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**Huadong Guo
Changlin Wang**
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GAO Jun, Information Engineering University (China)
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10 September 2009

Plenary Sessions

Michael Goodchild, LI Deren

CHEN Yuntai, Paul Uhler

Parallel Sessions

Digital Earth Frameworks, Models, and Data Warehouse

Gabor Remetey-Fulopp, SHAO Yun

Web Based Service for Digital Earth

Giuseppe Vilaro, YANG Chaowei

Digital Earth Geobrowser, Virtual Global and Simulation I

Tim Foresman, GONG Jianhua

Digital Earth Geobrowser, Virtual Global and Simulation II

David Wortley, Ya Chun Yu

Digital Earth and Global Environment I

Anthony Lewis, ZHANG Ying

Digital Earth and Global Environment II

Wayne Walsh, YANG Liming

Spatial Data Infrastructure for Digital Earth

Alessandro Annoni, HE Guojin

Virtual Environment for Digital Earth

LIN Hui, Ifan D H Shepherd

Earth Observation for Digital Earth

ZHANG Bing, Claudia Kuenzer

Digital Ocean

TANG Danling, Homayoun Khoashravan

Special Session for International Journal of Digital Earth

John van Genderen, Christina Low

Planet Action Contribution to Digital Earth

Louis-Francois Guerre, LIU Jianbo

Data Service Infrastructure for Global Change Research I

LIU Chuang, Nordin Hasan

Data Service Infrastructure for Global Change Research II

LIU Dingsheng, Linda Anne Stevenson

11 September 2009

Plenary Sessions

HE Changchui, Fraser Taylor
Bas Kok, GUO Huadong

Parallel Sessions

Digital Earth Education

Jean Sequeira, DENG Meixia

Digital Agriculture

WU Bingfang, G. Bareth

Digital Forestry

SUN Guoqing, Marian Rybansky

Digital Ecology and Land Use/Land Cover

Jimme Weber, LEI Liping

Digital City

Manfred Ehlers, TAN Kun

Digital Disaster Mitigation

Martino Pesaresi, FAN Yida

Data Processing Techniques for Digital Earth

Alfred Stein, ZHANG Li

Global Change, Atmosphere and Ocean Study Related to Digital Earth

Gopalakrishna V., YUAN Jinchun

Visualization and Simulation for Digital Earth

Peng Gong, XUE Yong

Virtual Reality and 3D Techniques for Digital Earth

Sei-ichi Saitoh, DANG Anrong

Data Mining Techniques for Digital Earth

Maxim Shoshany, MA Jianwen

Integrated Technologies for Digital Earth I

Ray Williamson, YANG Xihua

SPOTIMAGE Contribution to Digital Earth

LIU Jianbo, XU Liping

Enterprise Contribution to Digital Earth

Fred Campbell, CHENG Xiaoyang

Integrated Technologies for Digital Earth II

GAO Wei, Daniele Ehrlich

12 September 2009

Plenary Sessions

Robert Chen, Peter Woodgate
Mario Hernandez, Armin Gruen

Parallel Sessions

Digital Heritage

Mario Hernandez, WANG Changlin

Digital Ecology and Environment

SHI Jiancheng, William Sprigg

Airborne Remote Sensing

Randal T. Albertson, LI Jingwei

Integrated Technologies for Digital Earth III

Kyle Hence, ZHANG Yuanzhi

Network System and Data Processing Techniques for Digital Earth

Jan Kolar, Hiromichi Fukui

Geospatial Data Solution for Digital Earth

Michael Abrams, LI Zhen

Foreword



The Digital Earth Symposia have been held every two years, since the First International Symposium on Digital Earth was convened in Beijing in 1999. The symposia were held next in Canada, the Czech Republic, Japan and the United States from 2001 to 2007. The Sixth International Symposium on Digital Earth (the Sixth ISDE) was held in Beijing, 9-12 September, 2009. The theme of this symposium was *Digital Earth in Action*, and topics covered a range of technological advances and emerging applications, linking Digital Earth with many other related sciences and technologies.

It is exciting to see that, over the past ten years, the Digital Earth concept has become more and more widespread, as the Digital Earth technological applications have touched wider and wider aspects of society. People will learn more about this powerful tool, to fully apply it to their lives to promote information sharing, and solve various natural problems. These include topics such as natural resource shortages, environmental degradation, energy security and Global Change. On these points, the Sixth ISDE, as an international academic platform, played an important role in consolidating improvements and the further implementation of Digital Earth from concept into action.

These Proceedings consist of two volumes, with 147 research papers in total. All the papers included were selected through international Peer-Review by a Scientific Committee. Volume 7840 is comprised of sessions on the Digital Earth framework, models and spatial data infrastructure; web based services, system design and algorithms for digital earth; 3D Technology, virtual reality and visualization, information extraction, and data mining methods. Volume 7841 covers sessions on image processing and analysis, synthetic aperture radar data processing and analysis, digital earth applications in ecology, agriculture, and resources; disaster and hydrology, and digital earth applications for urban studies and heritage. Volume 7840 focuses more on the development of digital earth theory and technology, while Volume 7841 stresses applications of digital earth in each field, and includes some case studies. Through academic exchanges and discussions on current and developing trends in Digital Earth science and technology, it is becoming much easier for people to understand the Digital Earth concept, which integrates and combines Digital Earth technology with other fundamental research, technical developments, resources, environmental management, and disaster monitoring.

At the opening of these Proceedings, a speech entitled "Jointly Building the Digital Earth and Bringing Benefits to Mankind" by Her Excellency Madam LIU Yandong, state councilor of the State Council, China was given, and another entitled "Creating a Bright Future for Digital Earth" by Prof. LU Yongxiang, President of the International Society for Digital Earth, and President of the Chinese Academy of Sciences, was given, and these are included. And, two Declarations on Digital Earth, milestones in the history of development of Digital Earth science and technology, are also presented. At the First International Symposium on Digital Earth, the *1999 Beijing Declaration on Digital Earth* was promulgated. Ten years later, at the Sixth ISDE, the *2009 Beijing Declaration on Digital Earth* was approved and adopted by all attendees. It is clear through the contrasts in the two declarations that, during the past ten years, considerable progress has been made on Digital Earth. People's understanding of Digital Earth has changed from "vague" to "clear". This is particularly true in that Digital Earth is not only being applied in addressing social and economic problems, but is playing a more active role in much wider fields, for example, Global Change. This is in one of the objectives of the International Society for Digital Earth, one of the organizers of the Sixth ISDE, and which promotes international cooperation through Digital Earth to reach the ultimate goal of global sustainable development.

I would like to take this opportunity of the publication of these Proceedings to express my gratitude to the International Scientific Committee members of the Sixth ISDE for their contributions to the convening of this symposium, and also to the Organizing Committee members for their tireless efforts in preparing this fantastic symposium. I am grateful for the paper authors for the time and ideas they have contributed to the Symposium. Editorial Board members and reviewers, especially Profs. John van Genderen, Anthony J. Lewis and Fred Campbell are thanked for their work and devotion to the publication of these Proceedings. Special thanks are also expressed to Prof. GAO Wei, Organizing Committee Member from Colorado State University, for his direction and help with the final publication of these Proceedings. I also would like to extend my sincere thanks to SPIE for publishing the Proceedings. My thanks also go to Prof. LIU Yongwei, Prof. WANG Changlin, Ms. LIU Jie, Ms. LIU Zhen and Mr. JIANG Hao for their professional suggestions and editorial assistance.

Finally, I am honored to present these Proceedings and hope everyone enjoys them.

GUO Huadong
Chairman
Organizing Committee of the Sixth ISDE
Chairman
Chinese National Committee for ISDE
Director General
Center for Earth Observation and Digital Earth
Chinese Academy of Sciences

Opening Speech:

Jointly Building the Digital Earth and Bringing Benefits to Mankind



Her Excellency Madam LIU Yandong
State Councilor, State Council of China

Distinguished experts, delegates, ladies and gentlemen,

On this, the opening Ceremony of the 6th International Symposium on Digital Earth (ISDE6), on behalf of the Chinese government, I would like to express my congratulations on the opening of the Symposium and extend a warm welcome to experts, scholars and delegates from around the world! With the theme of "Digital Earth in Action", this Symposium will focus on the critical global issue of "building the Digital Earth and coping with Global Change". It is committed to promoting research, exchange and cooperation in Digital Earth theories and technologies, and their applications. It will have a profound and positive effect on strengthening our understanding of the role of Digital Earth in Global Change and promoting Digital Earth to better serve the survival and development of mankind.

Since the late 20th century, we have entered the age of information, and great changes have taken place in many areas, such as economic development, people's lives and governance, etc., due to rapid development and extensive application of information technology. Through the joint efforts of the governments, scientific communities, and enterprises of all countries, Digital Earth, developed using space science and technology, information science and technology, and geoscience, has made remarkable progress in various aspects of resource investigations, climate prediction, weather forecast, natural disaster monitoring, agricultural production estimates and regional planning, etc. It has become the best way to integrate, use, and share existing data and information, as well as a core data source for sustainable development, thus playing an increasingly important role in economic and social development.

Presently, all countries are facing a number of major issues that need to be addressed through joint efforts. These include topics such as climate change, energy conservation, emissions reduction, eco-environmental protection, food security, disease control, heritage conservation, major natural disasters and global financial problems, etc. These have become established as the imperative requirements to build Digital Earth. I believe that building Digital Earth will help mankind to better understand and grasp natural systems, as well as economic and social systems. It will help us to develop a comprehensive understanding of the planet where we live, and accurately grasp major natural changes, production, life, etc. Digital Earth will also promote communication among people of all countries, and provide support to Governments to improve the accuracy, timeliness and coordination in decision-making.

At present, the Chinese Government has set a goal of building China into an innovation-oriented country and promoting IT applications in our National economic and social development is very important. We are integrating IT applications with industrialization, transforming development patterns, and taking a path of comprehensive, coordinated and sustainable development.

In response to the global financial crisis, the Chinese Government developed a plan to expand domestic demand and boost economic growth. This plan considers promotion of information applications as an important element, and has sharply increased the IT research and development budget and construction of information infrastructure facilities. The global financial crisis slowed China's revenue growth, but our investment in science and technology has still grown by 25% this year, and scientific and technological input in information fields accounts for a high percentage of this amount. History has shown that a serious economic and financial crisis will provide new opportunities for technical breakthroughs, emerging industrial development and industrial structure upgrading.

I am convinced that Digital Earth will provide essential support for global cooperation for sustainable development, a new growth sector for economic and social development, and a new tool for the progress of human civilization. Despite all the difficulties and challenges on the road ahead, our confidence and efforts to build the Digital Earth will never wane, and Digital Earth development in all countries, including China, will surely propel it to reach new levels!

Ladies and Gentlemen,

Cooperation for mutual benefit and simultaneous development has become a common expectation of people everywhere. Convening the ISDE6 will promote sharing and use of global information resources, and speed up development of Digital Earth. I am firmly convinced that building Digital Earth, narrowing the digital divide,

and strengthening international cooperation will enable people around the world to reach the high-level economic and social development, progress, and better lives!

Finally, I wish the Symposium every success!

Thank you!

(Note: Translated according to Chinese speech manuscript, presented at the symposium by Prof. CAO Jianlin, Vice-Minister of Science and Technology of China)

Opening Speech:

Creating a Bright Future for Digital Earth



LU Yongxiang

**Vice-Chairman of the Standing Committee, NPC,
President of the Chinese Academy of Sciences,
President of the International Society for Digital Earth**

Honorable State Councilor Madam LIU Yandong,
Distinguished Guests,

Colleagues and Friends ,

Ladies and Gentlemen,

Today we are very pleased to gather here to hold the 6th International Symposium on Digital Earth. Ten years ago (in 1999), it was in the same place that we held the first International Symposium on Digital Earth. What happened then is still vivid and fresh in my memory. Today, we are so happy to get together again in Beijing in this golden season to renew our friendship, to exchange our past and newest progress and development on Digital Earth and to look forward to a brighter future. First of all, on behalf of the International Society for Digital Earth and the Chinese Academy of Sciences, I would like to extend our warmest welcome to all participants in this symposium, particularly to our colleagues and friends who have traveled thousands of miles from all over the world.

The concept of Digital Earth came into existence about ten years ago. The successful holding of the first ISDE and the release of Beijing Declaration on Digital Earth in 1999 marked the official extension of Digital Earth worldwide. Science is borderless and people the world-over have come to a consensus. In spite of different cultures, scientific disciplines, industrial and technical backgrounds, scientists, decision-makers and entrepreneurs from all parts of the world have taken action faced with new scientific and technological developments. They have jointly promoted the development of Digital Earth by mutually beneficial exchange, cooperation and actions.

It is such a pleasure and comfort for us to see the great achievements made worldwide in Digital Earth over the past decade. With the development of spatial information technology, network communication technology and earth system science, the shared Digital Earth platforms for both public and commercial use have come into existence. Some imaginative ideas have become, or are becoming, realities, with Digital Earth having entered households and changing the modes of production and lifestyles.

The past ten years have also witnessed academic progress in International Digital Earth. After the first ISDE held in China, the 2nd, 3rd, 4th and 5th symposium were held in Canada, the Czech Republic, Japan and the USA. International Digital Earth Summits were held respectively in New Zealand and Germany. In 2006, the International Society for Digital Earth was officially registered and established in Beijing. The society has become a home for all the academics in the field. In 2008, the Society published its official journal – *International Journal of Digital Earth*, in cooperation with Taylor & Francis Publishing Group. So far, seven issues have been published.

Over the last ten years, the themes of the 7 International Digital Earth Symposia have ranged over topics such as “Toward Digital Earth”, “Beyond the Information Infrastructure”, “Information Resources for Global Sustainable Development”, “Digital Earth as a Global Commons”, “Digital Earth down to Earth”, “Digital Earth and Sustainable Development” and “Digital Earth and Global Change” to the current one - “Digital Earth in Action”, leaving a footprint showing the development of Digital Earth, from its initiation to its present level.

Today, ten years after its initiation, we are celebrating not only the development of Digital Earth, but also human confidence and actions to further promote its development, which has gone beyond the boundaries of space and time. Digital Earth has already become one of the most challenging and extensive scientifically driven fields. At a high, globally-strategic objective, Digital Earth integrates and optimizes Earth Observation technology, geographic information systems (GIS), global positioning system (GPS), network and communication technology, virtual reality technology and grid computing technology. As such, Digital Earth can make great contributions to socially-sustainable development.

Earth is the only planet on which mankind depends for our existence and survival. We are all responsible for its rational and reasonable exploitation and utilization, as well as its effective protection and environmental optimization. This is particularly the case in our facing the tremendous challenges brought about by Global Change in recent years. In the era of a global knowledge-based economy, supported by information and space technology today, Digital Earth is considered as the core of future information. With the challenges of global environmental protection and sustainable development, development of Digital Earth has a long way to go. We should enhance all-round global cooperation to promote data sharing, minimize the digital

divide and boost a deeper and more extensive development of Digital Earth.

On Nov 29, 1999, in my report on the "Cooperation in the Development of Digital Earth and Sharing of Global Data Resources", at the first ISDE, I stated that: "We should set forth a unified scientific framework and a multi-level structure for Digital Earth. We need to explore the formulation of data sources and source-data standards and information exchange protocols based on independent development and global construction and sharing. We need to build a global network to ensure seamless global submissions and regular updates of earth observation data. We need to continuously improve user-friendly and visual interfaces. We must try to create transparent websites for visits and navigation, and we need to coordinate the formulation of international agreements and management standards for system efficiency and information security."

Today, I would like to further emphasize the need to pay particular heed to the applications of advanced Earth Observation technology, new generations of networking, search, browser and cloud computing technologies in the construction of Digital Earth to upgrade public services and reduce service costs. Let us unite our efforts to make Digital Earth available in every corner of the world, to make Digital Earth the information platform for decision-makers, and make Digital Earth the information home for all.

I wish you all closer cooperation and exchanges for a better and brighter Digital Earth tomorrow.

My best wishes for a successful Symposium.

Thank you.

Beijing Declaration on Digital Earth

Approved at the Closing Ceremony of the
6th International Symposium on Digital Earth
September 12, 2009

We scientists, engineers, educators, entrepreneurs, managers, administrators and representatives of civil societies from more than forty countries, international organizations and NGOs, once again, have assembled here, in the historic city of Beijing, to attend the Sixth International Symposium on Digital Earth, organized by the International Society for Digital Earth and the Chinese Academy of Sciences, with co-sponsorship of sixteen Chinese Government Departments, Institutions and international organizations, being held from September 9-12, 2009:

Noting That

Significant global-scale developments on Digital Earth science and technology have been made over the past ten years, and parallel advances in space information technology, communication network technology, high-performance computing, and Earth System Science have resulted in the rise of a Digital Earth data-sharing platform for public and commercial purposes, so that now Digital Earth is accessible by hundreds of millions, thus changing both the production and lifestyle of mankind;

Recognizing

The contributions to Digital Earth made by the host countries of the previous International Symposia on Digital Earth since November 1999, including China, Canada, the Czech Republic, Japan and the USA, and by the host countries of the previous Summit Conferences on Digital Earth, including New Zealand and Germany, for the success of the meetings as well as further promotion of Digital Earth;

Further, that the establishment of the International Society for Digital Earth and the accomplishments of its Executive Committee, the launch of the *International Journal on Digital Earth*, and its global contribution to

cooperation and data exchange;

That the themes of the previous seven meetings: Moving towards Digital Earth, Beyond Information Infrastructure, Information Resources for Global Sustainability, Digital Earth as Global Commons, Bring Digital Earth down to Earth, Digital Earth and Sustainability, Digital Earth and Global Change, and Digital Earth in Action, have laid out a panoramic scenario for the future growth of Digital Earth;

That Digital Earth will be asked to bear increased responsibilities in the years to come, in the face of the problems of sustainable development;

Further Recognizing

That Digital Earth should play a strategic and sustainable role in addressing such challenges to human society as natural resource depletion, food and water insecurity, energy shortages, environmental degradation, natural disasters response, population explosion, and, in particular, global climate change;

That the purpose and mission of the World Information Summit of 2007, the Global Earth Observation System Conference of 2007, and the upcoming United Nations Climate Change Conference of 2009, and that Digital Earth is committed to continued close cooperation with other scientific disciplines;

Realizing

That Digital Earth is an integral part of other advanced technologies including: earth observation, geo-information systems, global positioning systems, communication networks, sensor webs, electromagnetic identifiers, virtual reality, grid computation, etc. It is seen as a global strategic contributor to scientific and technological developments, and will be a catalyst in finding solutions to international scientific and societal issues;

We Recommend

a) That Digital Earth expand its role in accelerating information transfer from theoretical discussions to applications using the emerging spatial data infrastructures worldwide, in particular, in all fields related to global climate

change, natural disaster prevention and response, new energy-source development, agricultural and food security, and urban planning and management;

b) Further, that every effort be undertaken to increase the capacity for information resource-sharing and the transformation of raw data to practical information and applications, and developed and developing countries accelerate their programs to assist less-developed countries to enable them to close the digital gap and enable information sharing;

c) Also, that in constructing the Digital Earth system, efforts must be made to take full advantage of next-generation technologies, including: earth observation, networking, database searching, navigation, and cloud computing to increase service to the public and decrease costs;

d) Further, that the International Society for Digital Earth periodically take the lead in coordinating global scientific research, consultations and popular science promotion to promote the development of Digital Earth;

e) Expanding cooperation and collaboration between the International Society for Digital Earth and the international community, in particular with inter-governmental organizations, and international non-governmental organizations;

f) Extending cooperation and integration with Government Departments, the international Scientific and Educational community, businesses and companies engaged in the establishment of Digital Earth;

We Call for

Support from planners and decision-makers at all levels in developing plans, policies, regulations, standards and criteria related to Digital Earth, and appropriate investments in scientific research, technology development, education, and popular promotion of the benefits of Digital Earth.

Beijing Declaration on Digital Earth

Approved at the Closing Ceremony of the
1st International Symposium on Digital Earth

December 2, 1999

We, some 500 scientists, engineers, educators, managers and industrial entrepreneurs from 20 countries and regions assembled here in the historical city of Beijing, attending the first International Symposium on Digital Earth being organized by the Chinese Academy of Sciences with co-sponsorship of 19 organizations and institutions from November 29, 1999 to December 2, 1999, recognize that humankind, while entering into the new millennium, still faces great challenges such as rapid population growth, environmental degradation, and natural resource depletion which continue to threaten global sustainable development;

Noting that global development in the 20th century has been characterized by rapid advancements in science and technology which have made significant contributions to economic growth and social wellbeing and that the new century will be an era of information and space technologies supporting the global knowledge economy;

Realizing the decisions made at UNCED and Agenda 21, recommendations made by UNISPACE III and the Vienna Declaration on Space and Human Development, which address, among other things, the importance of the Integrated Global Observing Strategy, the Global Spatial Data Infrastructure, geographic information systems, global navigation and positioning systems, geo-spatial information infrastructures and modeling of dynamic processes;

Understanding that Digital Earth, addressing the social, economic, cultural, institutional, scientific, educational, and technical challenges, allows humankind to visualize the Earth, and all places within it, to access information about it and to understand and influence the social, economic and environmental issues that affect their lives in their neighborhoods, their nations and the planet Earth;

Recommend that Digital Earth be promoted by scientific, educational and

technological communities, industry, governments, as well as regional and international organizations;

Recommend also that while implementing the Digital Earth, priority be given to solving problems in environmental protection, disaster management, natural resource conservation, and sustainable economic and social development as well as improving the quality of life of the humankind;

Recommend further that Digital Earth be created in a way that also contributes to the exploration of, and scientific research on, global issues and the Earth system;

Declare the importance of Digital Earth in achieving global sustainable development;

Call for adequate investments and strong support in scientific research and development, education and training, capacity building as well as information and technology infrastructures, with emphasis, *inter alia*, on global systematic observation and modeling, communication networks, database development, and issues associated with interoperability of geo-spatial data;

Further call for close cooperation and collaboration between governments, public and private sectors, non-governmental organizations, and international organizations and institutions, so as to ensure equity in distribution of benefits derived from the use of Digital Earth in developed and developing economies;

Agree that, as a follow-up to the first International Symposium on Digital Earth held in Beijing, the International Symposium on Digital Earth should continue to be organized by interested countries or organizations biannually, on a rotational basis.