ka-band Doppler radar, two X-band polarimetric radars, and stereo photography, etc. A case study of early development stage of Cb was carried out with Ka-band Doppler radar data (Sakurai et al. 2012) and the thermodynamical retrieval using sector volume scan data by two X-band polarimetric radars at 1 to 2 min interval. Furthermore it was shown that the data assimilation of cloud liquid water content (latent heat) and potential temperature deviation had important effects to prediction of Cb development using cloud resolving model.

In 2013 and 2014, ten microwave radiometers, three Doppler lidars, and five Ka-band radars were additionally set up in the Tokyo Metropolitan Area covered by the X-band polarimetric radars for the observation of environment of cumulus clouds (Cu) initiation and Cb development, and cloud before precipitation. We can get information on water vapor, wind field in the clear air, and non-precipitating cloud, respectively. All data can be collected and processed in real-time in the NIED.

The field observation (LCbEx II) using these new remote sensors will be started from the summer season in 2015 for the understanding of development process including initiation of Cu and early stage of Cb development, precipitation formation process from cloud, and prediction of Cb development using an NWP model and data assimilation.

Performance of adaptive digital beamforming with MMSE technique for polarimetric phased array weather radar

Hiroshi Kikuchi[1,*], Takuro Tashima[1], Wu Ting[1], Gwan Kim[1], Tomoo Ushio[1], Hideto Goto[2] and Fumihiko Mizutani[2]

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We plan to develop a polarimetric phased array weather radar, which has a dual-polarized antenna with two-dimensional circular planar phase-array elements. It is capable of measuring the 3-D rainfall distribution in less than 10 or 30 seconds in a range of 20 or 60 km, respectively. A digital beam forming (DBF) method is one of the main components to determine an observation accuracy of the underdevelopment radar. This paper is focused on a DBF method for the under development radar. DBF is a signal processing method that makes a directional beam pattern. We proposed to apply minimum mean square error (MMSE) method. The planar phased array antenna is based on 6992 array elements that are placed in a circular shape. The interval of each element is 16 mm. Operating frequency of the radar is 9.4 GHz. We conducted a numerical simulation for precipitation measurements to evaluate an impact of a beamforming method. We compared estimation results with MMSE to those with the conventional DBF method such as Fourier beam forming (FR), to evaluate the effect on DBF. From the results, MMSE's performance was superior to DBF when comparing all polarimetric variables.

According to the operation of this radar, it requires a better understanding about the useful pulse numbers. When the antenna is rotary type, several tens of pulses are required for rapidly scanning. When the antenna is a fixed mount type, it is capable of using a large number of pulses (e.g. 128). A similar simulation was carried out with a differential number of pulses (i.e. 32 and 128) to consider design and operation of the radar for practical use. The results indicate that the number of pulses is almost independent of the estimated accuracies of MMSE. Considering design and operation of the radar for practical use, it is useful to be independent from the number of pulses with MMSE.

In this presentation, we will show the plan to develop the polarimetric phased array weather radar, the specifications and the results of a numerical simulation for precipitation measurements.

偏波レーダによる降水観測と直接観測

Katsuhiro Nakagawa

Applied Electromagnetic Research Institute,

National Institute of Information and Communications Technology (NICT)

情報通信研究機構が開発した沖縄偏波降雨レーダ（通称、COBRA）で観測した台風を可視化した様子や上空の雨の様子（雪、霰、雨がどのように分布しているか）を紹介するとともに、さまざまな観測機器を用いた直接観測の必要性、重要性について紹介したいと思います。

Multi-parameter weather radar observation and direct measurement for precipitation

Katsuhiro Nakagawa

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National Institute of Information and Communications Technology (NICT)

National Institute of Information and Communications Technology (NICT) developed the multi-parameter weather radar (COBRA, C-band Okinawa Bistatic RAdar). In this presentation, visualization of typhoon structure observed by COBRA will be presented. To compare and evaluate with the radar observation results, direct measurement is also very important. The direct measurement technique of precipitation will be presented.

Development of X-band Active Phased Array Weather Radar

Satoshi Kida and Masakazu Wada

TOSHIBA Co., Ltd.

In Japan especially in the urban area, the disasters caused by extreme weather are recently increasing and lives of citizen are at risk. Severe weather phenomena such as localized heavy rainfalls, gust and tornadoes are mainly caused by rapid growth of cumulonimbus clouds which grows more than 10 km attitude. Generally, lifecycle of a cumulonimbus cloud is short as 10 to 30 minutes. However, conventional weather radar system with parabolic antenna requires approximate 5 to 10 minutes for full volume scanning to observe three dimensional structure of a cumulonimbus cloud, which has inadequacy capability in temporal and spatial resolution for observing the behavior of cumulonimbus clouds. In order to achieve precise three dimensional observations of cumulonimbus clouds for predicting severe weather, weather radar is expected to observe the full volume of meteorological phenomena within 1 minute.

Toshiba have developed a technology for X-band active Phased Array Weather Radar (PAWR) with Digital Beam Forming (DBF). Toshiba's newly developed X-band PAWR has capability of observing cumulonimbus cloud within 1 minute. By using X-band PAWR, any changes in localized meteorological phenomena can be observed every 30 seconds or less. We can expect Phased Array Weather Radar system to be used for preventing disasters by forecasting localized heavy rainfalls, gust and tornadoes.

In this paper we describe the characteristics of this new-generation weather radar and its active phased array antenna. Also, we would like to show some of the example of heavy rainfall event in urban area captured by our phased array system.

Global Precipitation Measurement (GPM): More accurate and more frequent space-borne precipitation observations

Takuji Kubota

Earth Observation Research Center, Japan Aerospace Exploration Agency

The Global Precipitation Measurement (GPM) mission is an international cooperative project to achieve highly accurate and highly frequent global precipitation observations by satellites. The GPM mission consists of the GPM Core Observatory jointly developed by U.S. and Japan and Constellation Satellites that carry microwave radiometers and provided by the GPM partner agencies. The GPM Core Observatory was successfully launched at 3:37 a.m. on February 28, 2014 (JST).

The Dual-frequency Precipitation Radar (DPR) was developed by the Japan Aerospace Exploration Agency (JAXA) and the National Institute of Information and Communications Technology (NICT), and installed on the GPM Core Observatory. The DPR consists of two radars; Ku-band (13.6 GHz) precipitation radar (KuPR) and Ka-band (35.55 GHz) radar (KaPR). The DPR is expected to advance precipitation science by expanding the coverage of observations to higher latitudes than those obtained by the TRMM Precipitation Radar (PR), by measuring snow and light rain via high-sensitivity observations from the KaPR, and by providing drop size distribution (DSD) information based on the differential scattering properties of the two frequencies.

JAXA also develops the Global Satellite Mapping of Precipitation (GSMaP) product. The GSMaP produces high-resolution and high-frequent global rainfall map based on multi-satellite passive microwave radiometer observations with information from the Geostationary InfraRed (IR) instruments. The GSMaP near-real-time version product (GSMaP_NRT) has been in operation at JAXA since October 2008 in near-real-time basis, and browse images and binary data available at JAXA GSMaP web site (http://sharaku.eorc.jaxa.jp/GSMaP/). The GSMaP product is 0.1-degree grid for horizontal resolution and 1-hour for temporal resolution.

After the early calibration and validation of the products, all GPM standard products and the GPM-GSMaP product have been released to the public since September 2014. The GPM products can be downloaded via the internet through the JAXA G-Portal (https://www.gportal.jaxa.jp).

In this presentation, early results of the DPR and the GSMaP by the GPM mission will be shown, such as 3-dimentional precipitation structures of tropical cyclones and animation of the Baiu front from the global view.

Realtime monitoring of active volcanoes using infrared images from satellites and analyses of eruption sequences

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Eruption sequences of volcanoes, particularly in the medium to large scale activities, are generally complicated and consist of a series of eruption events. Although understanding of eruption sequences is important for considering disaster prevention measures, as well as scientific aspects of volcanoes, not enough researches have been done on this field, because of lucking uniform and sufficient datasets to be used for systematic comparative analyses. Database including wide variety of eruptive activities are necessary for understanding diversity of eruption sequences and their categorization, which will be the basis for more advanced studies on eruption sequences.

Satellites, being on the orbit circling the earth, can observe volcanic eruptions regardless of the areas, and collect eruptive information expeditiously. Using satellite data, we can build a database of eruption sequences efficiently. We have worked on developing and operating a satellite-based volcano monitoring system (http://vrsserv.eri.u-tokyo.ac.jp/REALVOLC/), and improving the analytical methods for detailed interpretation of eruption sequences. In the observation of eruption sequences, high temporal resolution and constant-monitoring capability are required for scrutinizing eruptive phenomena that can change dynamically in a short period. Low resolution infrared images having high observation cycle are suitable for such observation. We developed a method using "parallel-timeline chart", consisting of time-series variations of thermal anomalies and occurrence state of eruption clouds, based on low resolution infrared data from polar orbiting and gestational satellites. Here, we show an analytical result from the Sarychev 2009 eruptions in Kuril Islands. Some types of eruption sequences show characteristic changing in the variation of thermal anomaly related to state of gas emission, preceding explosive eruption stage. If we can discriminate these types of eruption sequence, we may predict beginning of explosive eruption stage, combining realtime information on thermal anomaly from the satellite monitoring system.

Aeromagnetic survey by using unmanned helicopter

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We've conducted aeromagnetic surveys in volcanoes by using unmanned helicopter for about ten years in order to detect the geomagnetic field changes due to volcanic activity.

Volcanic rocks are very weak magnets and their magnetization vanish at high temperature. It means that the measurements of the magnetic field changes supply some information on the temperature changes beneath the ground without digging deep holes under the ground. To detect tiny magnetic changes, however, it is important to measure the magnetic fields continuously or repeatedly at a lot of points.

The land-based measurements by setting the equipment provide continuous magnetic field data at the measurement sites, but it is impossible to install them at a lot of points, say, 100 and more. The repeated airborne survey can provide magnetic field data on the whole plane over the ground, but it is very difficult to measure at the same points repeatedly due to manual operation of crafts.

To overcome these difficulties and get some other merits, we use the unmanned helicopter rather than manually operated vehicles. The advantages for using unmanned helicopters are:

1) to avoid the risks of fatal accidents by volcanic activities,

2) to fly very slow at very low altitudes in order to measure highly resolved magnetic fields,

3) to take flights on the same tracks repeatedly according to programmed courses in order to detect the temporal changes of the magnetic fields.

We will show some results of surveys at Izu-Oshima island, Kirishima volcano and so on.

Gaseous detectors for cosmic muon radiography measurements

Dezső Varga
Wigner Research Centre for Physics, Hungarian Academy of Sciences

Detectors for cosmic ray detection need to offer reasonable tracking performance over a sizeable detection surface, which requires cost efficient and mechanically robust solutions. The presentation gives an overview of the existing technology choices advocating pros and cons. Gaseous detectors are particularly promising due to their lightweight construction and sufficient position and time resolution. Innovative design and usage of contemporary materials can lead to a class of detectors which is optimally suted for cosmic muon radiography applications.

Data Acquisition System for Portable Detectors

Gergő Hamer

Wigner Research Centre for Physics, Hungarian Academy of Sciences

Portable tracking devices need adequate electronic system for signal handling and data collection. Micro-computer based data acquisition systems can unite high performance i/o handling with high level computing capabilities. The presentation summarizes the main design issues of the RaspberryPi or micro-controller based DAQ of a gaseous cosmic muon tomograph, and with solutions for a complete system integration, emphasising its usability for tracking detectors.

Application of Portable Tracking Detectors for Muography

Oláh László

Wigner Research Centre for Physics, Hungarian Academy of Sciences

Portable gaseous tracking detectors with low power consumption have been developed for muography applications by the REGARD group in Wigner RCP, Budapest.

The applied innovative technologies allow us to perform measurements either underground or at ground level in the varying natural environmental conditions.

The cosmic muon flux has been measured at shallow depths underground (< 150 m rock-equivalent depth) and at ground level as well, with a muon tomograph of 0.1 - 0.25 sqm sensitive area. The applicability of the system to detect underground rock density inhomogeneities has been demonstrated via reconstruction of an underground tunnel system.

One of the main backgrounds, the soft component (electrons or positrons) have been studied experimentally and GEANT4, revealing its decomposition and other key properties.

Muography of the shallow part of Stromboli (Italy) by using nuclear emulsion detector

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The density distribution is one of most critical information also for geoscience to understand unknown targets. A new geophysical exploration by using attenuation of cosmic-ray muon has the sensitivity for density with better spatial resolution than any other typical methods. Nuclear emulsion, which is a kind of photographic film and have sensitivity for the minimum ionization particle such as high energy cosmic-ray muon, have the remarkable features for muography: high position resolution, no power supply, good stability for hard environment except high temperature and shock, but not available for real-time monitoring.

Stromboli is one of the most known and most active volcano in the world, belonging to Aeolian Islands, located at a volcanic arc north of Sicily Island, Italy. To investigate the shape of conduit is critical for the study of volcanic eruption dynamics. However the expected width of the conduit is just about 10 meter, and it’s difficult to get a stable power consumption. Nuclear emulsion is the best tool for this target. By using nuclear emulsion films as muon detector, we applied muography method to make the see-through image of shallow part of Stromboli volcano in Italy. The features of nuclear emulsion detector, the image of Stromboli muography will be presented.

Nuclear emulsion technologies for muography

Kunihiro Morishima

Institute for Advanced Research, Nagoya University, Japan

Muography (cosmic-ray muon radiography) is the nondestructive technique of large-scale objects with cosmic-ray muons. The principle is the measurement of transmitted incoming muons from sky. Nuclear emulsion is high-resolution photographic film for recording three-dimensional trajectories of muons with the position resolution of sub-μm. In addition, it does not require electronic power. And also, it is easy to enlarge detector area by placing nuclear emulsions side by side. These properties are suitable for a detector of muography at the point of portability and high-resolution imaging. In this presentation, I'll talk about our latest nuclear emulsion technologies and applications.

Muon radiography of volcanoes with nuclear emulsions.

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Muon radiography (muography) has been used for probing the internal density structure of volcanoes. The biggest advantage of the muography is its high spatial resolution (a few tens of meters), compared with other geophysical exploration methods. For muography, several types of detectors have been employed such as scintillation detectors, gas chambers and nuclear emulsions (special photographic films). Particularly, the nuclear emulsion is feasible to resolve small and highly heterogeneous structure of volcanoes because it has high resolution in determination of incident angles of muons and it does not require electricity for operation, enabling us to place a detector close to the summit. Emulsion observations have been performed at various volcanoes all over the world, such as Mt. Asama (Japan), Mt. Showa-Shinzan (Japan), Mt. Stromboli (Italy) so far.

In this talk, we briefly introduce the procedure of emulsion-based muography through the case of Mt. Showa-Shinzan observation. The main topics are as follows:

1. Requirement for emulsion-based muography & detector setups.
2. Analysis of emulsion films.
3. Density estimation of volcanoes & 3-D reconstruction.

Geo-neutrino Technology

Hiroko Watanabe

Research Center for Neutrino Science, Tohoku University, Japan

Neutrino is an elusive particle and it can penetrate even astronomical objects. While neutrino experiments continue to explore the neutrino properties, such as the oscillation nature of neutrino flavor transformation, the mass-square differences and the mixing angles and so on, we have began to utilize neutrinos as a tool to look into the Earth. Anti-neutrinos emitted from radioactive isotopes, geo-neutrinos, bring unique and direct information about the Earth's interior and thermal dynamics.

KamLAND, Kamioka Liquid-scintillator Anti-neutrino Detector, utilizes 1 kton liquid scintillator and reported the first experimental study of geo-neutrino in 2005 [1]. Later the geo-neutrino signals were used to estimate the Earth's radiogenic heat production and constrain the composition models of the bulk silicate Earth [2]. Following the Fukushima reactor accident in March 2011, the entire Japanese nuclear reactor industry has been subjected to a protected shutdown. This unexpected situation allows us to improve the sensitivity for geo-neutrinos [3].

The liquid scintillator detectors have the sensitivity for measuring total amount of geo-neutrinos. However, we do not have the technology to track the direction of incoming geo-neutrinos at present due to the high miss-identification in a neutrino's track reconstruction. The direction-sensitive detector can map out the U and Th distribution inside the Earth and this technic is also applicable to resolving crust versus mantle (horizontal vs mantle) flux contributions. Recent progress in studying this new technology confirmed that a significant improvement is possible in neutrino tracking identification with a combination of ^{6}Li-loaded liquid scintillator and imaging detector [4]. Experimental studies and Monte-Carlo simulation demonstrated that the ^{6}Li-loaded direction sensitive detector has the feasibility of producing geo-neutrinographic images of gigantic magmatic reservoirs and deep structure in the mantle.

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