SPIRE Field 3

Advanced Prediction Researches for Natural Disaster Prevention and Reduction

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HPCI Strategic Program Field 3

Advanced Prediction Researches for Natural Disaster Prevention and Reduction

SPIRE Field 3

JAMSTEC

SPIRE, Field3

Strategic Programs for Innovative Research

The "SPIRE" aims to yield the world's most cutting-edge study achievements by best leveraging the next-generation supercomputer "K computer" which will begin operation in 2012. This Program also aims boosting the creation of promotional frameworks for computer science and technology in the study fields under this program.

The Ministry of Education, Culture, Sports, Science and Technology (MEXT) received proposals that "K computer" should not only satisfy (general use) needs from a wide variety of scientists, but also be applied at the societal or national levels, where specific study disciplines can use "K Computer" selectively and strategically. As a result, the Strategic Conference on Next-generation Supercomputers has identified five strategic fields , which would benefit from K's computational resources and are expected to yield significant social and academic breakthroughs.

Applications for the Program's strategic organizations in each strategic discipline were accepted in 2009 and the feasibility study operator was selected to assess the study projects that the strategic organizations would undertake. Each strategic organization prepared in the preliminary phase in 2010, and now it has been carrying out full-scale studies since 2011 (for five years).

SPIRE, Field3

Advanced Prediction Researches for Natural Disaster Prevention and Reduction

Following the feasibility study of the "SPIRE",the Japan Agency for Marine-Earth Science and Technology (JAMSTEC) has been designated as a strategic organization for one of the strategic fields, "Projection of planet earth variations for mitigating natural disasters (Field 3)".

Our strategic goals are "to globally project tropical cyclone trends in simulated global warming, demonstrate prediction of local heavy rainfalls, establish the foundation for next-generation earthquake hazard maps and improve tsunami warning accuracy" in collaboration with universities and research bodies in Japan. Hence, we focus on yielding the world's most cutting-edge achievements, as well as establishing a promotional framework for computer science and technology in this field.

Toward reduction of large-scale natural disasters

Chief Officer of the HPCI Strategic Program, Field 3 : Shiro Imawaki : (JAMSTEC)

Japan has been attacked almost every year by typhoons, local heavy rainfalls, earthquakes, tsunamis, etc. and suffered severe damage. Especially, on 11 March 2011, it was attacked by a huge earthquake (Magnitude: 9.0) whose epicenter was located off the Pacific coast of Tohoku Area, and subsequent huge tsunami. Around the Tohoku Area, the victims amounted to almost 20,000, and the loss of property was devastating and catastrophic. It was really an unprecedented tragic disaster; we have sincerely re-realized the rage of Nature. Moreover, the tsunami caused severe damages of Fukushima Daiichi nuclear power plants, which resulted in massive injection of radioactive material to the environment. Those large-scale natural disasters have huge impacts on the society and economic activities, and therefore, prompt and efficient measures are required immediately to reduce and prevent the disasters.

Because field experiments cannot be done, in order to evaluate influences of natural hazards which cause those large-scale natural disasters, and verify the measures for disaster prevention and reduction, the measures should be examined by large-scale simulations using supercomputers. We have carried out large-scale simulations on "Earth Simulator", which used to be the fastest supercomputer in the world. In Field 3, "Projection of Planet Earth Variations for Mitigating Natural Disasters", of SPIRE (Strategic Programs for Innovative Research), we will carry out simulations of those natural hazards by using the next-generation supercomputer, "K Computer", in collaboration with universities and research institutions in Japan, in order to contribute to the measures for actual disaster prevention and reduction, as well as to stimulate the basic research. Specifically, we will try to project the intensity and number of typhoons, hurricanes and cyclones globally under global warming condition, demonstrate the feasibility of numerical prediction of local heavy rainfalls, provide the bases for next-generation earthquake hazard maps, improve the accuracy of tsunami warning, and reduce the damage by natural hazards through natural disaster simulation for entire urban areas. In that process, we will pursue the most efficient synergistic effect of using two supercomputers, "K Computer" and "Earth Simulator". We will also try to educate young scientists whom our society depends on in future.

Unfortunately, we cannot precisely predict when, where and how big in magnitude an earthquake and subsequent tsunami will occur even by using "K computer". However, if we can carry out faster and more accurate simulations on natural hazards, including typhoons and local heavy rainfalls, we can prepare more effective and efficient measures, and design urban areas which are more resistant to the natural hazards.

R&D Project Managing Director

Study on Prediction of Weather, Climate and Environment Toward Disaster Prevention/Mitigation

Shiro Imawaki
JAMSTEC

Numerical weather prediction study started with the use of the first electronic computer ENIAC almost 70 years ago, and has been utilizing always top class electronic computers at the time. The study target at the very beginning was the prediction of tropospheric barotropic flow over the North America with 300km resolution. Computer power developed exponentially since then, and we are currently performing numerical simulations on "K Computer" with a global atmospheric model of 870m resolution (Fig.1). We are challenging prediction of meso-scale phenomena with "K Computer" also and have succeeded in predicting tornados probabilistically which hit northern part of Tsukuba on 6th May 2012 (Fig.2) through evaluating terms in relevant physical laws more rigorously by increasing resolution to 50m. We are utilizing the computational power of "K Computer" to the extent possible in this program. Research outcome obtained in this study will surely be utilized in improving strategy of prevention and reduction of disasters in weather, climate and environment in Japan.

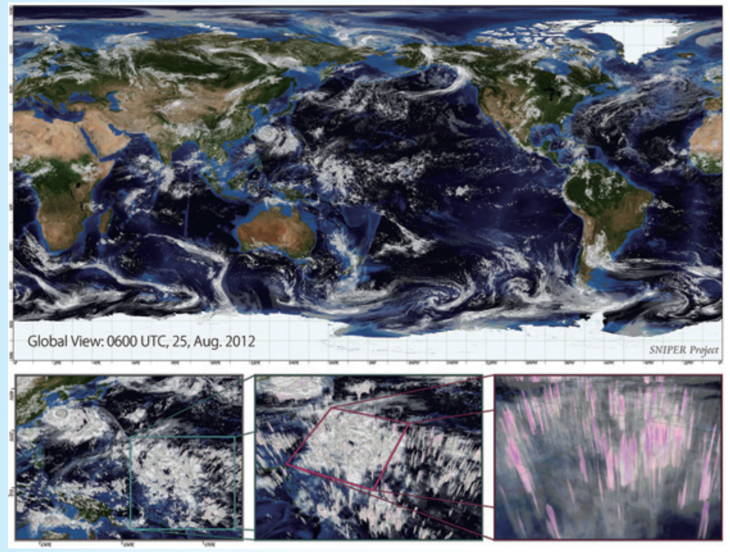


Figure 1
An example of three-dimensional distribution of clouds (mixing ratio of hydrometeors) simulated by NICAM of 870m horizontal resolution. Pink area shoes where mixing ratio is large. Top figure shows global distribution, and lower ones close-ups of the north-western Pacific area. (Miyamoto et al. (2013), submitted to GRL)

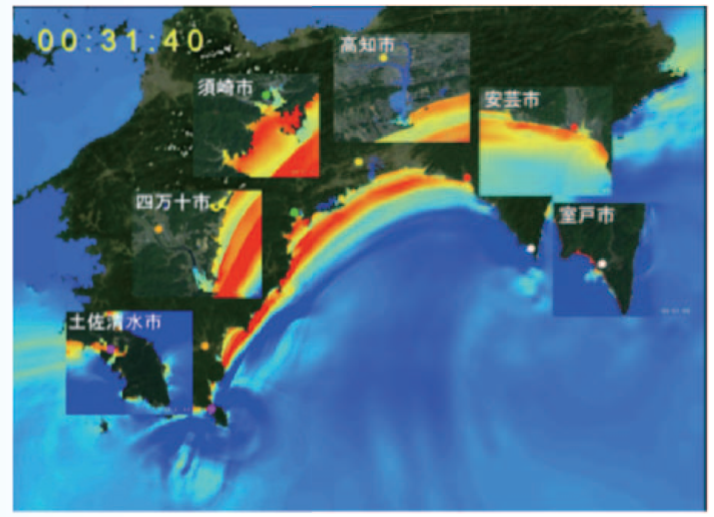
Study for Advancement of Prediction Accuracy on Earthquake and Tsunami

Yoshiyuki Kaneda
JAMSTEC

The Great East Japan Earthquake was a compiled disaster brought on not only the earthquakes and tsunamis. From this, we have learned that the most important issue related to the earthquakes and tsunamis Japan faces is the preparation for complex disasters extended over wide area. They could occur associated with earthquakes including Nankai Trough giant earthquake and their accompanying tsunamis. As a countermeasure, I think it is important to make clear the mechanism of generation of earthquakes and propagation process of earthquakes and tsunamis. Moreover, it is also important to predict the damage distribution of building collapse or inundation. Therefore, in this project I have been promoting ① - ③ as the research for improvement of the prediction accuracy of earthquakes and tsunamis.

①Research on improvement of prediction accuracy of earthquakes
②Research on improvement of prediction accuracy of tsunamis
③Research on simulations of earthquakes and other natural disasters in the entire city

It will become possible to develop more realistic simulation which could be applied to wide-area complex disasters by coordinating these simulations of earthquakes, tsunamis and damage prediction to metropolitan regions which are individually highly improved.



Simulation of tsunami inundation in Shikoku area when the Nankai Trough giant earthquake occurs

Creation of Promotional Frameworks for Computer Science and Technology

Keiko Takahashi
JAMSTEC

Our purpose is the establishment of research environment for using "K Computer" more quickly and more efficiently. For example, we have to optimize the applications, which have been executed on Earth Simulator, in order to make them work on "K Computer". We conduct to the promotion of the project by supporting the optimization of applications with sharing information between the engineers of AICS (RIKEN Advanced Institute for Computational Science) and us.

Also we try to educate young scientists and discuss the future and strategy for educating researchers. In addition, research products by this project are provided in various events for comprehensible understand of the public. On the occasion of your taking this pamphlet, we would appreciate it if you could access our website and take part in the events such as symposiums and the open house. (http://www.jamstec.go.jp/hpci-sp/index.en.html)

K Conputer (RIKEN AICS)

Earth Simulator (JAMSTEC)

Prediction of global climate and environmental changes

Managing Director : Masahide Kimoto
Professor, Atmosphere and Ocean Research Institute, the University of Tokyo

Applications of global atmosphere and climate computations range over wide temporal scales: from daily weather and long-range forecasts to global warming projections. Since longer target range requires massive amount of computations, the present-day models do not make explicit computation of individual clouds even for tomorrow' s weather. Instead, the effects of clouds as a whole are only semi-empirically incorporated in order to finish the computation before the day breaks. This research project tries to foresee what can be accomplished when such computational constraint is relaxed in the near future. Typhoons consist of enormous number of cumulonimbus clouds and how will they change under the influence of global warming? Would the success of predictions for slowly migrating super cloud clusters on the equator bring revolution for tropical weather forecasts? Not only spatial resolution, but incorporation of more detailed processes such as material cycles with bio-geochemical reactions may open the possibility of predicting future concentration of carbon dioxide or air pollution? With the help of computational power of the K-Computer, we seek for new possibility of global climate simulation.

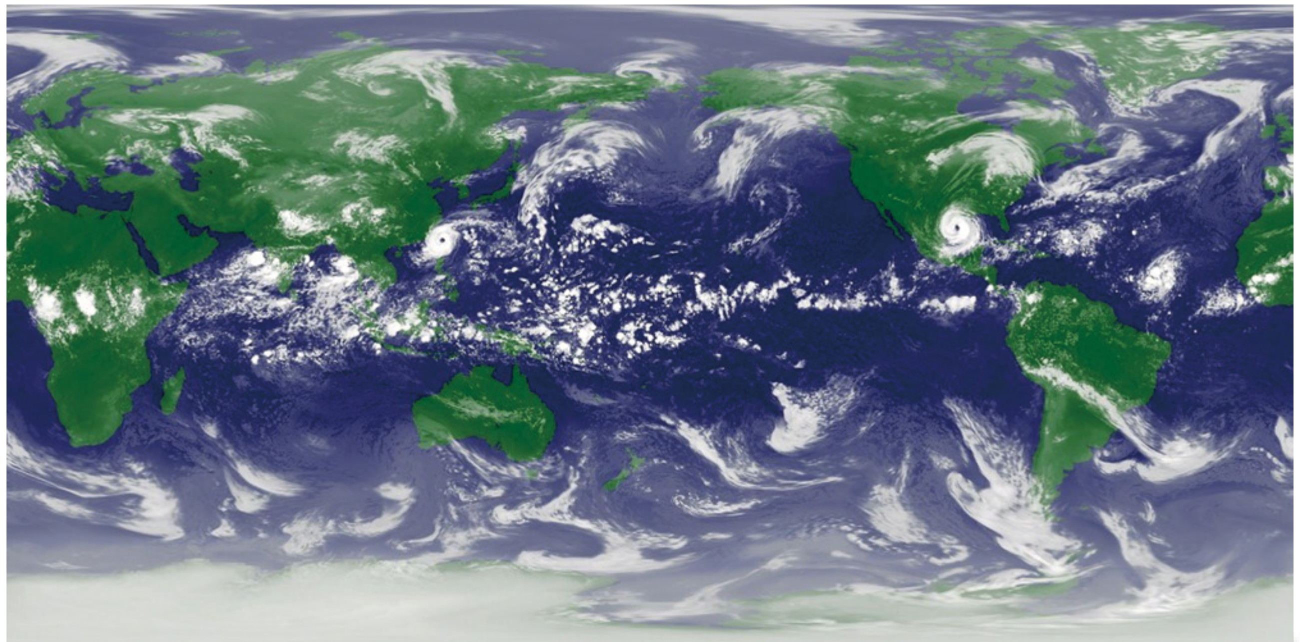


Figure 1　Simulation by the global cloud system resolving model, NICAM.

Expected outcome

The international community perceives that the models that make direct computation of individual clouds have the potential to bring revolution to numerical weather forecasting since its start with the birth of electronic computers. They might end up with disappointment, of course. This research project challenges to open the box. An encouraging initial result has come up to suggest useful one-month forecasts in the tropics, well beyond the oft-cited limit of two weeks for mid-latitude weather forecasting. Can we expect similar innovation in longer range predictions?

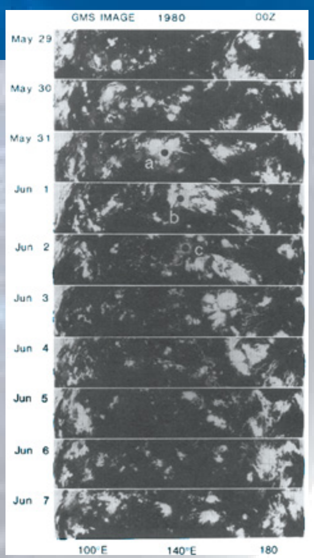


Figure 2　Super cloud clusters propagate along the equator exerting dominant influence on tropical weather. They also affect extratropics.

Study on typhoon activity changes in the future warmer climate

Yohei Yamada
(JAMSTEC)

Using a 14km resolution global non-hydrostatic model, present climate and future warmer climate are simulated. Figure shows tropical cyclone tracks simulated in the nine year integrations of the model for present and future. The simulated global tropical cyclone number is 840 in the present and 640 in the future, suggesting that the global number of tropical cyclones will decrease by about 20% in the future warmer climate. An increase in the mean tropical cyclone intensity in the future is also projected by the model.

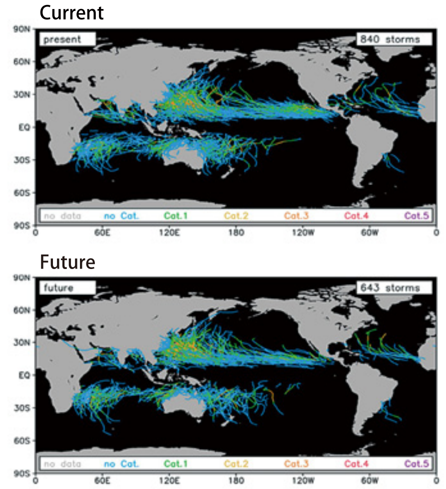
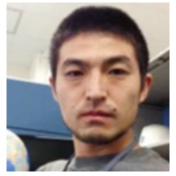


Figure 3　Tropical cyclone tracks simulated by NICAM, for the present (top) and for the global warming (bottom) climates.

Study of extended-range predictability using global cloud system resolving atmospheric model



Tomoki Miyakawa
(Atmosphere and Ocean Research Institute, the University of Tokyo)

The "MJO," a huge complex of cumulonimbi, is a dominant source of precipitation in the tropics. It releases massive latent heat from moisture, evoking various atmospheric waves that affect the entire globe. The difficulty to simulate the MJO has limited forecasts of longer than 2-weeks. We intend to prove, with the aid of the K computer, that a month-long MJO prediction can be made by resolving clouds in detail.

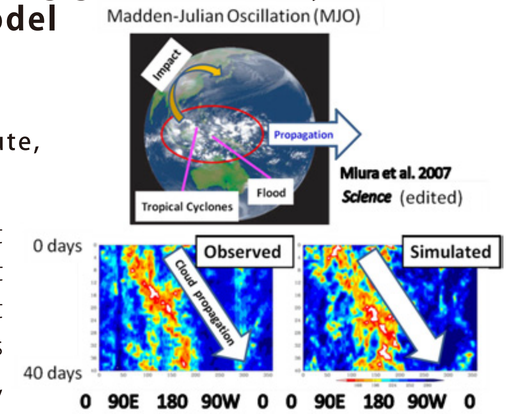


Figure 4　A gigantic eastward-propagating tropical storm simulated by a global cloud resolving model.

Development of application package for global change predictions

Hiroyasu Hasumi
(Atmosphere and Ocean Research Institute, the University of Tokyo)

We have realized a simulation of the ocean circulation where reproducibility of various oceanic phenomena is significantly higher than previous ones. The figure depicts the standard deviation of sea surface height variability (in cm): the upper and lower panels are based on satellite-observed data and the result of global ocean modeling whose horizontal resolution is 0.1 degree, respectively. The model captures the distribution and intensity of sea surface height variability fairly well as a result of model's success in reproducing mesoscale eddy activities associated with the Kuroshio, the Gulf Stream, the Antarctic Circumpolar Current, and the Malvinas Current.

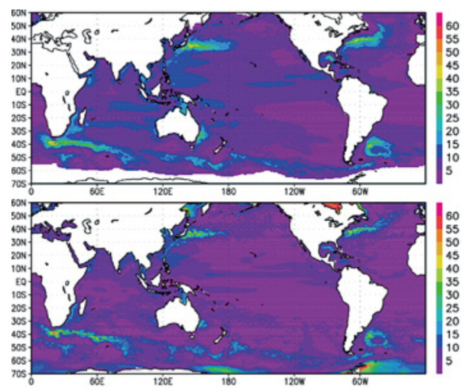


Figure 5　Standard deviation of sea surface height variability. Observation (top) and simulation (bottom).

Ultra-high Precision Meso-Scale Weather Prediction

Managing Director : Kazuo Saito

Director, Forecast Research Department of MRI

Accuracy of numerical weather prediction (NWP) has been remarkably improved in recent years, but precise prediction of severe meteorological phenomena such as torrential rains and local heavy rainfalls is still a difficult and challenging subject due to the following reasons.

1）Accuracy of initial condition is insufficient for small spatial scale of the severe phenomena.
2）Mesoscale convective systems are often very sensitive to small perturbations of the initial condition and computational conditions.
3）Cumulonimbus is not fully resolvable in the horizontal resolution of the current numerical weather prediction systems.

Data assimilation and the ensemble forecast with the cloud-resolving resolution are required to overcome above problems, and the computational resource is a key to reduce the compromise of the resolutions and the number of ensemble members. In this subject, we will perform following three subjects using the "K Computer" and show feasibility of precise prediction of severe mesoscale phenomena by a cloud-resolving NWP system.

1）Development of cloud resolving 4 dimensional data assimilation systems
(by MRI, JAMSTEC, NIED, ISM, DPRI, NPD)

To dynamically predict deep convection and associated local heavy rainfalls, we apply advanced data assimilation methods such as 4D-VAR and local ensemble transform Kalman filter (LETKF) to cloud resolving models. Dense observation data such as radar reflectivity, Doppler radar radial winds, GPS slant delay data are assimilated in storm scale to obtain more accurate initial conditions. A maximum likelihood ensemble filter using neighbor ensemble and a particle filter based on the nonhydrostatic mesoscale model are also under development.

2）Development and validation of a cloud resolving ensemble analysis and forecast system
(by MRI, JAMSTEC, Tohoku Univ., DPRI, Kobe Univ., NPD)

A full-scale regional analysis and prediction system using an incremental LETF is under development. This ensemble data assimilation system shares observation operators with the JMA' s operational nonhydrostatic 4DVAR system, while its target is the quantitative probabilistic forecast for heavy rainfalls using cloud resolving ensemble prediction. Results of the probabilistic forecast are validated and used as the input data for application systems for disaster prevention such as the ensemble river flow model.

3）Basic research using very high resolution atmospheric models
(by JAMSTEC, MRI, AORI, DPRI, NDA, HyARC, NDA, NPD, AICS, etc.)

"K Computer" allows to simulate the physical processes in much more detail than the conventional numerical weather prediction models. Typical examples of the physical processes are the turbulence in the lower atmosphere and the cloud physics in the precipitation systems. The latter process estimates conversion between cloud particles, rain droplets and snowflakes. Since these physical processes were difficult to directly simulate by the past computer systems, the effects of these processes were estimated by the simplified methods, so called 'parameterizations'. Comparing with the detail simulation by K-computer, we are going to evaluate the error in the parameterizations and improve the mesoscale numerical models.

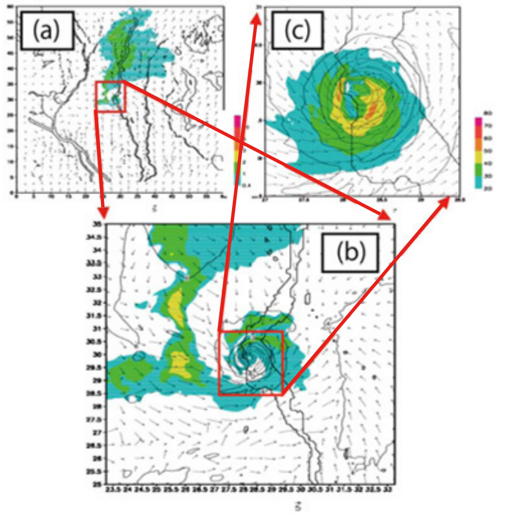
Expected outcome

This study demonstrates feasibility of high precision mesoscale weather prediction using huge computational resources such as the K-computer. Achievements of this study will contribute to progress of future numerical weather prediction and disaster prevention through their technical information.

MRI; Meteorological Research Institute/Japan Meteorological Agency
NPD; Numerical Prediction Division/Japan Meteorological Agency
JAMSTEC; Japan Agency for Marine-Earth Science and Technology
AORI; Atmosphere and Ocean Research Institute/Univ. of Tokyo
NIED; National Research Institute for Earth Science and Disaster Prevention
DPRI; Disaster Prevention Research Institute/Kyoto Univ.
ISM; Institute of Statistical Mathematics,
NDA: National Defense Academy
AICS; Advanced Institute for Computational Science
HyARC; Hydrospheric Atmosphere Research Center/Nagoya Univ.

Development of cloud resolving 4 dimensional data assimilation systems:

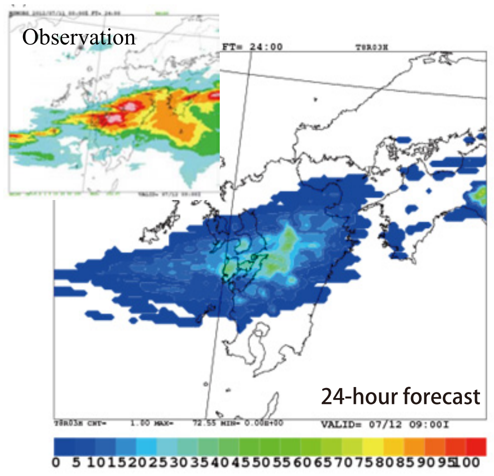
Tadashi Tsuyuki
(Meteorological College)



A two-way nested assimilation system of the local ensemble transform Kalman filter was developed, and it was applied to the tornadoes that occurred in the Kanto region on May 6, 2012. Right figures show a result of downscale experiments which was obtained by NHM with a horizontal resolution of 50m. Strong wind over 50 m/s caused by the vortex of tornado was well reproduced.
After Seko et al. (2013)

Development and validation of a cloud resolving ensemble analysis and prediction system:

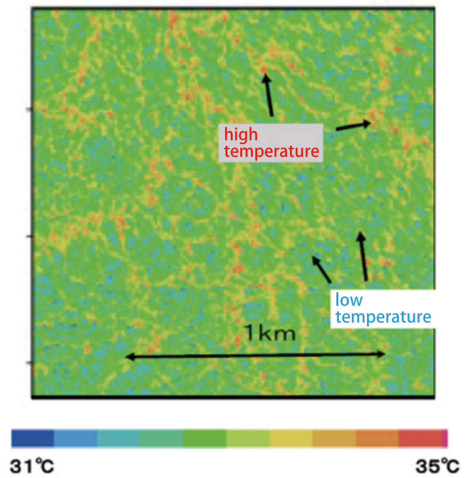
Hiromu Seko
(Meteorological Research Institute)



Ensemble forecast experiments based on the LETKF were conducted for the heavy rainfall case occurred on 12 July over Kyushu district. Right figure illustrates the probability of precipitation occurrence over 50 mm per 3 hours with a lead time of 24 hours. This result exhibits remarkable consistency with the corresponding observation, and suggests it should become a reliable data source for future decision-making.
After Kunii (2013)

Basic research using very high resolution atmospheric models:

Kozo Nakamura
(JAMSTEC)



Right figure shows temperature distribution at 2 m high during a sunny day simulated by a LES model. Although the ground surface is uniform, a fish-net-like heterogeneous distribution is formed with the amplitude of about 3 K. We are going contribute to improve the accuracy of the estimation methods for the exchange of heat, moisture and momentum between atmosphere and land/sea surfaces as well as the transport processes in the lower atmosphere.
After Ito et al. (2013)

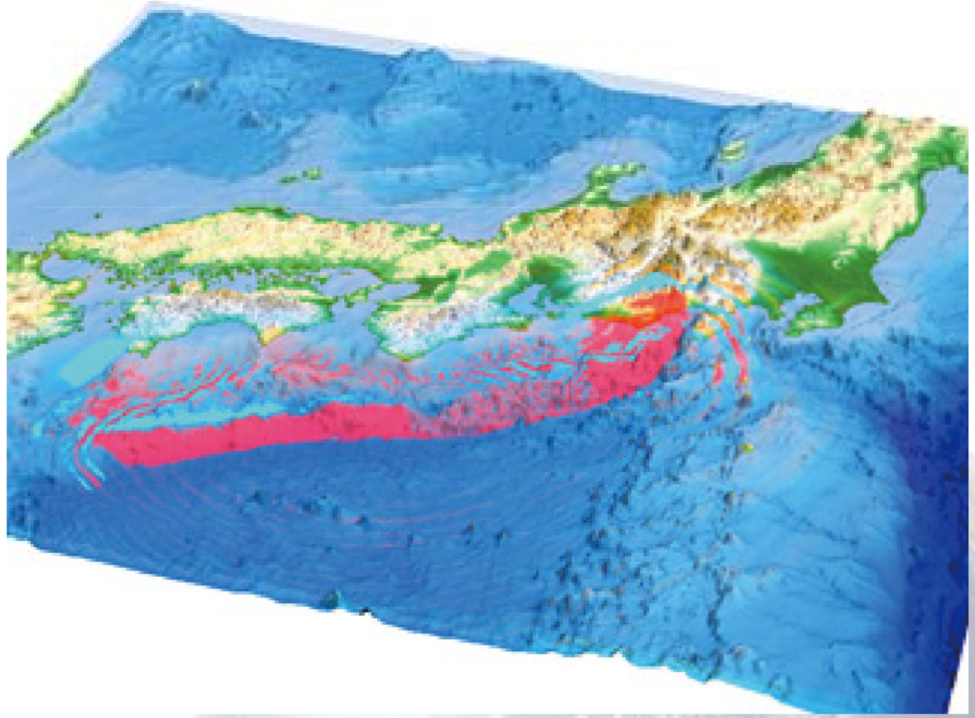
Study on improving earthquake occurrence history

Managing Director : Takashi FURUMURA
Professor, Earthquake Research Institute, The University of Tokyo

We are studying earthquake occurrence history using advanced large-scale simulations made possible by the "K Computer" . Large earthquakes occur as a result of complex fault movement, and as the seismic waves travel from the epicenter through the complex structure of the earth interior, the waves are amplified, causing strong motions over the surface of the Earth.

In order to accurately simulate such complicated propagation of the seismic waves, high performance computation is needed. With the arrival of the "K Computer" , the scale of the computer simulation has increased 50-fold from the previous simulation using the Earth Simulator (JAMSTEC).

We are currently examining the mechanism of Great off Tohoku Japan Earthquake of 2011, and large earthquakes which repeatedly occurred along the Nankai Trough in the past, and have reproduced the strong quakes and the subsequent tsunami. We are now trying to verify the result of our simulation by comparing our data in detail to those actually observed during the earthquakes. If we can realize a highly accurate simulation, we will be able to estimate and assess strong quakes and tsunami anticipated to strike in the near future. This will lead to damage prediction and mitigation.



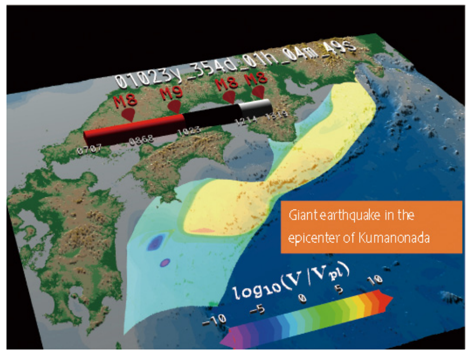
Creating Virtual Earth on "K Computer"

Observation status, such as seismometers and tsunami sensors are densely installed around the country, gathering real-time data nationwide. With advanced technology of analyzing these data, coupled with high-speed simulation technology, we can expect further progress in the field of earthquake study.

Our goal is to create a virtual Earth on "K Computer" , based on observation data that is constantly fed to the computer, and to understand possibility a large earthquake in the near future. We also aim to predict aftershocks and triggered seismicity after a quake. We believe that such earthquake simulation can be realized in the future.

Simulation to earthquakes occurrence

Mamoru Hyodo
(JAMSTEC)

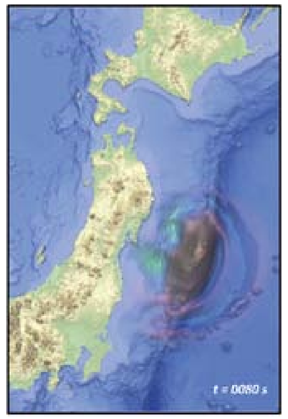


The continental plate carrying southwestern Japan is pushed against the oceanic plate, subducting along the Nankai Trough. The friction causes the continental plate to be dragged deep underground. When the friction reaches its limit, a large quake will occur.

This figure shows the mechanism of the Nankai Trough Earthquakes, reproduced and visualized by numerical simulations. If we can assimilate the complicated shape of the plate and the state of friction accurately into the simulation, we can reproduce the earthquake cycle and the patterns of the recurring destructive quakes, and make accurate predictions for the impending quakes.

Simulation of strong seismic motions

Takashi FURUMURA
(Earthquake Research Institute, The University of Tokyo)

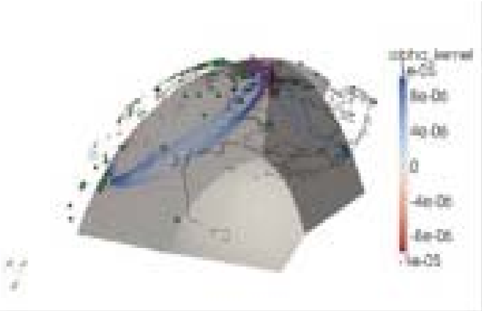


We have developed a new computation methodology for seismic phenomena, in which we can calculate strong ground motion, seismic land deformation, and tsunami all at the same time. Massive parallel computation using up to 80,000 CPU of "K Computer" is made possible by tuning the calculation code and maximizing the calculation efficiency.

This chart is the simulation of the 2011 Great off Tohoku Japan Earthquake, visualizing how the seismic waves propagated from the epicenter by fault motion, and how the land deformation on seabed raised the sea level and caused tsunami.

Simulation for investigation the internal structure of the Earth

Seiji Tsuboi
(JAMSTEC)



We are studying the simulation of the internal structure of the Earth, using seismic waves. This chart shows which part of the internal Earth most affected the seismic waves as it traveled from the epicenter to a distance and was recorded on the seismometer. This information is indispensable in further examining the internal structure of the Earth, but only became available with the emergence of "K Computer" , as it requires vast computation. We hope to get a detailed estimate of the structure of the subsurface of Japan and the plains where the population is concentrated, so as to improve accuracy of ground motion simulation.

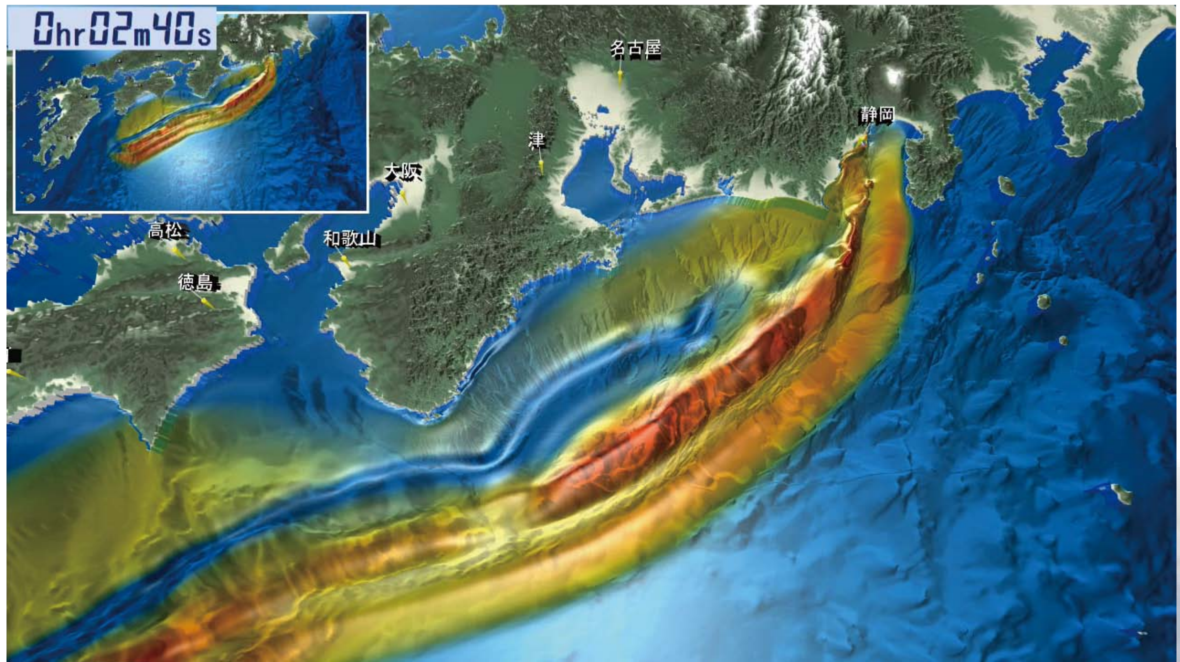
The advancement of the accuracy of tsunami for prediction

Managing Director : Fumihiko Imamura
Professor, International Research Institute of Disaster Science, Tohoku University

Tsunami is the secondary damage from an earthquake.　Many human lives have lost by the giant tsunami when the Great East Japan Earthquake occurred in 2011. In order to protect lives from the tsunami which has huge power in a wide area, information such as prior assumption and evaluation, and the real time alert are indispensable. If one knows when and how the tsunami attacks, he can avoid the harm by such means as evacuation. Now, in Japan, The system of quantitative forecasts is working mainly operated by the Meteorological Agency. However, in order to take quicker and more certain evacuation behavior, still more detailed and exact information is needed in more short time.

When carrying out of tsunami including the complicated building and geographical feature in the coast, it is necessary to adopt more complicated phenomenon. Then, HPCI "K Computer" which can process overly large-scale data at high speed is indispensable. Now we are researching the possibility to analyze the transmission of tsunami and the process of going upstream on real time, by using the three-dimensional data expressing the high density ground data and the building and roads on different spatial scale.

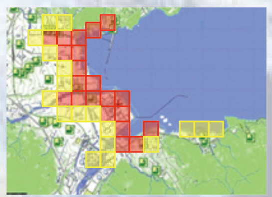
By reproducing the giant tsunami by the Great East Japan Earthquake in 2011 and predicting the largest tsunami may happen in Nankai Trough area, we can see the action of tsunami such as tree-dimension flow, impulse force, the movement of earth and sand, and flotsam which we did not know will today.

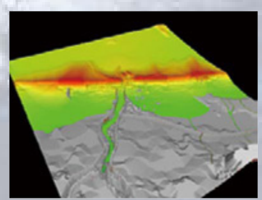


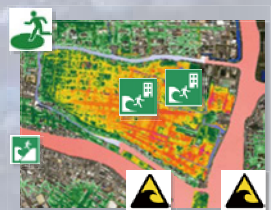
Expected outcome

It will become possible to solve the underestimate which was problem when the Great East Japan Earthquake happened by means of predicting the exact action of tsunami from the observational data of the tsunami on the offing or a coast in real time. In addition, it also becomes possible to see not only from the height of a wave but from an exact tsunami wave source, wave force (water pressure) and flotsam in a complicated area along the shore.

In order to provide information necessary to evaluation plan after earthquake with damage and combined damage, increase accuracy and speed of the prediction for inundation area and depth, tsunami hazard (flow and fluid force) by integrating real-time observation data.


Predicted distribution map of inundation depth on resolution 5m : Depth 1 m or more shown in red

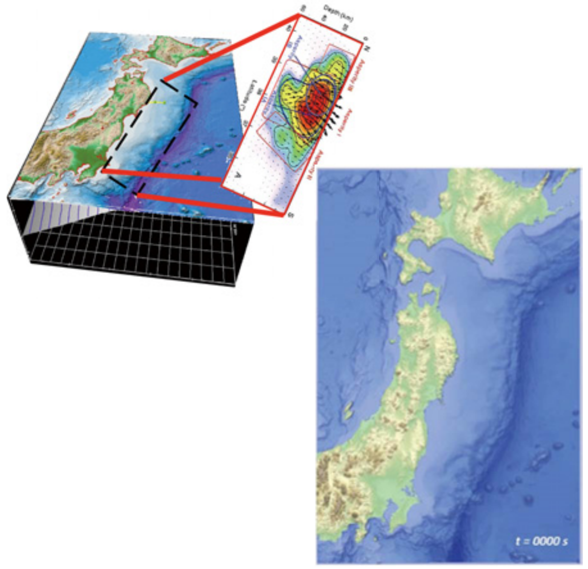

Predicted distribution map of flow velocity on resolution 5m : Depth 11 m or more shown in red


Tsunami hazard: Estimation of damage, Damage mitigation measures

Reproducing the tsunami of the Great East Japan Earthquake

Yusuke Oishi
Fujitsu Ltd.

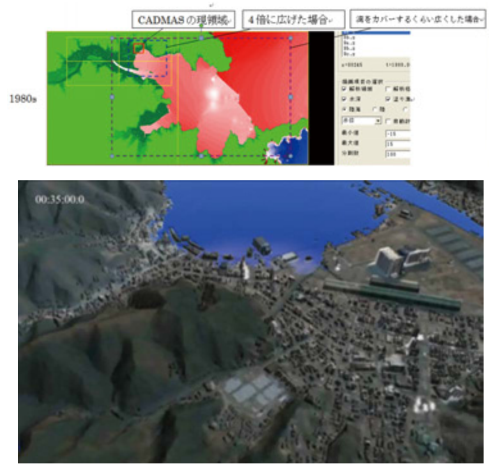
The tsunami which occurred by M9 massive earthquake brought serious damage. At that time, it is said that the fault of north-south 500 km moved, two steps of tsunami occurred, and attacked in various parts of a coast. We are trying to reproduce the giant tsunami from the observation and trace data of tsunami which were obtained just after the earthquake. We are studying how far it is possible to predict the tremendous damage in real time.



Reproducing behavior of tsunami represented in three dimensions in Kamaishi Bay

Taro Arikawa
Chuo University / Port and Airport Research Institute

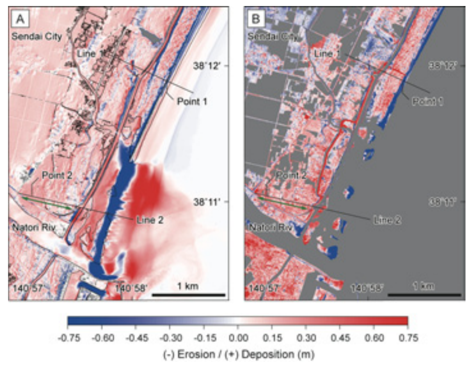
Tsunami which is two-dimensional figure in offshore becomes three-dimension in response to geographical feature and buildings in shallow area. It would be difficult to reproduce such a complicated move by the conventional tsunami simulation without "K Computer". Now we are on detail study about the effectiveness of defending facilities at that time by analyzing the wave movement against the 60 meter high breakwater which was located in Kamaichi Bay.



Earth and sand movement caused by the tsunami

Daisuke Sugawara
International Research Institute of Disaster Science, Tohoku University

The tsunami which added wave height in shallow area amplifies power to move the sand in the bottom of the sea at the same time. As the result, it moves massive sand in the bottom of the sea not only to the water but also to the land. It may also encroach on the land at the same time. As a result, sedimentary layers of sand are formed in addition to change of geographical land change. These sedimentary layers serve as a key to know the tsunami which record does not remain in the historical records.



[A] An example of erosion and disposition through simulation
[B] An example of erosion and disposition based on DEM difference between the data before and after disaster. Defective data due to submergence shown in gray.

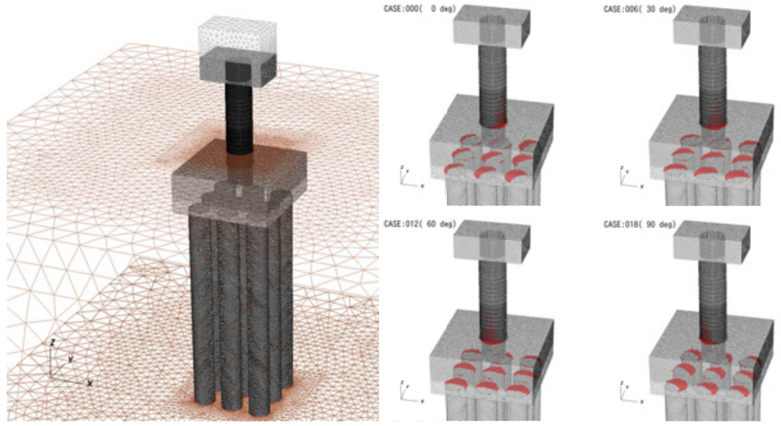
Natural disaster simulation for entire areas

Managing Director : Muneo Hori
Professor, Earthquake Research Institute, The University of Tokyo

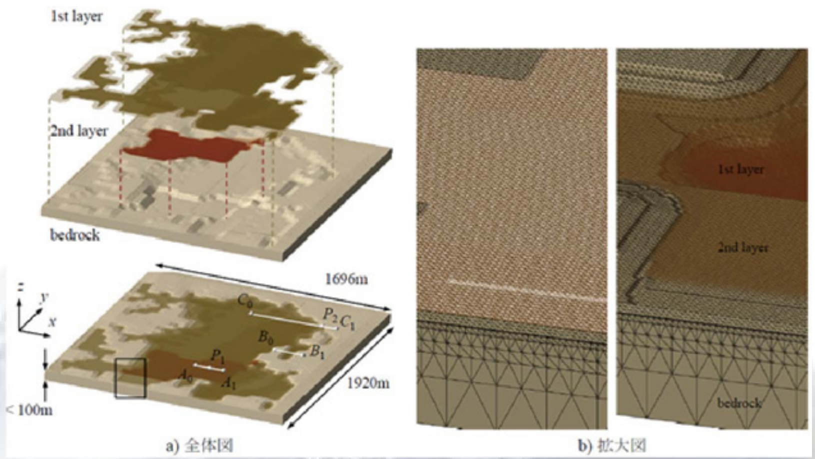
The primary objectives of structure and urban area simulation is to develop the following two analysis method:
1) a method of numerically computing the seismic structure responses of a structure, including local failures or global collapse; and
2) a method of numerically computing the seismic responses of an urban area, which includes damage of each building and evacuation of each resident.

The structure simulation is aimed at computing shaking, damaging, and collapsing due to strong ground motion for a detailed model of a structure which is constructed in centimeter scale. Base soil effects are included. A highrise building and an RC pier are the current target.

The urban area simulation provides a tool of constructing a next-generation hazard map for an urban area, using a model which includes every building and road in it and considering scenario of an earthquake.



Damage analysis of a reinforced concrete bridge pier: The simulation at the time of changing the direction of an earthquake motion



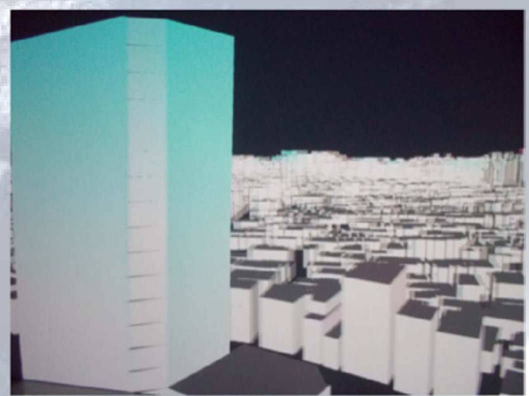
Three-dimensional ground structure. The right figure is an enlargement of the left square figure (the 1st layer a nd 2nd are soft layer, the 3rd layer is a hard layer)

Examination of application of advanced visualization technology

Application of advanced visualization technology is also examined to make city simulation result more correctly and intuitively. Creation of the three-dimensional picture and a three-dimensional animation is our present target.

Change of the view from head tracking

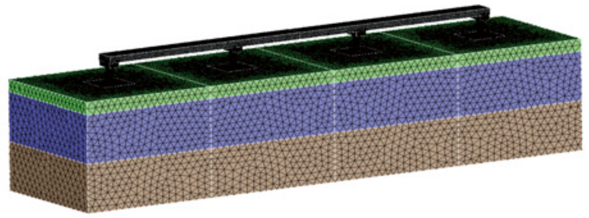
Three-dimensional picture



Numerical simulation of (the) seismic response

Numerical simulation of the seismic response of reinforced concrete bridge pier

Shigenobu Okazawa
(Nagano University)



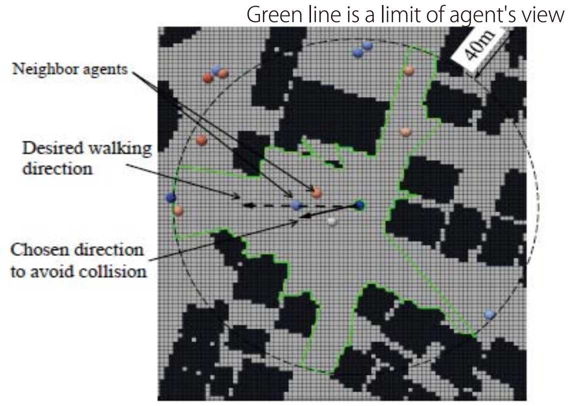
The analysis model of the large-sized bridge when the bridge pier was connected

The large-scale numerical calculation of "K Computer" can be used to examine the safety of the bridge which is one of the important infrastructure connecting cities. By using detailed analysis model that reproducing foundation and the surrounding ground, it became possible to predict the difference of damage level by the difference in the direction of earthquake vibration. In addition, it made possible to operate earthquake response simulation for multiple large-sized bridge pier. In consideration of modification of each bridge pier and its interaction, the safety of a large-sized bridge can be examined in detail.

The example of the complicated judgment by the agent

Lalith Wijerathne
(Earthquake Research Institute, The University of Tokyo)

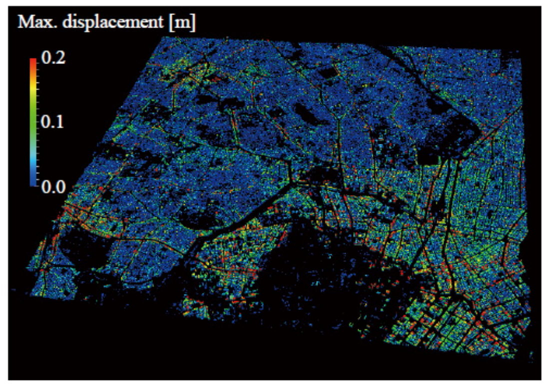
Green line is a limit of agent's view



By making throughout model of city roads, it became possible to simulate the evacuation of people after an earthquake which may accompany a tsunami. In addition, by making high level analysis model called "agent" for each citizen or traveler, it even enables to conduct a very complicated simulation of evacuation though environment filled with debris of damaged or collapsed buildings.

Earthquake simulation in city

Tsuyoshi Ichimura
(Earthquake Research Institute, The University of Tokyo)



When an earthquake hits cities, which are located near the plate boundary or the earthquake fault, it first shakes the ground, then building. The large-scale numerical calculation of "K Computer" enables the detail simulation of the vibration of buildings and the ground. "K Computer" built the three-dimensional model of the foundation and the super-large-scale-analysis model which modeled each building. Therefore it became possible to calculate the earthquake in cities, due to various scenario earthquakes.