'TASK GROUP of ACTIVE MONITORING' under IASPEI
proposed as an inter-association working group for IASPEI, IAVCEI and IAGA under IUGG

Mineo Kumazawa, Chair of TGAM (Task Group for Active Monitoring)
(Nagoya Univ. & Tono Geosciences Center, Japan)
(mkumazawa@eps.nagoya-u.ac.jp; mkz@tono.jnc.go.jp)
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We are boosting the International Task Group of 'Active Monitoring' (**TGAM**: Chair: Mineo Kumazawa, Vice Co-chair: Junzo Kasahara and Victor Seleznev) in the solid Earth Geophysics as one of the interdisciplinary working groups under IASPEI Commission on Tectonophysics and Crustal Structure since IUGG2003. This group launched by IASPEI is expected to promote the development of the interdisciplinary approach by active monitoring of the tectonically active solid Earth in corporation with IAVCEI and IAGA, whereas official endorsement has not been obtained yet. Since we are optimistic in doing science prior to bureaucratic procedures, we started to run the expected function. This is an intermittent report on the activity of TGAM with an additional explanation on the background.

1 TASK of TGAM

The purpose of this task group is to promote the following noted below:

1. Coordination of international workshop on 'Active Monitoring' of the Lithosphere (Planning the workshop on annual or biannual basis is a current schedule)
    a. Mizunami (Japan) Workshop, scheduled in June-July, 2004
    b. Special Session of Active Monitoring in IASPEI Chili in 2005
    c. Novosibirsk Workshop, sometime within 2005
    d. Beijing or California Workshop, sometime (uncertain) in or before 2006
2. Development and evaluation of technology (seismic and electromagnetic)
    a. Development of better hardware and evaluation of precision & stability
    b. Designing and development of practical phased array of transmitters
    c. Site calibration & monitoring by evaluation of transmitting characteristics
    d. Development of stable sensor array optimized to low level sinusoidal signals
3. Development of theory, algorithms and routine program for data processing
    a. Optimization theory of sinusoidal signals and its realization methodology
    b. Primary signal processing & evaluation of transfer function
    c. Maximum likelihood evaluation of ray-path model and mode model
    d. Forwards problem in frequency domain to describe frequency dependence.
    e. Inverse problem for the temporal variation of deep structures and states
4. International & interdisciplinary exchanges of information and experts
    a. Establishing the routine way for exchange of information
    b. Publication of Russian literatures in English for circulation
    c. Publication of handbook, protocol & textbook on the sinusoidal approach
    d. Financial and system supports for exchange of experts for training

5. Planning and coordination of joint experiments under the internationally funded corporative program for collaboration Several examples follow:
   a. Boundary zone between the Russian and Japanese territories
      (one of the candidate sites is Kuril Trench-Sakhaline-Hokkaido)
   b. San Andreas fault region
      (a typical seismogenic area under a variety of intensive studies)
   c. Some specific volcano, which has been studied well.
      (e.g., Izu-Oshima, Mt Fuji, Hawaii, Piton de la Foumaise etc)
   d Areas of intraplate orogen
   (e.g., Tien-Shan)

2 BACKGROUND

Whereas there would never be any doubt on the importance of **active monitoring** of the time-evolving structures and states in the tectonically active Earth's lithosphere, the demanded technology has not been sufficiently mature enough to fulfill our requirements. However, the **appropriate use of coherent (sinusoidal) signal** has been found substantial for the basic element of the demanded technology system. This aspect came out from the review of extensive and intensive works done by **Powerful Vibrators** of Russian group lead by academician Anatoly Alexseev at Siberian Branch of Russian Academy of Science since 1976 and the theoretical and experimental works on **ACROSS** by Japanese group lead by Mineo Kumazawa at Nagoya University and Tono Geoscience Center since 1995 in addition to the vast contributions by **Vibroseis**® (Conoco Co.) started in 1958 in USA and also some electromagnetic exploration methods such as CSMT proposed in 1960's. Reviewing the recent developments in control technology and theoretical background behind the sinusoidal approach, in particular, we come to convince that the sinusoidal approaches constitute a new and potential methodology for the active monitoring of active tectonics of lithosphere on a routine basis by means of both elastic and electromagnetic signals in wide range of frequency.

Recent aggressive approach of utilizing coherent signals has been made in Russia and Japan. Professor Anatoly. Alexseev and Dr. Valery Kovalevsky (both at **Novosibirsk**) and Professor Alexei Nikolaev (Moscow) attended the **International Workshop on 'Frontiers in Monitoring Science and Technology for Earthquake Environments'** held in 1998 at **Tono Geoscience Center** in Toki, Japan. The cooperation between Russia and Japanese was enforced since then. Occasionally, a Chinese group lead by Professor Cantao Zhuang at **Center for Analysis and Prediction,** Chinese Seismological Bureau also paid attention to the use of sinusoidal approach for the active monitoring of the earthquake field since 2001 and they started several test experiments.

In the last June, Kasahara and Kumazawa visited Dr. Victor Seleznev, director of Geophysical Survey, Siberian Branch, Russian Academy of Science and the intensive discussions were made with A. Alexseev, Sergey Goldin (Academican, director of Geophysical Institute, SB. RAS), Boris Mihailenko (Director of Inst. of Comp. & Math. Geophys., SB RAS) and many other scientists at Novosibirsk. Now it appeared a good time for us to push forwards the systematic developments and application of this potential methodology to a variety of targets of our concerns, in which the international and interdisciplinary corporations are demanded. Considering the present situations of technical levels and understanding of the sinusoidal approach in our community, we have to promote the theoretical and technical developments and

also the training of experts together with the extension of applications in parallel.

3. .RECENT MOVE at IUGG2003

At the occasion of IUGG2003 meeting held in Sapporo, June 30 to July 11, V. Seleznev, J. Kasahara, Naoyuki Fujii and myself made a campaign for this aspect informally to several scientists to ask for their opinions. Unexpectedly, everybody has supported and encouraged us and the short key name '**Active Monitorin**g' has been suggested by Dr. Walter Mooney of USGS for this approach. We presented this idea as a proposal to the task group meeting for 'Tectonophysics and Seismic Imaging of the Lithosphere' (Chair: Drs. D. Comte and Walter D. Mooney) of IASPEI and also to the business meeting of IAGA Division 1 (Chair: Dr. Alan Jones) both on July 8. At IASPEI meeting, president Brian L. N. Kennett and secretary E. Bob Engdahl supported our proposal and the committee decided to launch a working group on 'Active Monitoring' under the Commission on the Tectonophysics and the Crustal Structure chaired by Kevin Furlong. Further several suggestions were made at the IASPEI meeting: IASPEI will support (by small seed money) the International Workshop on Active Monitoring in 2004 at Mizunami under planning: Special session on Active Monitoring may be prepared for the 2005 IASPEI meeting in Chile, and so on. At IAGA meeting, our proposal was regarded as welcome, whereas there was no prior notice on discussion of this subject. The business meeting at IAGA suggested us to submit an informative document on this proposal to Dr. Yasuo Ogawa, IAGA WG I-2 Liaison, to process this matter. Although we have not communicated officially with IAVCEI yet, it appears important to submit the same documents as IAGA to IAVCEI, since it is obvious that one of the most stimulating frontiers in IAVCEI is the active monitoring of physical and chemical states beneath the volcanoes and geothermal areas.

4. ACTIVITY after IUGG2003

Responding to the decision on the start of 'Task Group of Active Monitoring' or **TGAM** under IASPEI, first we have summarized a tentative image on the tasks expected to be done by this task group as noted in section 1 above, by consulting with some of those whom we would like to have as members of International Advisory Board of TGAM (See section 5 below). Further we are preparing a powerful agent to support and to substantiate the net activities of the task group. It is the **JCEAM** (Japanese Consortium for the Earth's Active Monitoring), which is expected to promote domestic corporation in research, development and application of active monitoring technology, and also to support the international collaboration on national basis. We had the first meeting of JCEAM at the Earthquake Research Institute (ERI), University of Tokyo on Oct. 21-22. We have decided; (1) Professor Hiromichi Higashihara of ERI will take the leadership of JCEAM and (2) JCEAM in corporation with TGAM is to set forth officially the Local Organizing Committee of the International Workshop on Active Monitoring in the Solid Earth Geophysics in 2004 (abbreviated to **IWAM04**) at Mizunami. The local organizing committee of IWAM04 (**LOC/IWAM04**) will be chaired by Prof. Naoyuki Fujii of Nagoya University, and co-chaired by Profs. Junzo. Kasahara and Hiromichi. Higashihara of Tokyo University. They have quickly started the preparation of the workshop and worked out a draft of the first circular, which had been already circulated.

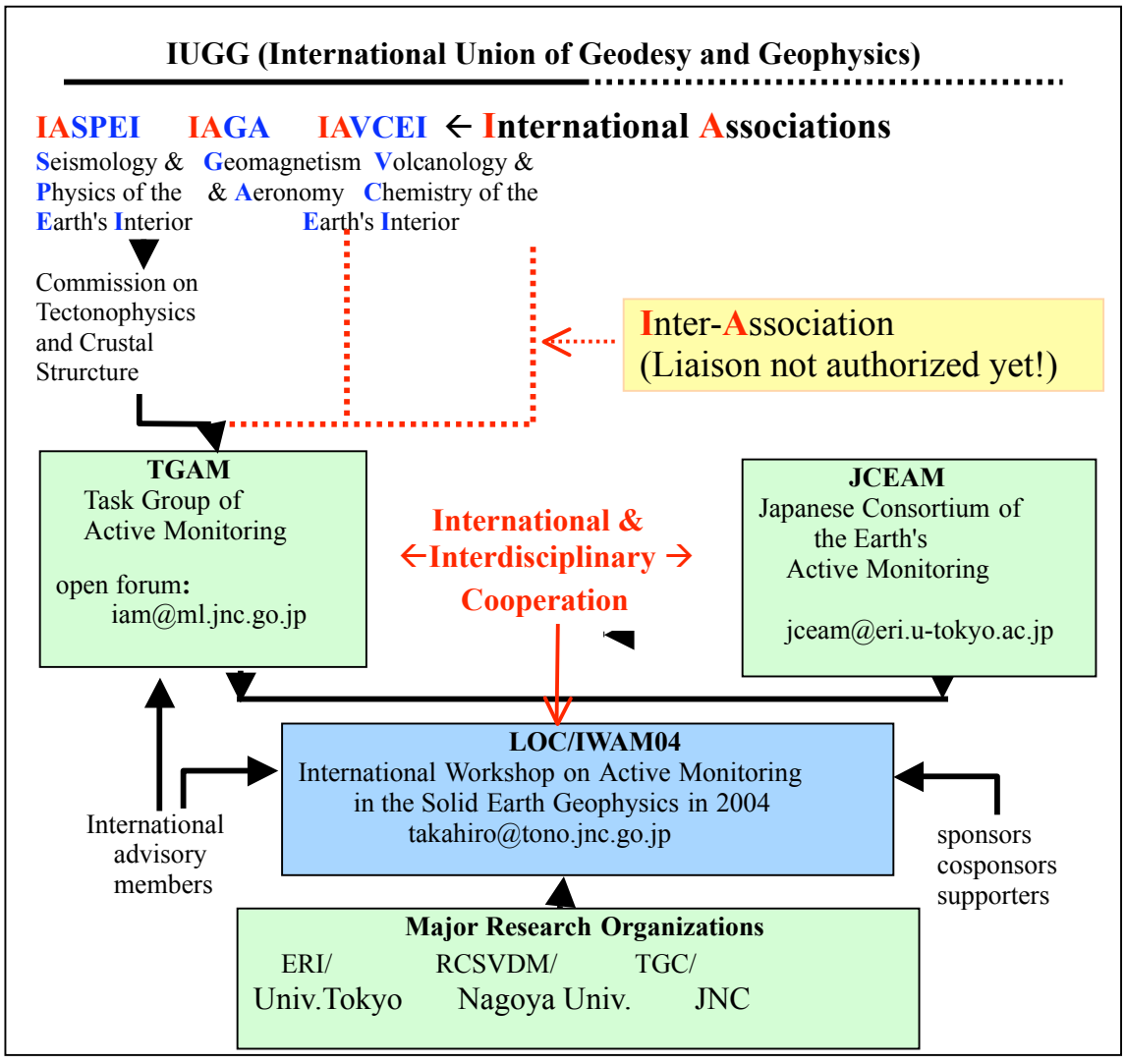
Everything runs in parallel simply because time is pressing, and everything is tentative right now in a sense that the agreement and consensus of those who may concern have not been obtained yet. From now on, we shall revise and consolidate the way to go by showing this tentative plan to those who are interested in the relevant subjects. Any comment is welcome to

Kumazawa <mkumazawa@eps.nagoya-u.ac.jp>or to the open forum below.

5. OPEN FORUM by email group

One of the most important activities may be the exchange of information and discussions on the active monitoring through the open forum by email <iam@ml.jnc.go.jp>. For any question and/or request to join this mailing group, have a contact with the correspondent, Dr. Takahiro Nakajima takahiro@tono.jnc.go.jp.

6. MEMO 1 - Summary of relevant organizations



TGAM (International Task Group of Active Monitoring, under IASPEI Commission on Tectonophysics and Crustal Structure(CTCS) chaired by Kevin Furlong, IUGG)
(may be abbreviated to **iam**; **i** stands for **i**nternational as well as **i**nterdisciplinary)
Chair: Mineo Kumazawa
(Nagoya University, Nagoya, & Tono Geoscience Center, Mizunami, Japan)
mkumazawa@eps.nagoya-u.ac.jp & mkz@tono.jnc.go.jp)
Vice Co-chairs:
Victor Seleznev (Geophysical Survey, SB RAS, Novosibirsk, Russia:
sel@gs.nsc.ru)
Junzo Kasahara (Earthq. Res. Inst., Univ. Tokyo, Tokyo, Japan:
kasa2@eri.u-tokyo. ac.jp)

JCEAM (Japanese Consortium of the Earth's Active Monitoring)
(open mail group mostly in Japanese: jceam@eri.u-tokyo.ac.jp)
Chair: Hiromichi Higashihara
(Earthq. Res. Inst, Univ. Tokyo, Tokyo & Earthq Disaster Mitg. Res. Center,
National Inst. Earth Sci. Disaster Prevention, Kobe, Japan:
higashi@eri.u-tokyo.ac.jp)
Correspondent: Masayuki Saeki (Earthq. Res. Inst., Univ. Tokyo, Tokyo, Japan:
saeki@eri.u-tokyo. ac.jp)

LOC/IWAM04 (Local Organizing Committee of the International Workshop on Active Monitoring in the Solid Earth Geophysics scheduled in 2004)
Chair: Naoyuki Fujii (Nagoya Univ., Nagoya, Japan: fujii@seis.nagoya-u.ac.jp)
Vice Co-Chairs:
Junzo Kasahara (Earthq. Res. Inst., Univ. Tokyo) and
Hiromichi Higashihara (Earthq. Res. Inst., Univ. Tokyo)

7. MEMO 2 - Explanation of keywords and topics

ACROSS is an acronym of Accurately Controlled Routinely Operated Signal System, which is the technology system started by Mineo Kumazawa, Yasuko Takei and Kazuji Suzuki at Nagoya University since April 1994, just before the disastrous Kobe earthquake of Jan 17, 1995. The developmental works on ACROSS has been made further by Katsuro Ogawa, Kosun Yamaoka, Naoyuki Fujii and students at Nagoya University and also promoted by ACROSS team at Tono Geoscience Center since 1996. Further it had also been developed by Prof. Hiromichi Higashihara, Dr. Yuji Ohtake and students at Earthquake Research Institute, University of Tokyo.

The most important starting point of ACROSS is the strategy for the data acquisition most robust against the observation noise. Such a technology is to be linked with the better method of data analysis of the transfer function between the source and receiver with the possible highest S/N and also the inversion strategy to acquire the information on the physical states as well as the geometric structures. All of these demand the use of coherent wave to obtain the observation data in frequency domain.

Titles (and abstracts) of the oral and poster presentations at several science meetings (mostly in Japanese since 1994) are available on request to iam@ml.jnc.go.jp by pdf file through web site, http://www.activemonitoring.org/.

active monitoring

Most of the geophysical observations on used to be made passively to record the time evolution of nature; temperature, wind direction, magnetic field, seismic activity, crustal deformation, etc. These observations are

to sense the signals originated from or transmitted by natures. The active observation has been introduced for structure exploration by using the control source, such as explosion in seismology and electric current source in conductivity. The active monitoring we are trying to develop in a systematic way is the routine continuation of the active observation targeted to the specific subjects or to the exploration of something new.

The important consequence of active monitoring is not only to trace the time evolution of nature, but to make the high resolution analysis of the underground structures and states on the basis of large S/N acquired by stacking of data for long period of time.

active seismology, active geophysics

Usually we try to observe natures as they are in order to understand them. However, we like to predict the time-development of nature, protect ourselves by escaping from the possible disasters, and further to control the natures that may be harmful to us. It would be an inevitable consequence of science to use some active operation to natures in order to understand or to control. A straightforward idea of using sinusoidal seismic sources is the study on the irradiation-induced fatigue of rocks by stress waves in the prone zone of seismic activity. Russian workers have started the study along this line.

appropriate use of coherent signals

There is a variety of different say of using coherent signals in the underground exploration in addition to those having been used by vibroseis, powerful vibrator and also by CSMT. The binary coded pseudo random signals (with a spread spectrum) are also used in active geophysical exploration in the frequency range higher than several hundreds herz. In the low frequency range useful for long distance exploration, however, we expect the existence of better signals and their better use.,

coherent (sinusoidal) signal

Usually the coherent wave means the monochromatic one like a LASER beam with a line spectrum in frequency, for which the sharpness of the spectral line is emphasized. When the finite number of very sharp spectral lines are overlapping, the wave form is still coherent, whereas it is sinusoidal. The robustness of such a signal against noise is the most important characteristics for the active observation, and the coherency of signal meet the demanded robustness.

color holography

We ask a question whether color holography is possible or not in viewing the deep Earth's interiors. The Earth crust is sometimes transparent and coherent wave transmission is surely recognized, whereas it appears really foggy due to scattering of the incident waves to incoherent mode. There is certainly such condition that allows the use of coherent wave to constitute a hologram in digital computer to view the fine structures and physical states of the deep delicate targets (e.g., barrier and asperity in focal zone of earthquakes) that scatter the coherent wave. The frequency-dependent material property (color) is usually a very good indicator of the state of the material, which is the important target of monitoring by observation in frequency domain.

CSMT

Controlled source magneto-telluric method, in which the sine wave signals are used usually in a way of step scanning of frequency. The wider extension of this approach is expected to provide us with a powerful method.

International Workshop on 'Frontiers in Monitoring Science and Technology for Earthquake Environments'

This was held in November 16-19, 1998 on the three subjects; Active fault prove, Earthquake/groundwater research, and ACROSS at Toki and Kamioka Mine by Tono Geoscience Center. The intermittent reports on the Earthquake Research Program run by TGC were presented at this workshop. The program and abstracts of the papers presented at the workshop are available on request to iam@ml.jnc.go.jp, or from web,http://www.activemonitoring.org/.

The first meeting of JCEAM（Japanese Consortium of the Earth's Active Monitoring）

The first kick-off meeting of JCEAM was held in September 21-22, 2003 at the Earthquake Research Institute, University of Tokyo. Most important is the start of systematic corporation among the different disciplines and different organizations towards the development of 'the Earth's Active Monitoring'. Four science topics among the discussions at the meeting are as follows. (1) Takahiro Kunitomo of TGC reported

that the continuous broadcasting of very accurate elastic FM signal with a sophisticated spectrum designed newly was successfully made for 9 months at Tono mine. (2) Yasuhiro Yoshida of JMA (Japanese Meteorological Agency) reported that the sent signal from Tono mine had been detected by a number of hi-net stations up to 100 km or more from the Tono mine. (3) Yumi Misu of Nagoya University reported that the presence of several events indicative of the reflected SH wave from the deep in the lower crust below the Nojima fault in Awaji Island by utilizing the ACROSS source installed at Awaji. (4) Takahiro Nakajima of TGC reported ~3 m/μs (1/100 of light velocity) at ~100 Hz for the group velocity of electromagnetic diffusion wave at Tono mine as determined by observation of EM ACROSS signal, and also the presence of temporal variation beyond the observation error evaluated very carefully.

Novosibirsk

There are one test site and three institutions of Siberian branch of Russian Academy of Science making a close cooperation in development and application of their powerful sinusoidal seismic sources.

Powerful Vibrator:

This is the name by which Russian scientists at Novosibirsk call their large seismic transmitters. There are several different types: rotary type with rotation of eccentric mass and hydro-resonant type (resonance motion of fluid in a container is sued). Generated force is 40 ~100 tonf ((4~10)x10^5 N) in amplitude at the frequencies down to ~6 Hz. The signal sweeping up in frequency is recorded at the distance of 400 km.

The developmental works have been lead by academician Anatoly Alexseev at Siberian Branch of Russian Academy of Science since 1976. Information available in English is limited. The English translation of the contents (3 p) of a Russian Book entitled '**Active seismology with powerful vibrational sources**' (pp474) by Dr. A. Alexseev et al published in 2002 will be available soon through web. Translation and publication of this book in English is one of the tasks for the TGAM in order to be beneficial for all.

Tono Geoscience Center (TGC):

One of the works of Japan Nuclear Cycle Development Institute (JNC). TGC is located at Toki-Mizunami area with the Tono mine (Uranium). Nowadays TGC is mainly devoting to the technology development for the safe geologic disposal of high level radioactive wastes. After the disastrous Kobe earthquakes of 1995, TGC had started a research program beneficial for earthquake prediction study, under the name of 'Earthquake Frontier Research' since April 1996. One of subjects in this research program is the development of ACROSS.

Vibroseis is a trade mark of a seismic exploration tool invented in 1958 by Conoco Co. Nowadays it appears almost a common name for the frequency-sweeping seismic source and the related method of underground exploration, since it has been so widely used and very popular.

to be added more:
Site calibration
transfer function
phased array
Chinese Seismological Bureau
event analysis and spectrum analysis
etc