

# STRATEGIC STUDY ON TAIWAN INTEGRATED EARTH OBSERVATION SYSTEM

Guey-Shin Chang <sup>a</sup>, Franz Cheng <sup>b</sup>, Ya-Ting Hu <sup>c</sup>, and Bo Chen <sup>d</sup>

<sup>a</sup> Director General, National Space Organization, National Applied Research Laboratories  
8F, 9 Prosperity 1st Road, Hsinchu Science Park, HsinChu, Taiwan;  
Tel: + 886-3-578-4208#8101; E-mail: gschang@nspo.narl.org.tw

<sup>b</sup> Director, Business Development Division, National Applied Research Laboratories,  
3F, No. 106, Ho-Ping E. Road, Sec. 2, Taipei 106, Taiwan;  
Tel: + 886-2-6630-0620; E-mail: franz.cheng@narl.org.tw

<sup>c</sup> Research Assistant, National Space Organization, National Applied Research Laboratories  
8F, 9 Prosperity 1st Road, Hsinchu Science Park, HsinChu, Taiwan;  
Tel: + 886-2-6630-5292; E-mail: vanessa@nspo.narl.org.tw

<sup>d</sup> Director, Satellite Image Division, National Space Organization, National Applied Research Laboratories  
8F, 9 Prosperity 1st Road, Hsinchu Science Park, HsinChu, Taiwan;  
Tel: + 886-3-578-4208#1592; E-mail: bochen@nspo.narl.org.tw

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## ABSTRACT:

National Applied Research Laboratories (NARL) consists of twelve national laboratories with missions to establish R&D platform, support academic research, promote frontier science and technology, and foster high-tech manpower in Taiwan. Encompassing core technologies in satellite remote sensing, environment and disaster reduction, and information technology, NARL has developed many earth observation and disaster reduction related technologies by synergizing various core competences from different affiliated laboratories. A project entitled “3D GIS Taiwan” is one of the pilot projects in which NARL consolidate the research capacities from various laboratories to build up an integrated platform for environment and disaster reduction applications. NARL also takes a leading position to promote and initiate the “Taiwan Integrated Earth Observation System (TIEOS)”. The TIEOS working group formed by several geosciences research institutes and governmental agencies is working together to promote the inter-agency cooperation and synergy on earth observation applications within Taiwan. The concept of TIEOS is in parallel to that of the Global Earth Observation System of Systems (GEOSS) advocated by Group on Earth Observations (GEO). The aims of TIEOS initiative are to: (1) integrate the domestic earth observation resources to enhance the social benefits of Taiwan, (2) implement TIEOS as a pilot project to promote and showcase the value of earth observations integration, (3) promote TIEOS as a policy making support system for Taiwan sustainable development, and (4) expand TIEOS from local level to regional level and engage to international communities. The research topics of TIEOS including policy and strategy, multi-discipline and synergy, interoperability and standards, and technology and innovation, etc. are elaborated as well.

## 1. Introduction

The earth's temperature has risen dramatically since 1970's. Observation data from NOAA and NASA of US, Japan, and UK in which different groups of scientists use different methods to track global surface temperatures show that all of the groups' data exhibits the same trend of warming temperatures during the past several decades as illustrated in Figure 1 (NASA Earth Observatory, 2011). The 15 hottest years globally all occurred in the last 15 years since 1995 according to NOAA ranking. Meanwhile the global catastrophe swept the whole world leading to the dramatic property damage and life loss in recent years. The global warming and climate change become one of the crucial issues for the human being in the next decade.

The first Earth Observation Summit was held on 31 July 2003 in Washington, D.C. to recognize that international collaboration is essential for exploiting the growing potential of Earth observations to support decision making in an increasingly complex and environmentally stressed world. To incorporate the global efforts, the Group on Earth Observations (GEO) is coordinating efforts to build a Global Earth Observation System of Systems (GEOSS, 2005). As of March 2011, GEO's Members include 86 Governments and the European Commission. In addition, 61 intergovernmental, international, and regional organizations with a mandate in Earth observation or related issues have been recognized as Participating Organizations. GEO is also constructing GEOSS on the basis of a 10-Year Implementation Plan for the period 2005 to 2015.

On 29 Nov 2010, Mexico Cancun Climate Conference was held and gathered More than 190 countries for two weeks of talks under the United Nations Framework Convention on Climate Change (UNFCCC). The aim of the talks is to curb global warming by cutting carbon emissions. Cancun Agreement was concluded and brought up a long-term goal that keeps temperature increase below 2 degrees Celsius. Although this agreement is not sufficient to put the long term goal into contract, global environmental protection organization approve Cancun Agreement is a valuable step forward in the difficult process of constructing a sound foundation for the global action.

To engage with the global efforts on GEOSS, the National Applied Research Laboratories (NARL) initiated a project, funded by the National Science Council (NSC), entitled the “The Strategic Study on Taiwan Integrated Earth Observation System (TIEOS)” in 2008 with a goal to study the strategy and implementation plan that will facilitate the TIEOS becoming a comprehensive, coordinating, and integrating network in support of recently environmental threats, ranging from disaster mitigation, climate change to humanitarian relief. The TIEOS working group formed by several geosciences research institutes and governmental agencies is working together to promote the inter-agency cooperation and synergy on earth observation applications within Taiwan. The concept of TIEOS is similar to that of the Global Earth Observation System of Systems (GEOSS) advocated by Group on Earth Observations (GEO), but TIEOS is dedicating its implementation at the national level.

## **2. Global Earth Observation Efforts**

To mitigate stresses from the global warming and climate change, understanding the Earth is of importance in which the earth observation data and related geospatial technologies constitute one of important components that greatly helps the scientists and researchers to better understand our planet. There are many efforts and projects of the earth observations have been implemented by many countries at the national level and regional level among the world.

The US Government is dedicating to improve earth observation capacity and provide the seed technologies for the next generation implementation. Its earth science research emphasizes on six areas, including atmospheric composition, carbon cycle and ecosystems, climate variability and change, weather, water and energy cycle, and earth surface and interior. US Government focuses on the earth’s system and its response to natural or human-induced change in order to improve the predicting of climate, weather, and natural hazards. NASA always takes Digital Earth research as one of its key missions and provides open access to its data. (Guo, et al. 2010; Bambacus, 2009)

Different European countries have utilized their own geo-spatial system as a tool in support of resolving the emerging issues such as the economic globalization and global climate change. Nevertheless, the decision makers of the European Union (EU) need the equivalent and real-time information on all aspects from the different countries. As a result, European Commission proposed the CORINE (Coordination of Information on the Environment) project to ensure the coherence in gathering and coordinating environmental and natural resource information at the EU national level. In the mean time, EU also launched two projects, GMES and INSPIRE, to sustain the implementation of CORINE. The GMES (Global Monitoring for Environment and Security) introduced in 2004 is an Earth Observation system and provides environment monitoring information to actively response to global needs. The INSPIRE (Infrastructure for Spatial Information in Europe) started in 2007 aims at serving the community’s environmental policies and activities that influence the environment. (Guo, *et al.* 2010)

Virtual Australia was initially proposed by Australia in 2008. It described as a virtual/digital model covers all interests of Australia’s environment, economy and society, and reaches any points below, on and above the ground. Its information system enables users to access complete, correct, and current spatial data and information. (Thompson, *et al.* 2008)

China takes the fundamental spatial and attribute information as a basis to explore, integrate, and combine all kinds of information and knowledge at nation and local level by spatial information technology and provides users a virtual 3D service platform. (Tong, *et al.* 2009) China builds Digital Terrain /Elevation Model (DTM/DEM) database, DEM database of key river and flood prevention areas, large-scale map of cities, and geospatial and thematic databases. (Du, *et al.* 2009) The geospatial information are observed from satellite and airborne remote sensing images that cover the whole country and all provinces. Digital provinces and cities are under construction as well. (Cheng, *et al.* 2007)

Digital Asia is a network of agencies to capture the prowess of digital earth for sustainable development throughout Asia. The project was funded by Japan Aerospace Exploration Agency (JAXA) and Keio University to initiate the system of sharing and archiving spatial data through Digital Asia Project. The aim of Digital Asia is to provide people with easy access to geospatial information and its services by using GIS and remote sensing over the Internet through open data sharing. (Fukui, 2005)

### **3. Taiwan Integrated Earth Observation System (TIEOS)**

#### **3.1 TIEOS Initiative**

Taiwan is located in the southern-east Asia and along the west coast of Pacific Ocean where is in path of the tropic cyclones frequently occurring in the summer season. There are 3~4 typhoons per year influencing Taiwan in average. Taiwan is also situated in the plate-boundary zone between the Eurasia plate and the Philippine Sea plate. Taiwan is frequently afflicted by natural disasters such as floods, typhoons, and earthquakes that dramatically threat the safety of living environment in Taiwan. Therefore, monitoring and assessing environmental changes have become one of the critical issues in Taiwan's internal planning. In fact, Taiwan has been pursuing sustainable development for more than ten years and has gained a wealth of experience. Over the past decades, Taiwan has devoted significant resources to mitigating natural disasters, improving weather prediction, and monitoring climate change. However, a more comprehensive and extensive strategy that incorporates the synergy of earth observation data and the state-in-the-art technologies is required to face the challenge of the rapidly global environmental changes. In 2008, the TIEOS working group was then initiated by National Applied Research Laboratories (NARL) with supports from various governmental agencies, research institutes, and academic research centers. Currently, the joint team of TIEOS include: National Science Council (NSC), Environmental Protection Administration (EPA), Information Center of Ministry of the Interior, Central Weather Bureau (CWB), Industrial Technology Research Institute (ITRI), Taiwan GIS Center (TGIC), Center for Space and Remote Sensing Research (CSRSR) of National Central University (NCU), GIS Research Center of Feng Chia University (FCU), Digital Earth Research Center of Chinese Culture University (CCU), and NARL. NARL is leading the TIEOS efforts to integrate the existing data and technologies related to earth observations and to advocate performing multi-discipline cooperative researches in Taiwan.

NARL is a nonprofit organization branched out from National Science Council (NSC) in 2003 to consolidate eleven major national laboratories in Taiwan. Seven out of eleven of NARL's affiliated laboratories that conduct research in a broad spectrum of earth observations. NARL's competence on geosciences of affiliated research centers includes space- and air-borne remote sensing imagery, electric-optic remote sensing instrument, image processing technique, grid technology, 3D virtual reality visualization, earthquake engineering, ocean research, typhoon and flood modeling, and disaster reduction technology which can be synergized and operated on the NARL-owned high-end cloud computing, storage, and networking facility and deployed for the practical uses on the earth observation applications. (Chang, et al, 2010)

#### **3.2 The aims of TIEOS**

The aims of TIEOS are to: (1) integrate the domestic earth observation resources to enhance the social benefits of Taiwan, (2) implement TIOES as a pilot project to promote and showcase the value of earth observations integration, (3) promote TIEOS as a policy making support system for Taiwan sustainable development, and (4) expand TIOES from local level to regional level and engage to international communities. The status and progress of strategic study to constitute the TIEOS is elaborated as follows.

##### **3.2.1 To Integrate the Domestic Earth Observation Resources to Enhance the Social Benefits of Taiwan**

The concept of TIEOS is similar to that of GEOSS and Digital Earth that is an integral part of earth observations, geo-information systems, global positioning systems, communication networks, sensor webs, virtual reality, grid computation, etc. The ultimate goal of TIEOS or GEOSS will yield advances in the societal benefit areas including disaster, health, energy, climate, water, weather, ecosystems, agriculture, and biodiversity. It will build on and add value to existing earth observation systems by coordinating efforts, addressing critical gaps, supporting interoperability, sharing information, reaching a common understanding of user requirements and improving delivery of information to users. (GEOSS, 2005) Therefore, how to synergize the existing and available resources and technologies becomes one of crucial tasks of TIEOS. It is found that the most of the useful data and technologies are existing and available among governmental agencies in Taiwan. However, each agency has their own implementations and applications to fulfill their mission needs. One typical example is the Flood Mitigation Sensor Network developed by National Center for High Performance Computing (NCHC) for the Water Resources Agency. This system integrates the satellite imagery, sensor network, virtual reality, and grid computing to monitor the water level of the major rivers during the high raining season and can display in a user friendly interface based on OpenGL as shown in Figure 2. (Tsia, et al. 2010) This system, by definition of GEOSS, represents a distributed but small scale of the earth observation system. It is found that the strategy of developing TIEOS should focus on how to build an integrated system by synergizing these available distributed systems instead developing one single system that can be applied to all applications. Therefore, TIEOS mainly emphasizes on the information sharing and resource coordination among different agencies from which the collaboration of multi-agency and multi-discipline can be exercised to demonstrate the value of the integrated earth observation systems beneficial to the society.

### **3.2.2 To Implement TIOES as a Pilot Project to Promote and Showcase the Value of Earth Observations**

#### **Integration**

In order to promote TIEOS as a pilot project to exhibit the value of the integrated earth observations in association with GEOSS framework, the TIEOS working group has endeavored to build TIEOS portal (Figure 3) and 3D GIS Taiwan platform (Figure 4) since 2009. The TIEOS portal provides Earth Observation's latest news of GEOSS related conference and meeting information, internet address link to the existing domestic earth observation agencies and resources, and Taiwan historical disaster information, etc. A prototype TIEOS portal has been built with an intention to provide the users a gateway to access the various databases archived by various agencies for past decades. The 3D GIS Taiwan platform is also initiated by synergy of NARL's core competence on environment monitoring and disaster reduction techniques of the high-resolution satellite image processing, virtual reality visualization, grid computing, and disaster mitigation technology along with the advanced cyberinfrastructure environment. It emphasizes on synergy of multi-discipline with inter-agency cooperation for geosciences applications from which a benchmark of the GEOSS implementation can be established. (Chang, G.S. *et al.*, 2008) The 3D GIS Taiwan platform encompasses FORMOSAT-2 satellite and airborne images coupled with the high-resolution Digital Terrain Model (DTM) capable of displaying the 3D Taiwan geospatial information. It can be implemented by overlaying specific GIS information for various applications. However, it has been found that the establishment of the 3D GIS Taiwan platform only demonstrates the technical feasibility of integrating the earth observation data and advanced computing and visualization techniques. The strategy to showcase the value of TIEOS should be focusing on the scenario-based applications instead of constructing a 3D display model itself. Therefore, the TIEOS working group will continuously explore the scenario-driven applications in various social beneficial areas. One example of the scenario-driven application is the comparison of the 3D navigational images for disaster areas before and after the Typhoon Morakot in 2009 as shown in Figure 5. It has demonstrated the value of the scenario-driven 3D model from which more information and visualization can be provided to decision makers for aftermath's assessment of disaster via the synergy of the earth observation data and advanced techniques.

### **3.2.3 To Promote TIEOS as a Policy Making Support System for Taiwan Sustainable Development**

Pursuit of sustainable development is one of the ultimate visions of the Taiwan government. The Taiwan National Council for Sustainable Development (TNCS) was established in 1997. Its mandate is to enhance the protection of the ecosystem, guarantee social fairness and justice, and pursue national sustainable development. Many documents and action plans have been published and implemented in response to the UN's mandate. It's commonly agreed by the government and public that the TIEOS can play an important role for the Taiwan sustainable development in which TIEOS can provide a more systematic and integral geospatial information to the government in support of the policy making. As a result from the preliminary study of the TIEOS working group, there are still many challenges ahead to achieve this goal due to the issues of coordination, data interoperability and authority among governmental agencies, etc. Therefore, it is crucial that the promotion and implementation of TIEOS have to become one of the action plans of the Taiwan sustainable development. From a long term point of view, a dedicated agency or organization is essential to be authorized by the government responsible for coordinating the TIEOS efforts in a more effective manner. Currently, a volunteer work group formed by NARL and the associated agencies is the most efficient way to promote the TIEOS in preliminary phase. We believe that TIEOS can't achieve its goal without the strong support from the government as well as the inter-agency cooperation in volunteer basis.

### **3.2.4 To Expand TIOES from Local Level to Regional Level and Engage to International Communities**

To make effort to engage and contribute Taiwan's earth observation capability to the international communities, TIEOS has actively conducted many activities to communicate with regional and international communities. On 9 June 2009, the TIEOS Forum had been held in Taipei to initiate and promote the TIEOS efforts. Two topics have been extensively discussed by the local and international experts and researchers: 1) Strategy to develop and implement the TIEOS and 2) Lessons learned and recommendations for establishment of the earth observation systems from other experienced countries. Many valuable recommendations had been made by the local and international participants from which TIEOS has achieved the first step to engage the TIEOS with the international communities. In March 2010, NARL became the data provider member of Sentinel Asia, operated by the Japan Aerospace Exploration Agency (JAXA), in which NARL is committed to provide FORMOSAT-2 satellite images in near real-time via National Space Organization (NSPO) to the member countries for the purposes of disaster reduction and humanitarian relief when the natural disasters occur. Consequently, FORMOSAT-2 imagery became one of the important data in support of the aftermath's assessment of the Japan Sendai Earthquake and Tsunami occurred in 11 March 2011. In October 2010, the working group hosted a TIEOS session in the 22nd International CODATA (The Committee on Data for Science and Technology) Conference in Cape Town, South Africa from which Academia Sinica has granted to host 23rd International CODATA Conference in Taiwan in 2012. To

promote the interoperability of geospatial data, TIEOS also sponsored the International Interoperability Day (2011 II DAY@TW) in conjunction with the Open Geospatial Consortium (OGC) TC/PC Meeting hosted by Feng Chia University in June 2011. TIEOS also actively communicate with Environmental Monitoring from Space of East Asia (EMSEA), International Association of Geodesy (IAG), International Global Monitoring Aerospace System (IGMASS), Pacific Rim Applications and Grid Middleware Assembly (PRAGMA), Global Lake Environmental Observation Network (GLEON), and Coral Reef Environmental Observation Network (CREON), etc. TIEOS will continuously works closely with international earth observation organizations to enhance Taiwan's effort and visibility in the world.

#### 4. Conclusion

Since TIEOS was initiated in 2008, many efforts have been performed to promote the synergy of the earth observation resources in Taiwan. A working group has been formed by the representatives from governmental agencies and academic research institutes in the volunteer basis. The strategy and approach to achieve the TIEOS goals have been studied and brainstormed by the group members routinely. The TIEOS portal has been prototyped to promote the concept of TIEOS and to survey the availability of the current domestic earth observation resources. A pilot project entitled "3D GIS Taiwan" has been conducted to demonstrate the synergy of multi-discipline with inter-agency cooperation for environmental monitoring and disaster reduction applications. Many activities have been conducted to engage the TIEOS with the global efforts on earth observations as well. In the mean time, there are four important topics that require further studies by the TIEOS working group. There are: 1) study of governmental policy and implementation strategy, 2) enhancement of multi-discipline and multi-agency synergy, 3) promotion of the interoperability and standards for the geospatial data, and 4) exploration of innovative technologies and scenario-based applications for TIEOS. TIEOS is willing to be the communication channel and education platform from which the earth observation information and knowledge can be transmitted to whom might be interested. It is anticipated that TIEOS can make a significant contribution to the GEOSS in various topics of interest as well.

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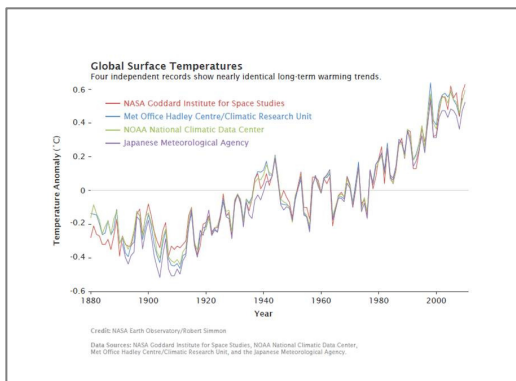


Figure 1: Global Surface Temperature



Figure 2: Flood Mitigation Sensor Network

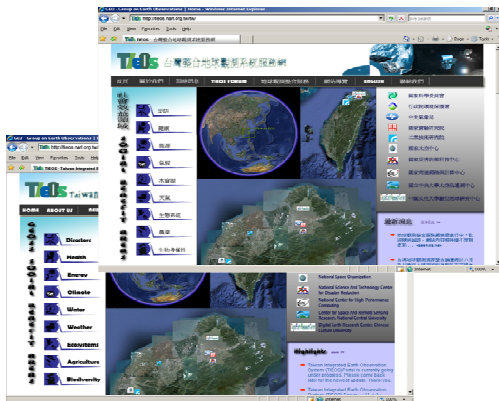


Figure 3: A prototype of TIEOS portal

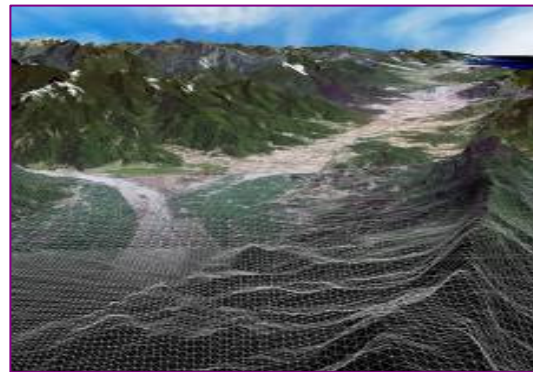


Figure 4: 3D GIS Taiwan platform

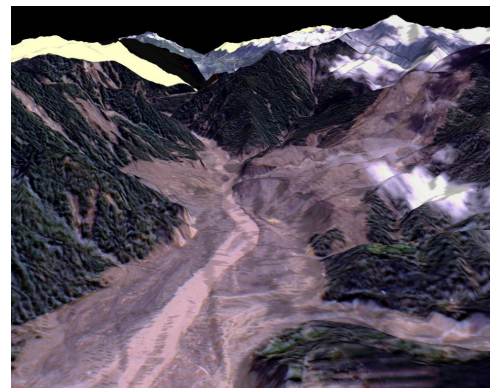
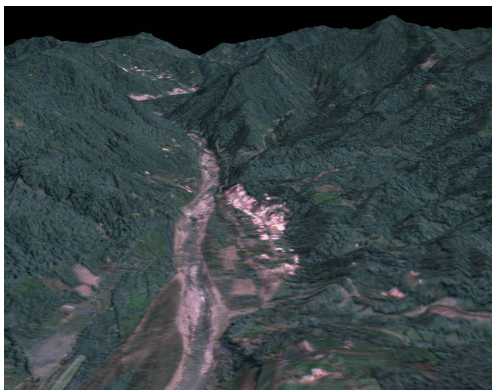


Figure 5: Before (left) and after (right) the Typhoon Morakot in 3D navigational visualization