**Research Institute for Sustainable Humanosphere (RISH), Kyoto University**

# Collaborative Research based on the MU Radar and Equatorial Atmosphere Radar (EAR) (Period: June-November 2019)*
## including
# MU Radar Campaign Observations (Period: December 2019-November 2020)

The MU (Middle and Upper atmosphere) radar installed in Koka, Shiga, Japan (34.85N, 136.10N) is one of the most powerful and multi-functional VHF-band atmospheric radar operated by Research Institute for Sustainable Humanosphere (RISH), Kyoto University. The MU radar, which is the first large-scale MST radar with a two-dimensional active phased array antenna system, was selected as IEEE Milestone which honors significant technical achievements in all areas associated with IEEE. The MU radar imaging observation system installed in 2004 enables us to monitor detailed structure inside radar range volume. In 2017, the MU radar high sensitivity observation system was installed for improving receiving sensitivity. The Equatorial Atmosphere Radar (EAR) is an atmosphere radar located in Kototabang, West Sumatra in the Republic of Indonesia is operated by collaboration between RISH and National Institute of Aeronautics and Space of Indonesia (LAPAN), Indonesia since 2001. RISH is a regular member of ICSU-WDS (World Data System) related to the observation database of both radars.

We widely call for research proposals to use these radars from world scientists. The research proposal of the simultaneous observations with the MU Radar and EAR is encouraged. Proposal of the globally networked observations using the MU radar, EAR and other radars is also welcomed.

This document describes instructions to apply to the MU radar and EAR collaboration research.

**(*) If conditions are satisfied, we can accept the proposal for one year. Please see Section 5 for details.**

**Note: In recent years, there is the application whose contents are the almost the same as the previous one. Please include the research progress and the differences from the previous application. If the page is insufficient, you can attach separate sheet(s).**

### 1. Description of the Program

This program enhances scientific research activity by using the MU radar, EAR and associated facilities, and their database. The program also accommodates to install research facilities of visiting scientists at the MU radar and EAR sites. The program covers wide research areas in the entire

atmosphere from the troposphere to the ionosphere and various fields of humanosphere.

The collaborative research is classified to the following three categories.

(A) Observations with the MU radar, EAR, and their related facilities

Observations of the atmosphere and ionosphere by means of the MU radar, EAR, and other facilities operated at their sites (see Section 3 in detail）.

(B) Use the MU radar and EAR sites as observational field of applicants' own facilities

Various research activities have been conducted by combining the MU radar/EAR and applicants' own facilities since the establishment of two radar sites. The applicants can bring their own facilities, or use the sites as a research field of their scientific activities.

(C) Research subject to use the MU radar and EAR database

Researches to use the existing database obtained with the MU Radar, EAR, and other related facilities are also welcomed. Note that, for instruments in the EAR site, LAPAN might require some agreement form to applicant's institute.

## 2. MU Radar Campaign Observations

### 2.1 Campaign observation proposal

We simultaneously call for the MU radar campaign observation to use the MU radar for a long time (100 hours or more in non-standard observation mode). The observation time of the MU radar will be assigned preferentially to the accepted campaign subject. The proposal over one year is also acceptable for the campaign subject. Continuous observations for 1-2 months (including maintenance time) or special observations performed every month for a year are assumed to be the campaign subject.

### 2.2. Simultaneous observations with the campaign

There is no proposal as campaign observation (prolonged observation) to be carried out in this term (June-November 2019).

## 3. Facilities of Collaborative Research

### 3.1. Facilities at the MU Radar site

#### 3.1.1 The MU Radar

The MU radar is one of the most multi-functional atmospheric radar with an active phased array system consisted of 475 antenna elements. The MU radar has a monostatic circular antenna with a diameter of 103 m, which can be divided to 25 independent subarrays. Tropospheric and lower stratospheric observations (2-25 km), mesospheric observations (60-90 km), and ionospheric observations (80-500 km) are available.

The MU radar imaging observation system installed in 2004 can switch the operational frequency

between 46.0 MHz to 47.0 MHz in every Inter-Pulse Period (IPP). The receiver system is also upgraded to 29-channel digital receivers. The received signal of each sub-array can be independently detected, and combined in the digital processing. This new feature enables us the multifunctional observation of Coherent Radar Imaging (CRI) and Range Imaging (RIM) techniques. The signal source of the MU radar is replaced to the GNSS synchronized signal generator and the timing of transmission is synchronized to the atomic clock boarded on GNSS satellites. The polarization was fixed to the right-circular to decrease the loss in polarization relay switch.

See the following paper for details of the MU Radar system:


Fukao *et al.*, The MU radar with an active phased array system: 1. Antenna and power amplifiers, *Radio Sci.*, **20**, 1155-1168, 1985.

Fukao *et al.*, The MU radar with an active phased array system: 2. In-house equipment, *Radio Sci.*, **20**, 1169-1176, 1985.

Fukao *et al.*, MU radar: New capabilities and system calibrations, *Radio Sci.*, **25**, 477-485, 1990.

Hassenpflug *et al.*, Description and demonstration of the new Middle and Upper atmosphere Radar imaging system: 1-D, 2-D, and 3-D imaging of troposphere and stratosphere, *Radio Sci*., **43**, RS2013, doi:10.1029/2006RS003603, 2008.


See the web page (http://www.rish.kyoto-u.ac.jp/mu/en/) too.

**(a) Standard Observation Mode**

Two standard observation modes: GRATMAC and GITCAD observations are conducted (almost) every month for the lower and middle atmospheric and ionospheric observations, respectively. The data of the standard observation are recommended for all users, who requires no special observation in their research purpose.

- GRATMAC observation (troposphere/stratosphere and mesosphere standard observations)

The troposphere and the lower stratosphere and the mesosphere (daytime only) are continuously observed for about 100 hours every month. The basic specification of GRATMAC observations are shown below.

| | |
|---|---|
| Beam directions (degree): | (Azimuth angle, Zenith Angle)=(0, 0), (0, 10), (90, 10), (180, 10), (270, 10) |
| Height range: | |
| Daytime at 6:00-18:00 | 0-24 km and 60-90 km |
| Night-time at 18:00-6:00 | 0-24 km |
| Obtained Data: | power spectral density of clear-air and precipitation echo. |

Spectral parameter (radial wind velocities, echo power intensity, and spectral width) are also available.

Temporal resolution: two minutes daytime and one minute in night-time

Range resolution: 150 m in troposphere/stratosphere mode
600 m in mesosphere mode

- GITCAD observation (ionospheric standard observation)

Beam directions: (Azimuth angle, Zenith Angle)=(355, 20), (85, 20), (175, 20), (265, 20)

Height range: 190-800 km

Data output: Electron density
Auto-correlation function calculated from four pulses in the electron-ion temperature mode
Auto-correlation function calculated from two pulses in the ion-drift mode

Temporal resolution: Echo power: one second
(1-hourly average is required for practical use.)
Auto-correlation function: 10 seconds
(1-hourly average is required for practical use.)

Range resolution: Echo power observation: 4.8 km
Electron-ion temperature observation: 9.6 km
Ion-drift observation: 38.4 km

**(b) Other Observation Modes**

Meteor trail mode:

The three dimensional wind velocities and temperature profile at 80-100 km obtained with meteor trail observation modes with the height and temporal resolutions of 1 km and 30 minutes, respectively.

Ionospheric coherent echo (FAI) mode:

The MU radar can observe Field Aligned Irregularities (FAI) in the ionosphere E and F regions in mainly night-time.

Interferometry observation modes:

A spatial and a frequency domain interferometry mode are available with the MU radar.

RASS (Radio Acoustic Sounding System) mode:

Temperature profile is obtained by using the MU radar and collocated acoustic speakers.

### 3.1.2 Radiosonde Receiver

The VAISALA MW21/MW41 and Meisei RD-08AC receivers are available at the MU Observatory. The Observatory can provide radiosonde, balloon, and helium gas, although payment is required to the users. The users are also required to engage in the operations of radiosonde observation. When the droppoint of radiosonde is predicted near urban areas, the radiosonde launch has to be postponed. (c.f., http://www.rish.kyoto-u.ac.jp/mu/trajectory/)

### 3.1.3 Other collaborative facilities at the MU radar site

- Ionosonde: electron density profile is monitored every 15 minutes by sweeping the transmitted frequency in HF band.
- Surface meteorological observation: Surface pressure, temperature, humidity, wind direction and velocity, solar radiation intensity, and precipitation are continuously monitored at the MU radar site.
- Disdrometer: Optical disdrometer is operated to monitor the precipitation rate and drop-size distribution.
- Boundary layer radar: LQ-7 manufactured by Sumitomo Electric Industries is mainly employed. (*)
- Rayleigh-Mie-Raman lidar: Lidar systems are designed for profiling atmospheric temperature, water vapor, and aerosols. (*)
- Doppler sodar: Wind profiles up to several hundred meters are measured. It is an active phased array system consisting of 216 elements. Center frequency is 2100 Hz, output power 600 W, and antenna aperture 2.1 $m^2$. (*)
- All sky camera: A visible image in a whole sky is taken every minute. (Prede PSV-100)
- Ceilometer: Vertical profiles of back-scattering echoes from clouds are measured using a laser beam.

* Consult to the contact person to use them.

## 3.2. Facilities at the EAR site

### 3.2.1 EAR

The EAR is a large Doppler radar for atmospheric observation at the Equator in West Sumatra in the Republic of Indonesia (100.32E, 0.20S). The EAR has a circular antenna array of approximately 110 m in diameter, consisting of 560 three-element Yagis. It is an active phased array system with

each Yagi driven by a solid-state transceiver module. This system configuration makes it possible to direct the antenna beam electronically up to 5,000 times per second. The EAR transmits an intense radio wave of 47 MHz into the sky, and receives extremely weak echoes scattered back by atmospheric turbulence. It can observe winds and turbulence in the altitude range from 1.5 km to 20 km (troposphere and lower-stratosphere). It can also observe echoes from ionospheric irregularities at heights more than 90 km.

The EAR has been continuously operated in the tropospheric and lower-stratospheric standard observation mode (TR mode) and ionospheric FAI standard observation mode (FAI mode) (one observation cycle is about 3 min in daytime and about 3.5 min in night-time) except for special observation or maintenance periods.

Tropospheric and lower-stratospheric standard observation mode (TR mode):

Clear-air and precipitation echoes are observed in the troposphere and the lower stratosphere.

| | |
|---|---|
| Beam directions (degree): | (Az, Ze)=(0, 0), (0, 10), (90, 10), (180, 10), (270, 10) |
| Height range: | 1-23 km |
| Data output: | Power spectral density of clear-air and precipitation echo. Radial wind velocities, echo power intensity, and spectral width are also available.) |
| Time resolution: | 1.5 minutes |
| Height resolution: | 150 m |

Ionospheric FAI standard observation mode (FAI mode) :

Field Aligned Irregularities (FAI) in the ionospheric E- and F-regions is observed.

| | | |
|---|---|---|
| Daytime at 6:00-18:00: | F1 Layer, 4 beams (Az: 150, 165, 180, 195), | Range Reso.: 1200 m |
| | E Layer, 3 beams (Az: 153, 180, 207), | Range Reso.: 600 m |
| Night-time at 18:00-6:00: | F Layer, 16 beams (Az: 125-230), | Range Reso.: 2400 m(*) |
| | E Layer, 3 beams (Az: 153, 180, 207), | Range Reso.: 2400 m |
| | E Layer, 6 beams (Az: 153-222), | Range Reso.: 600 m |

(*) The effective Doppler speed is not obtained in this observation mode.

FDI (Frequency Domain Interferometry) mode:

By switching the transmitting frequency, detailed structure of atmospheric turbulence can be retrieved with frequency-domain interferometric (FDI) method.

RASS mode:

Temperature profile in the troposphere can be observed with RASS technique by receiving

echoes from acoustic wave fronts generated by the loud speaker system. Consultation to the contact person shown in Section 9 is required in advance.

See the following paper for details of the EAR system:

Fukao *et al*., Equatorial Atmosphere Radar (EAR): System description and first results, *Radio Sci*., **38**, 1053, doi:10.1029/2002RS002767, 2003.

### 3.2.2 Other facilities at the EAR site

Instruments operated by RISH:

- Surface weather instruments (surface pressure, temperature, humidity, wind direction/velocity, and precipitation)
- All sky camera
- Internet connection*
- Disdrometer**
- Ceilometer**
- Micro-rain radar**
- Meteor radar**

*Due to bandwidth limitation of Internet connection, contact to address shown in Section 9 before using Internet connection at the EAR site.

** To use these instruments, consult to the contact person.

Other instruments operated by other universities and organizations:

Multi-wavelength all-sky airglow imager, VHF ionospheric radar, GPS receivers, Magnetometer (ISEE, Nagoya Univ.), Rayleigh lidar, Resonance scattering lidar for metallic ions, Mie lidar (Tokyo Metropolitan Univ.), X-band weather radar, Radiometer, Optical raingauge (Shimane Univ.), Ionosonde (NICT)

Note that RISH cannot provide data of these instruments belonged to PI of each institute. Terms and conditions to use these data are determined by PIs. Inquiry of data availability to the PI is required, if you are interested in using them.

### 3.3. Data disclosure policy

All observation data obtained with collaborative instruments operated by RISH will be opened in public. Data of standard observation mode with the MU radar and EAR is immediately opened at the database web page (http://database.rish.kyoto-u.ac.jp/). This data has been registered in

IUGONET (Inter-university Upper atmosphere Global Observation NETwork) metadata database, and IUGONET also prepared the iUgonet Data Analysis Software (UDAS). For other observation, the data will be opened after one year's grace. Data of the radiosonde launched by collaborative researchers will be also opened.

The original radar data and/or special observation data which are not exhibited on the web site, Application to the database collaboration program is required.

**4. Cost for operation and support**

1. Operation cost of the MU Radar and EAR is supported by RISH. Typical observation time allocated for a proposal for non-standard mode is limited to 12 to 48 hours.
2. Operation cost for the other collaborative instruments operated by RISH is basically supported by RISH.
3. Domestic travel and living expenses in Japan/Indonesia are supported by RISH within the limitation of the budget. Overseas flight expense from overseas is beyond our support.
4. Those who wish travel support should describe their travel detailed plan including their contact email address in the application form.
5. The P.I. of observation subject is recommended to participate to the observation at the radar site during the assigned period, although this is not compulsory.

**5. Observation Period to Receive Applications**

We divided a year into two observation periods (June-November and December-May) and call for research proposals twice a year. The application to the general proposal for the following period is now opened.

**June 1, 2019-November 30, 2019**

The application including the research in the next term (December 2019-May 2020) can be submitted, clarifying the following regulations:

Research subject using the standard observation only,

Research subject requiring to assign no their own observation period, and

Research subject using the existing database.

In this case, the submitted application in this period will be evaluated in next term again.

The following subjects are received as `one year application'. These are unnecessary to submit the same application this time.

| No. | PI | Research Title |
|---|---|---|
| 2018-F49 | Y. Maekawa | A study on the effects of precipitating clouds on the propagation paths of satellite communications |
| 2018-A52 | H. Hashiguchi | Development of MU Radar Real-time Processing System with Adaptive Clutter Rejection |
| 2018-A53 | H. Hashiguchi | Development of imaging wind profiler radar and measurement of fine-scale turbulence in the lower atmosphere |
| 2018-A54 | M. Yabuki | Development of a compact rotational Raman lidar for temperature measurements |
| 2018-B64 | S. Saito | Validation of real-time ionospheric 3-D tomography |
| 2018-C68 | Marzuki | Improvement of vertical profiles of raindrop size distribution from MRR using Parsivel measurements |
| 2018-C69 | Marzuki | Variability of rain drop size distribution at Kototabang and Padang |
| 2018-C70 | Marzuki | Long-Term Observation of Vertical Profile of Raindrop Size Distribution over Sumatra |
| 2018-D79 | Y. Otsuka | Radar observations of the field-aligned irregularities in the ionosphere in Indonesia |
| 2018-FD84 | S. Sinha | Correlation Studies of Wind Patterns at multiple Locations to Model Climate and its significance for the Projections of Continental Weather Changes |

**Call for the MU radar campaign proposal in December 1, 2019-November 30, 2020 is simultaneously opened now.** Note that the application form of the campaign will be uploaded at our website to increase the harvest of the campaign observation by the synergy effect to the other general research subjects.

**6. Requirements for Applicants**

Applicants to this program are limited to scientists. Applicants from other countries are strongly recommended to find a collaborating scientist in Japan for successful and fruitful observation. If the person of RISH is not included in cooperative researchers, please fill in the 'Contact Person in RISH' column of your application. Proposals related to other international scientific programs are welcome.

The proposal should be written in English (or Japanese) on the fixed application format and submitted to the following e-mail address.

mu+ear@rish.kyoto-u.ac.jp

The form can be downloaded from the following web page.

Web: http://www.rish.kyoto-u.ac.jp/mu+ear/english/

For the application to the MU radar campaign observation, the summary of the present scientific results by proposed observation mode should be attached in the separated sheet (free format). All proposals are evaluated by the steering committee and determined the accepted subject and observation schedule. The determination will be informed to the applicants immediately after the decision.

**7. Deadline of Submissions**

General proposal: April 1, 2019

MU radar campaign: July 12, 2019

**8. Others**

1. Research report is required after the collaborative research.
2. Description to use the MU radar and/or EAR should be included in your research papers or reports. We appreciate it if you send us a copy of your papers, if published. Co-authorship may be required according to RISH researcher's contribution.

**9. Contact Person**

Contact person

Prof. H. Hashiguchi,

E-mail: hasiguti@rish.kyoto-u.ac.jp, TEL: +81-774-38-3819

Mail Address:

Research Institute for Sustainable Humanosphere (RISH), Kyoto University,

Gokasho, Uji, Kyoto 611-0011, Japan

FAX: +81-774-31-8463