DIGITAL EARTH: BRIDGING THE SCALES FROM GLOBAL TO LOCAL FOR SUSTAINABLE DEVELOPMENT

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ABSTRACT

Digital Earth is a virtual representation of the planet, an information system with tremendous amount of multi-resolution and multi-scale data as shown in multiple dimensions. By acquiring the large amount of data of the Earth, and utilizing the techniques of computer, image and graphic processing, network, virtual reality and so on to study the real earth and its relevant phenomena in digital way, the Digital Earth provides us a brand-new view to see our world.

Sustainable development is a major issue to be addressed in the goals and activities of the International Society on Digital Earth, which will be established very soon. The Digital Earth activities, to date, have already focused on sustainable development in the past three International Symposiums on Digital Earth, especially the third one addressing Information Resources on Global Sustainability. Regarding our views of the Earth from global to local scales, earth observation technology plays a key role in building the Digital Earth, providing huge amount of spatial information data of various resolutions and scales about our earth for sustainable development. Based on spatial information data, we have built a Digital Earth prototype system, which bridges the scales from global to local, and demonstrates its applications in crop growth monitoring, disaster, digital archaeology, environment management, and digital city etc. The development of Digital Earth will significantly contribute to global sustainable development, and better bridge the scales from global to local for assessment of environment and other related subjects.

1.0. INTRODUCTION

The Earth we live on has been studied for lots of years and accumulated lots of data, however, much of data have not been fully utilized. There are many reasons on this aspect. One of the reasons is that some data have not been changed to easily understandable information, and another maybe lack of fusion or integration for these tremendous amount of data derived from different sources, different types and different resolutions of resources, environment, and social economy, and also lack of comprehensive analysis to the data of global, regional and local scales. The advent of “Digital Earth” enables us to use digital and global data with computer and its network systems for processing, analyzing and managing these data to meet our demands on solving problems for global sustainable development.

The conceptual vision of Digital Earth (DE) was originated with the published version of a speech of the U.S. former Vice-president Al. Gore (Gore, 1998). In it, he describes an immersive environment that would allow its users to explore and learn about the Earth and its human and physical environment. Realizing the impact of Digital Earth that will bring to global societies and citizens, people from governments, institutions, private and other sectors began to discuss, understand and implement the Digital Earth. Although there is no unique definition of Digital Earth scientifically, it is commonly accepted that the Digital Earth is a virtual representation of our planet and is an oneness digital representation of the earth's relevant phenomena. Tremendous amount of data acquired by all kinds of means including satellite, aircraft, balloon, ground surveying and mapping, geochemical exploration and geophysical prospecting, which are characterized with multi-scale, multi-resolution, and multi-dimensions, are processed with computer together with comprehensive analysis of the relevant data and models. These form a huge system to digitally embody the earth in the computer network system. Such an information system is Digital Earth.

Regarding to the activities on the research of Digital Earth, the most significant event was the International Symposium on Digital Earth, held in Beijing from November 29 to December 2, 1999. The symposium was organized by the Chinese Academy of Sciences, and attended by over 500 delegates from 27 countries. This event is regarded as a milestone of DE development, as published a Beijing Declaration on Digital Earth, and set up an International Steering Committee for International Symposium on Digital Earth. From then on, the second and the third International Symposium on Digital Earth were held in New Brunswick, Canada in 2001, and in Brno of Czech Republic in 2003, respectively. It can be seen from the themes of these three symposiums, which are "Towards Digital Earth", "Beyond Information Infrastructure", and "Digital Earth: Information Resources for Global Sustainability" that the understanding of Digital Earth is deepened from addressing what is digital earth to its role in global sustainability. The fourth International Symposium on Digital Earth will be held in Tokyo, Japan in March 2005. To further enhance the activities on Digital Earth initiative, an International Society on Digital Earth (ISDE) will be soon established. The ISDE is a non-political, non-governmental and not for profit international organization, principally for academic exchange. The purpose of the society is to promote international cooperation and exchange on digital earth, and enable the digital earth technology to play key roles in economic and social sustainable development, environmental protection, disaster mitigation, natural resources conservation and improvement of human beings' living standard etc.

As we know, human kind has won itself an unprecedented and materially splendid civilization in our history over the past 100 years. Accompanying the technological and economic progress, however, are increasing concerns over the environmental deterioration, natural resource depletion, natural disasters and population explosion etc. We have to come to realize that we will not be able to sustain the constant improvement of our societies unless we take a global and systematic approach to the development. Global sustainable development is a major issue confronting everyone on this planet and Digital Earth is the idea platform to develop and implement the right solution (Lu, 1999). In this regard, Digital Earth is a solution to bridge the scales from global to local for global sustainable development. The developing trends on Digital Earth since the launch of DE initiative have shown the rapid development in building "Digital Community", "Digital Towns", "Digital Rivers" "Digital Cities", "Digital Country", Digital Continent", and "Digital Globe", for example, digital Olympic, digital Beijing, Digital Asia, and digital World. As Earth observation data provide significant amount of resources and also play a key role in building the Digital Earth, this paper will mainly focus on the introduction of Earth observation systems developed in China, and introduce a Digital Earth Prototype System developed at the Chinese Academy of Sciences based on earth observation data and virtual reality techniques. Application examples in relation to eco-system issues on flood monitoring, sandstorm monitoring, ecology recovering, and virtual reality system for 2008 Beijing Olympic game are also presented.

2.0 THE DEVELOPMENT OF EARTH OBSERVATION TECHNOLOGY

Within the scope of science and technology, only earth observation technology from the space can provide a global, repeat and continuous data coverage for the earth surface. These data are used to understand the earth system (Asrar and Dozier, 1994). The Earth is a comprehensive system involving all fields related to every discipline about geosciences. The earth observing technology and complex computer simulation works are playing an irreplaceable role in the study of the earth system, and are key techniques in building up the Digital Earth.

Over the past 30 years, earth observation technology has achieved a considerable progress. At present, a series of satellite-borne and airborne earth observing programs are implementing. The sensors on board are operated at visible, infrared and microwave bands. Satellite earth observation, particularly in recently years, has been undergone rapid development. Several civilian and commercial satellites were developed and are in operation. The optical remote sensing sensors has increased up to 0.6m (Quickbird). Radar remote sensing is also in progress with increased resolution of Radarsat 2 (3m), multi-modes and full polarimetry. The shuttle imaging radar topography mapping program has acquired 80% land surface of the globe within 11 days mission, the DEM results for the continents have been released for 90m resolution and 1km resolution. These are huge amount of data resources for building the Digital Earth.

In China, the space program has made noticeable progress in the world over the past 30 years. By far, some 50 satellites and 5 spacecrafts have been launched. According to the prediction of the white book "China's Space Program", China will continuously develop and launch about 30 different satellites, in the tenth five-year period, for communications, meteorology, ocean, mineral resources, navigation, astronomy, environment and disaster monitoring, as well as scientific space probing satellites. This constellation of satellites will strengthen directly or indirectly the Chinese capacity for acquiring Earth observing remote sensing data and information. It is foreseen that in about ten years time, a durable and stable period for operational satellite observing system will be established, consisting of meteorological satellite series, resources satellite series, ocean satellite series as well as environment and disaster monitoring constellations. Thus, dynamic global monitoring of land, atmosphere, and ocean can be implemented as an operational national program. On October 15, 2003 the successful launch of SZ-5 spacecraft with a first Chinese astronaut realized the dream of Chinese people for traveling in the space. Details regarding the acquisition capacity of Earth observing remote sensing data from orbiting satellites are given below.

2.1 Spaceborne Earth Observing System

A. "FY" Series Meteorological Satellite

China has built a "Fengyun (FY)" meteorological satellite series with polar-orbiting and stationary-orbiting satellites as well as a data application system. Four "FY-1" series satellites were launched in 1988, 1990, 1999 and 2002 respectively. The payload sensors of FY-1A and FY-1B satellites are 5-channel visible and infrared radiometers. The FY-1C satellite has increased the number of channels to 10, therefore, enhancing the Earth observing capability to acquire 4-channel global coverage data with a resolution of 3.1km once a day. The "FY-2" series are the Earth stationary-orbiting meteorological satellites. The FY-2A and FY-2B satellites were launched in 1997 and 2000 respectively, which can provide a scene of Earth imagery covering one third of the globe every half an hour. The second-generation polar-orbiting "FY-3" series meteorological satellites have been arranged into the developing program of 2002 to 2020, which will greatly enhance the Earth observing and space probing capabilities.

B. Resources Satellite Series

In October 1999, the China-Brazil Earth Resources Remote Sensing Satellite (CBERS) was successfully launched. The satellite made a landmark example of space high-technology cooperation within developing countries. The satellite's payload sensors includes a 5-band CCD camera with a resolution of 20m, a 4-band infrared multi-spectral scanner with a resolution of 78m, and a 2-band wide field-of-view imager with a resolution of 256m. After three years of operation, China has acquired remote sensing images over 80% of China, as well as of neighbouring countries and regions. The relevant agencies have acquired and archived over 320,000 scenes of images. On 21st October 2003, the second satellite (CBERS-2) was successfully into the orbit, although this satellite has the same specification as CBERS-1, the image quality could be improved considerably.

C. Ocean Satellite Series

On May 15, 2002, China launched an ocean satellite (HY-1) along with a FY-1D satellite on the same rocket. The HY-1 satellite has a 10-channel ocean color scanner and a 4-channel CCD imager, used for detecting ocean color and temperature, evaluating fisheries, forecasting fishing seasons, monitoring ocean pollution, providing information about estuary sediments, sea-shore ecology, and sea ice, etc. In addition, China will develop the Ocean Dynamic Environment Satellite series (HY-2 series satellites) for acquiring all-weather ocean wind field, sea surface height and sea temperature, through microwave detection to reach the support of disaster mitigation and prevention. An Ocean Environment Integrated Monitoring Satellite series (HY-3 series satellite) is also going to be developed for acquiring synchronous information of the ocean color and dynamic environment.

D. Earth Observing Small Satellite

In June 2000, the "Tsinghua-1" small satellite, developed by Tsinghua University in cooperation with Surry University of the United Kingdom, was successfully launched. The satellite has three CCD cameras operated at visible and near-infrared bands, which are able to make optical imaging of the Earth with 40m resolution along a 40 km imaging swath. This light weight satellite can be used in the fields of mineral resources investigation, environment and disaster monitoring, military reconnaissance, hydrological and geological surveying, and meteorological observation.

E. Environment Satellite Program

At present, China is speeding up the development of satellite systems for environment and disaster monitoring. It is planned that a small satellite constellation consisting of two optical satellites and one S-band SAR (synthetic aperture radar) satellite be launched before 2006 and another small constellation comprising of four optical satellites and four radar satellites be launched before 2010. These small satellite constellations will be developed to enable all weather and all time monitoring of the environment and disaster events.

F. "Shenzhou" Spacecrafts

In March 2002, the third "Shenzhou" spacecraft (SZ-3) was orbited with a medium resolution imaging spectrometer (CMODIS) onboard. The CMODIS, orbited at a height of 343±5km above sea level, has a ground resolution of 400-500 m, two day repeated coverage and a 650-700 km imaging swath, with 34 bands, over a spectral range from 0.4-12.5μm. In December 2002, the fourth "Shenzhou" (SZ-4) spacecraft carried a multi-mode microwave sensor system comprising a microwave radiometer, a radar altimeter, and a radar scatterometer. This experiment marked the first world record that three microwave observing sensors operated under the same monitoring system, and the first time adopting a scanning antenna to measure wind direction and wind speed. The acquired data will play an important role in understanding wind field, ocean wave dynamics and the exchange of ocean-atmospheric energy, as well as analysis of ocean disasters and fishery resources. The successful mission of the manned spacecraft has laid a firm foundation for the future development of SZ series and enhanced the capacity of earth observation from the space.

2.2 Airborne Earth Observation and Experimental System

China is continuously improving its capacity to construct airborne Earth observing systems. It should be noted that the systems, developed under the direction of the Subject of Information Acquisition and Processing Technology as part of the National High-Tech Research and Development Program (863-308), consists of five new remote sensing sensors. These include an Operational and Modular Imaging Spectrometer (OMIS), a Push-broom Hyperspectral Imager (PHI), a Plane Array CCD Digital Camera, a 3D imager, and an L-SAR. These sensors provide for high spatial and spectral resolutions, 3-D imaging, all weather, and all time imaging capabilities.

The OMIS has wide band coverage; there are 128 detecting bands distributed in the range of 0.46μm-12.5μm at the atmospheric window. The instrument has a scanning field-of-view over 70°. The scanning system, imaging system, and spectrometer system are designed as individual modules, enabling alternation of two working modes at 128 bands and 68 bands. The GPS system can acquire the positioning data of the image, and standardized image products can be produced for specific mineral and natural resource applications. The PHI contains 244 bands, with a spectral range of 0.40μm -0.85μm, and less than 5nm spectral resolution, a FOV of 42°, and a signal to noise ratio greater than 100. The high-resolution plane array CCD digital camera system is a fully digital with detectors of 4096 by 4096 pixels. The CCD camera includes a 3-axis gyratory stabilizing platform, data storage system with high-speed and large capacity, GPS positioning and receiving system, and other parts to make it an aerial photogrammetric camera system with digital, high resolution, and good suitability characteristics. The 3-D Imager’s innovative characteristics are with real-time or near real-time 3-D image production capability. Its major functions can synchronously generate terrain image at one time, or provide contour line and orthographic images. The secondary products include 3-D demonstrations, thematic, and surveying map production. The L-SAR operational system has two polarizations enabling the acquisition of multi-polarization radar images. Two imaging modes can be selected for either narrow swath at high spatial resolution (resolution 3 x 3 m) or wide swath at a lower resolution. It is also an ideal test-bed for developing the Chinese SAR satellite.

2.3 Remote Sensing Data Processing and Acquisition Capability

The China Remote Sensing Satellite Ground Receiving Station 1986, has the capacity of receiving Landsat, SPOT, RADARSAT, ERS-1/2, JERS-1, Envisat and CBERS data, and is able to distribute data for the Quickbird, IKONOS, IRS, and EROS satellites. Thus, it can provide a complete range of high, medium and low resolution as well as multi-spectral, panchromatic and radar image products, in essence realizing the goal for an all-weather, all time, near real-time, and multi-resolution satellite Earth observation information center. A number of MODIS satellite receiving stations were set up in Beijing, Guangzhou, and Xinjiang Provinces. Combined with the China Resources Satellite Application Center, Meteorological Satellite Center, and Ocean Satellite Application Center, China has constructed a networked operational system for acquisition of remote sensing satellite data keeping abreast with the most current international level of the operational systems.

3.0 DIGITAL EARTH PROTOTYPE SYSTEMS

The Digital Earth Prototype System (DEPS) developed at the Institute of Remote Sensing Applications, Chinese Academy of Sciences aims to provide a basic platform for establishing a storage, inquiry, indexing system with remote sensing and relevant data of TB level. To realize 4D dynamic performance of multi-scale and multi-temporal data of the earth, the DEPS will be integrated with data of remote sensing, geography, and social economics, etc., and be used as a digital platform for comprehensive analysis and interdisciplinary research and also a platform for network interoperability. The construction of DEPS mainly contains the following aspects. 1) Spatial data ware house and spatial data clearing house; 2) Geoscience information research; 3) information system and distributed database research; 4) Image processing techniques; 5) Digital Earth virtual environment technology; 6) high performance and parallel computation research; 7) User interface and evaluation research.

The DEPS presents a conceptual model of the Digital Earth, i.e., a virtual Earth consisting of tremendous amount of, multi-resolution, multi-temporal, multi-types earth observing data and geoscience measuring data, and analytical algorithms and models. The system currently possesses some 3TB data and tens of database system, and owns computer network interlocks to link with other computer resources. The system will provide support to crop estimation, disaster monitoring, urban remote sensing dynamic change, digital city, digital Olympic, energy resources, remote sensing archaeology, ecological environment changes, virtual tourism, military simulation etc.

4.0 APPLICATIONS ON ECOLOGY RELATED FIELDS

Remote sensing applications in ecology in China has achieved significant results, such as Tianjing-Bohai environment remote sensing experiments in early time, urban hot island effect and urban remote sensing monitoring, wetland monitoring, forest inventory, grassland monitoring, drainage basin management, and desertification monitoring. For example, desertification monitoring with remote sensing data was started from 1981. Since then and from remote sensing images, it has been known that the desertification occurs in 471 counties of 18 provinces and autonomous regions, and the desertification land is about 2.64 hundred million Mu (1 Mu = 1/15 hectare), and there are also 2.37 hundred million Mu land endangered by the desertification. The sandy desertification land is increased at a rate of 2460 square kilometer per year. The result provides a basis for decision-making to control and manage desertification by the relevant government agencies.

Sandstorm in China occurs frequently in China every year, which influences the people’s life and worsens the environment. With NOAA/AVHRR visible, near infrared and thermal infrared image can calculate surface albedo, and brightness temperature, and to extract sand dust information, therefore, get the information about dust weather process and sand content in the atmosphere. In the China’s Desertification monitoring Center of National Forest Bureau, a sandstorm remote sensing monitoring and disaster assessment system have been built. The system utilizes remote sensing, GIS and internet technology to monitor the occurrence and developing process in real time, and gives short period early warning and disaster influence assessment.

Flood disaster is also a major problem concerning with ecosystem issues. In 1998, an unprecedented flood event was occurred along the Yangtze River and Nen-Songhua River areas. Remote sensing imagery, especially radar images, had played key role in monitoring the flood, and the L-band airborne SAR system demonstrated its value in contribution to flood monitoring. As a measure to control the flood, returning farmland to forest or to grass land was conducted in whole China. Where land with slope greater than 25° or with heavy soil erosion or NDVI below 0.2 or eco-environment quality less than 4 should become forest land or grass land. In this process, GIS and remote sensing have played an important role in calculating the area for returning to forest or grass land, and provided a basis for supervising the work on this aspect. In addition, a whole country resources and environment database have been set up, which contains vegetation index database, band-match database, dynamic monitoring database, 3D landscape database, standard base-map database and landsat TM or ETM database covering whole country.

The 2008 Olympic game in Beijing will be built with a slogan of “Green Olympic, Science and Technology Olympic, Cultural Olympic”. Based on virtual reality technique and utilizing various kinds of earth observing data which includes images taken by the a set of airborne remote sensing sensors described in Section 2.2, Quickbird and Ikonos image, Landsat ETM, TM, Envisat data etc, dynamic monitoring of the construction process as well as its relation to its surrounding environment has been undertaken. The DEPS contains simulation of the planned Olympic Game site. Figure 1 gives the Olympic game site area, which is overlying on the airborne color image. Figure 2 shows the scene of Olympic game constructed with virtual reality technique.

Fig. 1 View of the main site area of 2008 Olympic game in Beijing

Fig. 2. A scene of Olympic game's main stadium and swimming pool, which were constructed before releasing the results of bids, therefore, there is a difference with the real scene.

5.0 CONCLUSIONS

The Digital Earth is an ideal tool to bridge the scale from globe to local for sustainable development. Earth observation technology provides tremendous amount data for the earth with multiple scales, multiple temporal, multiple imaging modes, which are essential for building the Digital Earth. A noticeable progress of earth observing systems were built in China on both spaceborne and airborne platforms. The Digital Earth Prototype System developed at the Institute of Remote Sensing Applications, Chinese Academy of Sciences has demonstrated the applications of Digital Earth technology in some ecosystem related issues, such as flood monitoring, desertification and sandstorm monitoring. The application of virtual reality technology in building 2008 Olympic game sites is also a good example of Digital Earth applications.

REFERENCES

Al. Gore, 1998, The Digital Earth: Understanding our planet in the 21st century. Http://digitalearth.gsfc.nasa.gov/vp/vp19980131.html.

Lu Yongxiang, 1999, Building up the digital earth together, sharing global data resources each other, in Toward Digital Earth, the proceeding of the 1st International Symposium on digital earth.

Asrar, G., J. Dozier, EOS Science Strategy for the Earth Observing System, NASA, AIP Press, 1994, 1-119.