**Ten-year Review for the Ocean Hemisphere Research Center**

## 1. Committee and its Charge

The external committee to review the Ocean Hemisphere Research Center (hereafter OHRC) consisted of five members. In alphabetical order, they were Professor Hiromi Fujimoto (Tohoku University), Professor Kazuo Hirahara (Kyoto University), Dr. Mizuho Ishida (National Research Institute for Earth Science and Disaster Prevention), Professor Jean-Paul Montagner (University of Paris VII, France), and Professor Toshiro Tanimoto (University of California, Santa Barbara, USA). The Chair of the committee was Professor Tanimoto.

The charge to the committee, given by Professor Shuhei Okubo (Director of Earthquake Research Institute), was (1) to evaluate the performance of OHRC over the last ten years on its administration and research activity and (2) to provide suggestions and recommendations for its future directions.

## 2. Procedure for Evaluation

From the beginning, OHRC had multi-faceted goals; it was expected to (i) maintain the Ocean Hemisphere Network, originally developed by a Grant-in-aid research program called the Ocean Hemisphere Project (1996-2001), (ii) develop new instruments for geophysical observations (seismic and electromagnetic), (iii) conduct cutting-edge research projects and (iv) provide OHP data as a data center to international research community. We broadly reorganized these four points into three and evaluated performances on (1) Observation, (2) Scientific achievements, and (3) Data Center. We also discussed and evaluated OHRC from its (4) graduate education records and (5) international collaboration. These five items are elaborated in more detail in the next section.

## 3. Evaluation

### (3.1) Observation

Truly pioneering, world-class achievements were made by OHRC researchers in various aspects of observations. The committee was particularly impressed with

a) Development of Broadband Ocean Bottom Seismometers (BBOBS). It now seems possible to plan and conduct temporary, flexible seafloor arrays using many broadband OBSs. Such a capability is unique in the world. OHRC with collaborations with JAMSTEC, leads the world in this aspect.

b) Completion of seafloor borehole seismometer installation (WP-1 and WP-2). Seafloor (semi-)permanent facilities are still rare in the world. Needless to say, data from remote oceanic areas are valuable for understanding earth structure and earthquakes. These stations, along with JT-1 and JT-2 by JAMSTEC, are excellent prototypes for future permanent stations on the seafloor.

c) Seafloor electric field measurements using submarine cables. From its trans-Pacific scale, these data provide constraints on electrical conductivity in the deep

earth and are a unique source of information. This is also a good example of successful international collaboration (with US institutions, in this case).

d) Development of seafloor electromagnetic observation techniques.

e) Heat flow measurement at shallow oceans. Heat flow measurements at shallow ocean floors has been known to be very difficult because of large temperature variations. Successful measurements were made on the Japan side of the Nankai Trough.

Each of these five developments contains innovative approach and may point to the way the future observations should be done in geophysics.

OHRC also successfully maintained on-land permanent broadband seismic stations, located in Southeast Asia and Pacific islands. Some of them were the legacy of previous projects, POSEIDON and OHP, and are important and valuable stations for researchers in the world. Standardized instruments and good maintenance, as well as contribution of data to other seismological data centers (FDSN data center and IRIS-DMC in US) are important contributions to the international community.

Because of its importance, the committee felt that the maintenance of these broadband seismic stations must be responsibly continued in the future. We hope these valuable assets will not be lost by reorganization of research institutions. Because OHRC (and ERI) is a research institution which should put priority on performing creative research, we think the maintenance of permanent seismic stations and the data center should be transferred to other institutions in the future such as JAMSTEC.

Data center has received requests that peaked over 2000 in 2004. It has carried out its task faithfully and provided important data sets to the international community.

**(3.2) Scientific achievement**

The committee was especially impressed with the combined study of seismic and electromagnetic tomography. Strictly speaking, joint inversion was not done or even possible at present but this combined approach for the same region provides additional perspectives as to the cause(s) of 3D mantle anomalies. Results are clearly richer in information content than seismic tomography alone. We recognize a number of difficulties in the interpretation of two tomographic results. But the fact that this committee was unanimously impressed, with members consisting of different backgrounds, probably means that this line of approach also appeals to other researchers and the joint seismic and EM study may become a popular approach in the near future. These results by OHRC researchers will then be recognized as the cutting-edge work that demonstrated their importance at its early stage.

Research activities at OHRC also led to surprising by-products such as

a) Continuous oscillations, now often called the HUM outside Japan,
b) Seismology in the atmosphere,

c) Broadband seismological study of volcanic processes.

They are all first-class research achievements. We regard them as by-products of OHRC because these projects were not the ones that led to the original formation of this research group. But there is no question that collection of global seismologists at OHRC led to these serendipitous discoveries. We think it would not have been possible without the existence of a research unit like OHRC.

The original goal of OHRC is closely related to the Stagnant Slab Project (2004-2009, hereafter SSP). Members of OHRC are the main players in the SSP. This is an on-going project with great promise for breakthrough because of the planned data collection using BBOBS and data from WP-1 and other permanent stations maintained by OHRC. We expect these results will lead to more robust results to clarify the nature of stagnant slabs in this western Pacific region and possibly lead to our new understandings of large-scale mantle dynamics.

**(3.3) Future Projects**

SSP is the main project that currently occupies the main research efforts by members at OHRC. This project will last until 2009, so a large portion of research efforts at OHRC must be expended on this large, funded project. An important question of future is what are potential scientific questions that OHRC should pursue beyond SSP.

For future directions after SSP, we felt that questions that address large-scale, deep mantle dynamics is the area that should be pursued. While there will undoubtedly be much progress in our understanding of tectonics from SSP, some important questions still remain such as

(1) How deep slabs will go after stagnation at 700 km?,
(2) Do slabs stop at about 2000 km as some seismic tomographers have proposed?
(3) What is the role of fluids in geodynamics? The fluid content in the crust and mantle may have important implications to earthquakes, volcanic processes and mineralogical compositions.

These are certainly long standing questions that have been addressed many times before and are crucial ones in understanding mantle dynamics. With dense array data from lands (NECESSArray) and oceanic regions, both in seismic and electromagnetic data, efforts at OHRC may lead to breakthroughs in this area of research topics and we hope this line of efforts to be continued after SSP.

Another question the committee addressed is how we regard the current NECESSArray proposal, which is a proposal for on-land array observation in the Northeastern China (NE China). This proposed project is similar to USArray, the efforts in North America being pursued in US.

We believe the proposed NECESSArray project will be a good, complimentary project to SSP; the dense observation in NE China will most likely clarify the shallow structure above the stagnant slabs that extends from Japan to NE China. Effects from stagnant slabs on tectonics may be crucial in determination of the style of tectonics in this

region and we may gain some perspectives by this project. Considering its promise for success and relatively cheaper cost in comparison to seafloor instruments, we believe the proposal to purchase some on-land seismic instruments is a good idea.

The committee also felt that future efforts should be interdisciplinary. We note such an attempt is already under way within SSP, which includes mantle convection calculations and high-pressure experiments. It is obvious to us that any future projects that are related to deep earth dynamics should contain interdisciplinary elements, because understanding mantle dynamics requires understanding rheology, temperature effects and compositional variation effects. Seismic and EM data alone are clearly not sufficient.

It is also a good idea to take advantage of fantastic computing facilities that are uniquely available to Japanese scientists. "Earth Simulator" and the next generation supercomputer are important resource that gives an edge to scientists in Japan. We believe that interdisciplinary efforts should include this computational element whether it is in the form of simulation, modeling or data analysis.

**(3.4) Graduate education**

OHRC produced 13 Ph.D. students over the last 10 years. For the same period, ERI as a whole produced 68 Ph.D. students in science and 82 Ph.D. students, including engineering students. Within ERI, the number of students are on par or slightly better than average. Thirteen students over 10 years are not necessarily high for a graduate academic institution but all of their graduates went on to research positions in academia or government research laboratories. In that sense, we believe OHRC has done a job of producing researchers in geophysics for the next generation.

After the 1995 Kobe earthquake, study of the Earth's interior by Japanese seismologists has tended to focus exclusively on local structure surveys related to problems of earthquake occurrence. Only a small number of groups have pursued research on global structure and dynamics. Among them, OHRC has played an important and central role in this field. We recognize the foresight that ERI had when OHRC was formed, and hope that ERI will support this group and continue to attract young researchers to this field.

**(3.5) International collaboration**

Because of limitation on time, we could only briefly discuss this point and mainly focused on the visiting professorship program. Over the 10 years, there were 22 visiting professors with two of them returning for the second time. Publication list indicates good interactions and collaboration between visiting professors and scientists at OHRC. Also joint funding application has been attempted in various counties; for example, funding for the new project NECESSArray is being submitted to Japanese government by Professor Kawakatsu and to the US National Science Foundation by Professor Niu and Professor Grand, two scientists who came as visiting professors (The proposal includes Professor Ni, who has not been to OHRC/ERI as a visiting professor). We think this visiting professor program has been a successful, important element for the activity of OHRC and encourage continuation of the current program.

It appears that the current rule for visiting professors has an undesirable, inflexible element. For a given year, OHRC typically had three visiting professors, but the current rule stipulates that their stay cannot overlap; only one researcher could be at ERI at any given time, meaning two other scientists' visit (on average) must be scheduled to avoid this time period, even though the total number of appointments for three scientists do not exceed 12 months. Considering the difficulties for senior scientists to leave their home institutions for long period of time, a more flexible rule would probably have attracted other prominent scientists to this program. Changes for more flexibility should be explored within the rules of the University.

**4. Recommendations**

Review of performance of OHRC during its first 10 years indicated to us the development of first-rate observational facility, innovative new observation techniques and scientific achievements. Many aspects of them are world-class and a few of them (BBOBS, Seafloor borehole facility) are ahead of the world. OHRC has clearly achieved distinction and respect in the field of global seismology and electromagnetic study.

We make the following recommendations with hopes of maintaining success and achievements by this research group within ERI:

I. **We unanimously and whole-heartedly support to continue OHRC beyond the original 10-year period.** We have no doubt that this group will bring further distinction to ERI and the University of Tokyo as a world-class global geophysics group.

II. **We recommend to take advantage of a few techniques that this group uniquely possesses**. This includes BBOBS and EM (Electromagnetic) measurements on the seafloor. Both are related to observation in oceanic regions. Naturally, this will require some ship-time and close collaboration with JAMSTEC. Development of future plans and close collaboration with JAMSTEC should be sought.

III. **As for future projects, we recommend that OHRC will further pursue study of deep interior and mantle dynamics in general. And this effort should be an interdisciplinary effort**. Developed techniques for oceanic observations, both seismic and electromagnetic ones, will give special advantage to this group. Combined inversion of seismic and EM tomography will inspire scientists in the world and we believe that such efforts will naturally lead to distinction of this group in global geophysics. The effort should also include numerical modeling and simulation, taking advantage of fantastic computational facilities in Japan.