Int. J. Disaster Risk Sci. 2010, 1 (2): 9–16
doi:10.3974/j.issn.2095-0055.2010.02.002

ARTICLE

Applications of the Small Satellite Constellation for Environment and Disaster Monitoring and Forecasting

Weixing Zhang* and Sanchao Liu

National Disaster Reduction Center and the Satellite Disaster Reduction Application Center, Ministry of Civil Affairs, Beijing 100024, China

Abstract Small Satellite Constellation for Environment and Disaster Monitoring and Forecasting (SSCEDMF), loaded with the Charge Coupled Device (CCD), hyperspectral imager (HSI), infrared scanner (IRS), and S band Synthetic Aperture Radar (S-SAR), featuring large width, high revisitation rate, and medium spatial resolution, is an important part of China's earth observation system. On 6 September 2008, China successfully launched two small optical satellites (HJ-1-A/B) of SSCEDMF. Since then, the Office of the China National Committee for Disaster Reduction has, according to the demand of disaster reduction and relief, actively organized the application of these satellites for disaster reduction, established a sound system of products applying space technology in disaster reduction, and included HJ-1-A/B into the national system of disaster reduction and alleviation decision-making support services. This has played an important role in the monitoring and early warning of emerging major natural disasters at home and abroad.

Keywords disaster, disaster reduction application, HJ-1-A/B, Small Satellite Constellation for Environment and Disaster Monitoring and Forecasting

1 Introduction

In recent years, with rapid global economic and social development and the acceleration of industrialization and urbanization, serious population, resource, disaster, and environment problems have become increasingly more important issues for human survival and development. China has had many serious natural disasters that have various intensive impact characteristics, wide distribution, and high incidence. Often these events occur as multiple disasters or a concentrated eruption of disasters, causing increasingly serious losses. These frequent disasters destroy material wealth, threaten people's lives, disrupt social order and cultural heritage, and give rise to social psychological problems. These impacts seriously affect economic development, social progress, livelihood improvement, and national security. During the two decades from 1990 to 2009, the death toll from disasters in China accounted for one tenth of the losses experienced globally, the number of Chinese affected by disasters accounted for over one half of that in the world, and the direct economic losses amounted to one fifth of the global total.

Under the background of global climate change, natural disasters in China are being aggravated and changes and new characteristics have emerged in terms of disaster formation mechanisms, patterns of occurrence, temporal and spatial features, extent of losses, and impacts. Disaster monitoring and early warning, assessment, and decision making are also in urgent need of improvement. These situations have brought about new challenges to disaster prevention and reduction. The severe situation of natural disasters urgently requires high-technology solutions such as satellite remote sensing to set up three-dimensional disaster monitoring systems that can meet the need of disaster reduction and rapid emergency response in the country.

2 Environment and Disaster Reduction Constellation

Faced with a serious disaster situation, China has put forward and started to construct the Small Satellite Constellation for Environment and Disaster Monitoring and Forecasting (SSCEDMF), and completed the "4+4" small satellite constellation formed by four optical small satellites and four radar small satellites projected in the future. The goal is to realize the constant monitoring of disasters in all weathers (Bai, Shen, and Wang 2009). On 6 September 2008, two environment and disaster reduction small optical satellites A and B (HJ-1-A and HJ-1-B) were successfully launched at the same time in one rocket, symbolizing that disaster early warning, monitoring, and assessment in China have developed a stable and independent spatial data source.

HJ-1-A and HJ-1-B are two small optical satellites, mainly loaded with four major sensors. HJ-1-A carries two CCD cameras, a hyperspectral imager, and a Ka wave band communication sensor. HJ-1-B carries two CCD cameras and an infrared camera. Table 1 shows the important parameters of related sensors.

The life of both HJ-1-A and HJ-1-B is three years. Through the cooperative work of the two satellites, repeated observation of the same region at least once every two days can be

* Corresponding author. E-mail: zhwx@mca.gov.cn

Table 1. Important parameters of the sensors of HJ-1-A and HJ-1-B

Satellite	Sensor	Spatial resolution (m)	Width (km)	Wave bands
HJ-1-A	CCD	30	One 360; Two≥700	4
	HSI	100	50	115
HJ-1-B	CCD	30	One 360; Two≥700	4
	IRS	B1-B3: 150; B4: 300	720	4

achieved, and the monitoring and assessment problem of specific aspects of disasters can be solved, which indicates that disaster reduction and alleviation in China have entered a new stage of scientific management.

3 The System of Products for Disaster Reduction by Space Technology and the Work Mode

Disaster management is a systematic task, which is characterized by continuity and cyclicality. It is a continuous activity in which internal driving forces are interconnected. Based on its course of development, disaster management can be divided into five stages: disaster preparation, emergency response, disaster relief, restoration and reconstruction, and disaster reduction. According to the demands of different stages of disaster management, the products of space technology for disaster reduction can be classified into four major categories: disaster warning products, disaster monitoring products, disaster assessment products, and policy support products.

According to the timeliness requirements of data and products, disaster reduction by space technology can be divided into regular operation and emergency response modes. The regular mode is mainly characterized by high precision, strong regularity, and low timeliness of data or information products, and validation of remote sensing data products and other remote sensing inversion products such as vegetation index, water body index, disaster risk index, and disaster reduction application products (Figure 1). The emergency response mode is mainly characterized by high timeliness and very high rapidity and reliability and accuracy of data flow and order flow, with the ability of quick-viewing, speedy automatic processing, and intelligent processing of the related satellite data acquired (Figure 2).

4 Reduction of Emerging Disasters by Satellite Applications

To meet the demands of disaster reduction and alleviation, the China National Committee for Disaster Reduction (NCDR) has vigorously developed and promoted satellite applications in disaster reduction. NCDR has used the remote sensing data sharing mechanism established by related domestic and overseas organizations to establish business operations such as disaster monitoring and early warning, disaster emergency response, disaster assessment, and decision support to carry out a continuous analysis of disaster risks. The data of HJ-1-A and HJ-1-B have played an important role in this system. Furthermore, emergency response monitoring and evaluation are carried out for all new natural disasters in China and abroad, providing important policy support for disaster relief (Liu and Yang 2010; Yang et al. 2010).

4.1 Risk Assessment of Flood and Waterlogging from Melting Snow

Disaster risk monitoring and assessment is of high importance for disaster prevention and preparation. The National Disaster Reduction Center of China (NDRCC) / Satellite Disaster

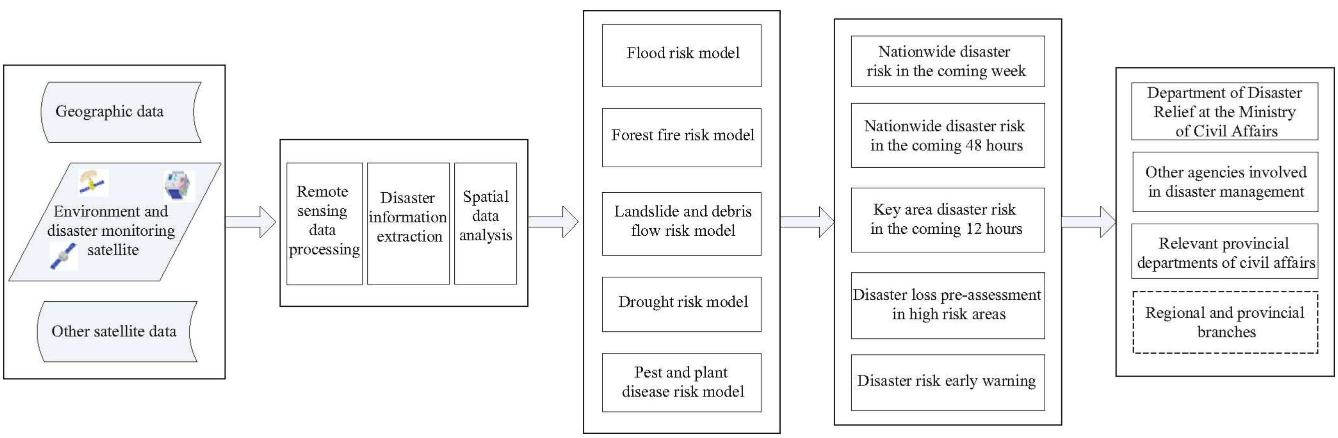

Figure 1. Flow of regular operation mode of disaster reduction by space technology

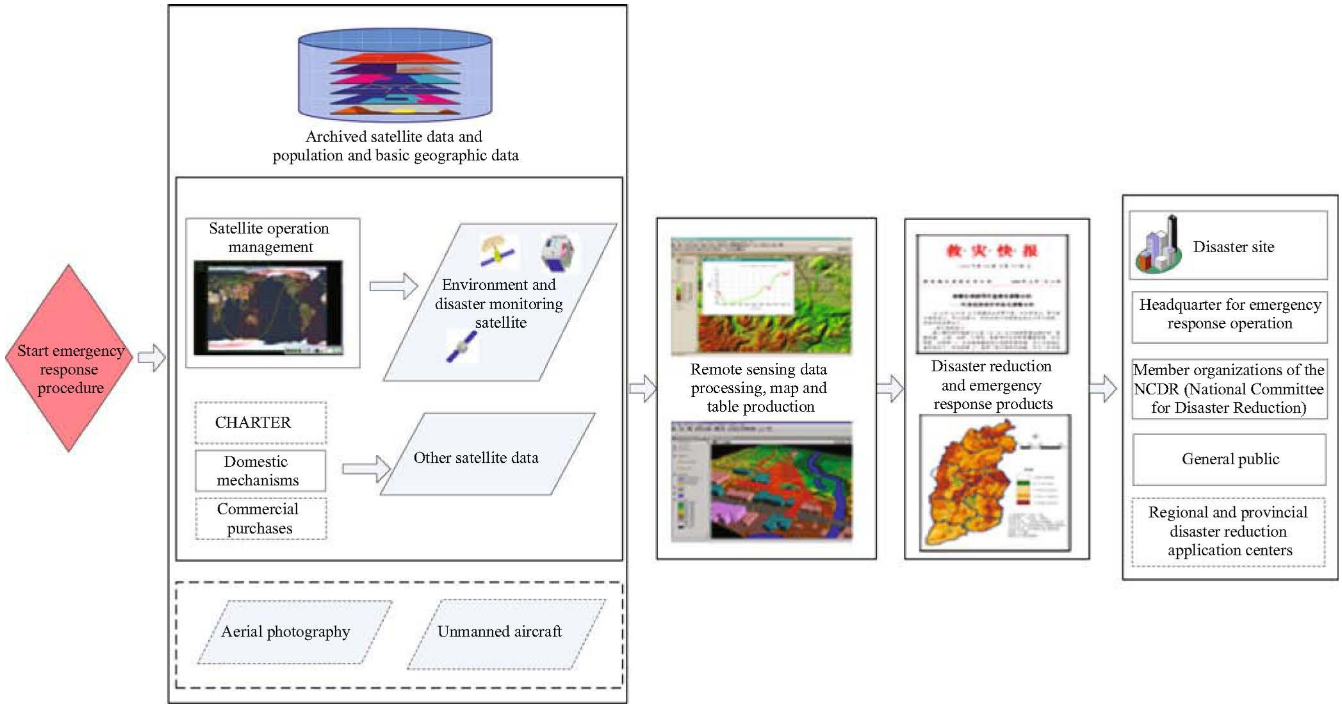

Figure 2. Flow of emergency response mode of disaster reduction by space technology

Reduction Application Center of China (SDRCC) has put the data of HJ-1-A and HJ-1-B into routine use for risk monitoring of snow disaster, drought, flood, landslide and debris flow, and similar disasters. Since the winter of 2009, Yili, Tacheng, and Aletai of Xinjiang have been to various extent subjected to the attack of snowstorms and snowfalls and depth of snow have exceeded the historical record of the same time period of the year. From the start of spring 2010, as the weather warmed up, many areas in the region were increasingly exposed to the flood risk posed by melting snow. Figure 3 is the result of melting snow flood risk assessment of Tacheng, Xinjiang in March 2010.

4.2 Snow Coverage Monitoring

Determining the coverage of snow is very important for assessing snow disaster risk and impact. Based on the data from the environment and disaster reduction satellites, NDRCC/SDRCC has regularly carried out monitoring and analysis of snow covered areas all over China. Figure 4 shows that most land areas were covered by snow in Urumqi and surrounding areas in March 2010. The map was derived by using the remote sensing images of HJ-1-A and HJ-1-B in conjunction with the reported disaster information from the local governments in these areas.

4.3 Monitoring Sea Ice Areas

CCD and infrared camera images of HJ-1-A and HJ-1-B have the advantage of wide coverage. They can also be used to effectively monitoring large-scale natural disasters such as sea ice, flood, and drought. Since December 2009, northern China experienced several episodes of cold weather in which large-scale gales and temperature drops occurred, and the

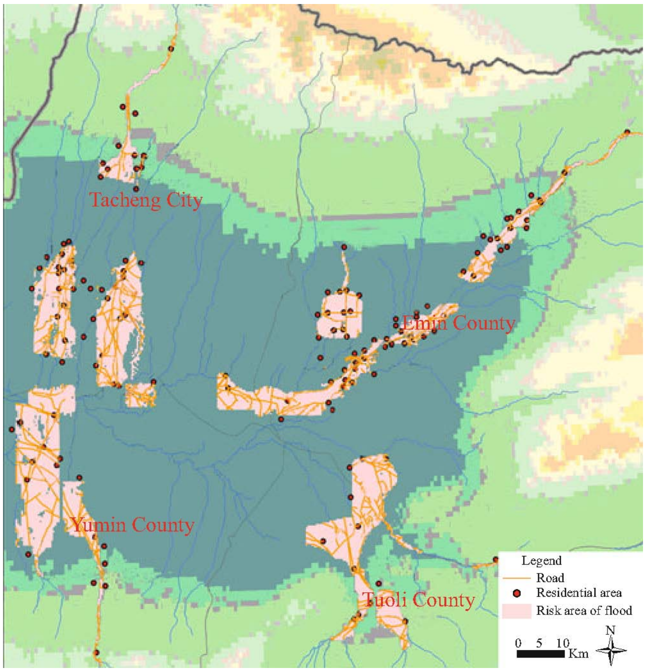

Figure 3. Risk assessment of melting snow flood in Tacheng, Xinjiang in March 2010

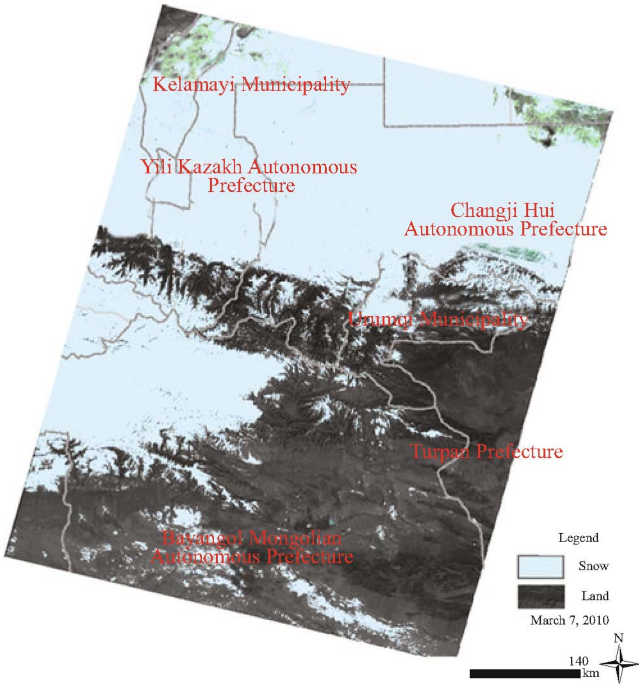

Figure 4. Snow coverage monitoring in Urumqi and surrounding areas in March 2010

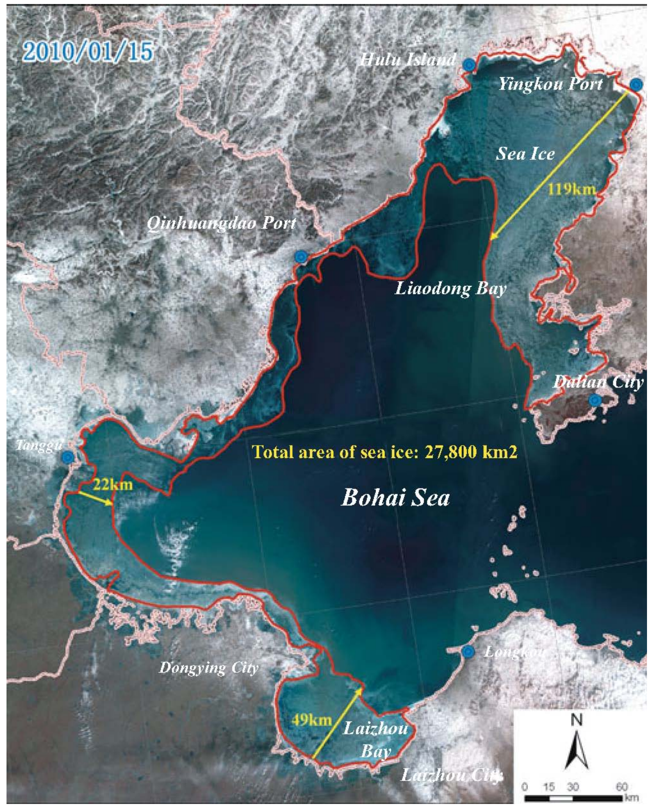

Figure 5. Remote sensing monitoring of sea ice disaster in the Bohai Sea area on 15 January 2010

lowest temperatures in some areas have exceeded the historical record. The sea ice covered area in the Bohai Sea area such as the Liaodong Bay, the Bohai Bay, and the Laizhou Bay, as well as the Jiaozhou Bay of the Yellow Sea was significantly greater than the multi-year mean level. Some areas experienced sea ice disasters of several decades recurrence interval and the freezing affected port functions and marine traffics as well as fisheries. The NDRCC/SDRCC has used HJ-1-A and HJ-1-B data to continuously monitor sea ice disasters in northern China, with good monitoring results (Figure 5).

4.4 Monitoring Drought in Southwest China

From the second half of 2009 to the summer of 2010, Yunnan, Guangxi, and Guizhou provinces in China were influenced by low precipitation and high temperature, resulting in serious drought with a several decades recurrence interval, which exerted a serious impact on people's living conditions and the industrial and agricultural production of the region. The NDRCC/SDRCC used the data of HJ-1-A and HJ-1-B to continuously monitor and assess the development of the drought. The NDRCC used these data, in conjunction with information from field investigations, to carry out a comparative monitoring over the water area of the Yangpai Reservoir in Yao'an County, Yunnan province (Figure 6). A comparison of the 2 February 2010 image with that of 29 January 2009

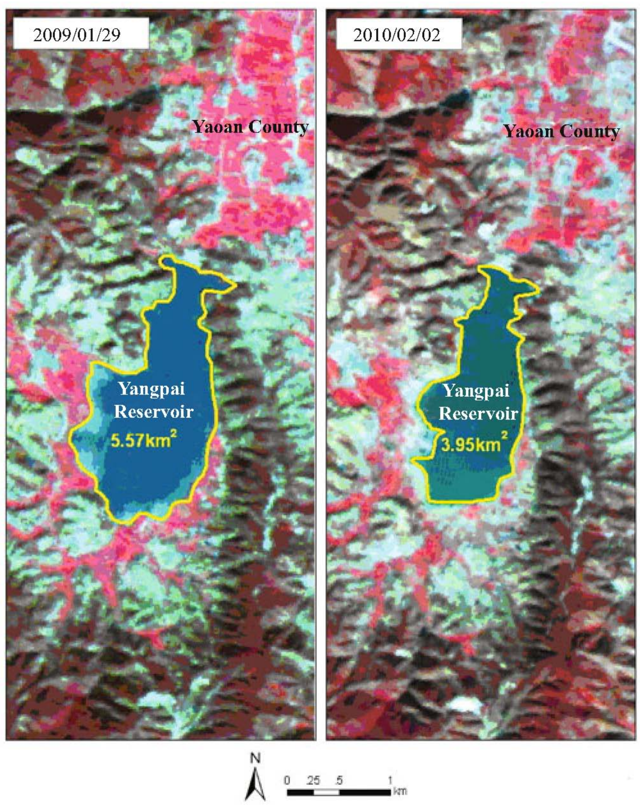

Figure 6. Remote sensing monitoring of water area of the Yangpai Reservoir in Yao'an County, Yunnan Province

showed that the drought had caused a substantial reduction of water area of the reservoir.

4.5 Yushu Earthquake Disaster Monitoring

A magnitude 7.1 earthquake on the Richter scale took place in Yushu Tibetan Autonomous Region of Qinghai Province at 7:49 a.m., 14 April 2010. It was the most destructive earthquake in the past two decades in China other than the Wenchuan earthquake. Because of the Yushu quake affected area's high altitude and remote location, obtaining timely information is critically important for disaster rescue. The NDRCC/SDRCC urgently carried out a satellite observation plan and acquired the first scene of the HJ-1-A data from the area stricken by the earthquake at 12:19 p.m. on the same day, which was the first scene of the disaster-stricken area monitoring data acquired after the earthquake. Figure 7 shows the data of HJ-1-A on the Jiegu Town, Yushu County, the prefecture seat of the Yushu Prefecture, and its surrounding areas. Using the images, a rapid appraisal of the destruction of important infrastructure such as local houses, power stations, and airport was carried out, providing important decision support for preparing immediate disaster relief.

4.6 Fire Monitoring

Fire is a frequent natural disaster in China. Fire sites and burned areas can be monitored and evaluated using the data from CCD and the infrared camera onboard the HJ-1-A and HJ-1-B (Liu and Yang 2010). Figure 8 shows the monitoring results of fire sites of the forest fire occurred in the Daxing'anling forest zone at the border of the Heilongjiang Province and the Inner Mongolia Autonomous Region due to continuous high temperature and little precipitation. This image also showed that the fire produced severe smoke and would spread to the southwest direction.

4.7 Monitoring Flood and Waterlogging

HJ-1-A and HJ-1-B have the advantages of high revisitation and wide coverage. Continuous monitoring of natural disasters such as floods also can be conducted through direct comparison and time series analysis of different images. Since June 2010, rainy weather continued in the middle and upper reaches of the Yangtze River, dramatically increasing the quantity of water in rivers and lakes. Therefore, some areas were affected by severe flooding. Figure 9 shows the dynamic

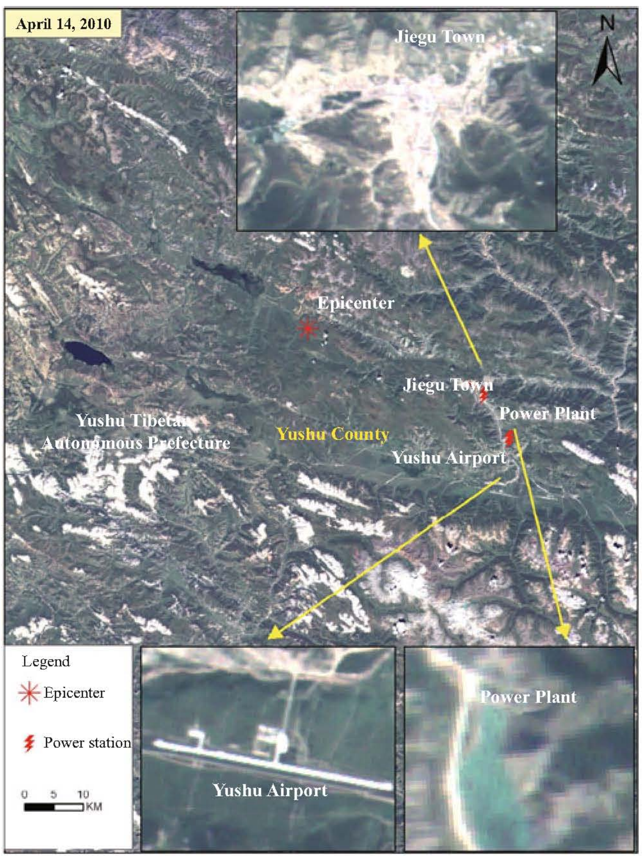

Figure 7. Remote sensing monitoring of the Yushu earthquake-stricken area by HJ-1-A on 14 April 2010

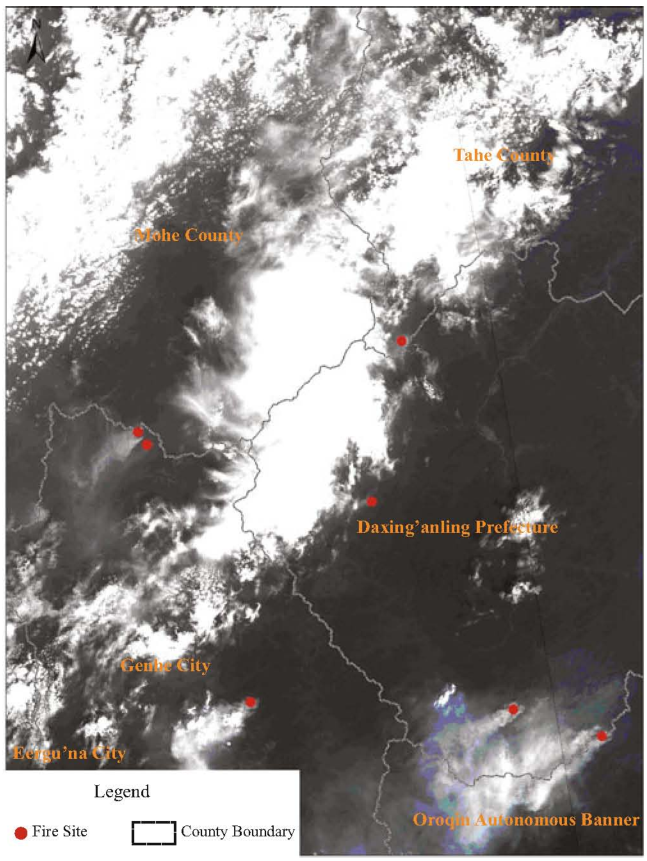

Figure 8. Remote sensing monitoring of the forest fire in Northeast China on 28 June 2010

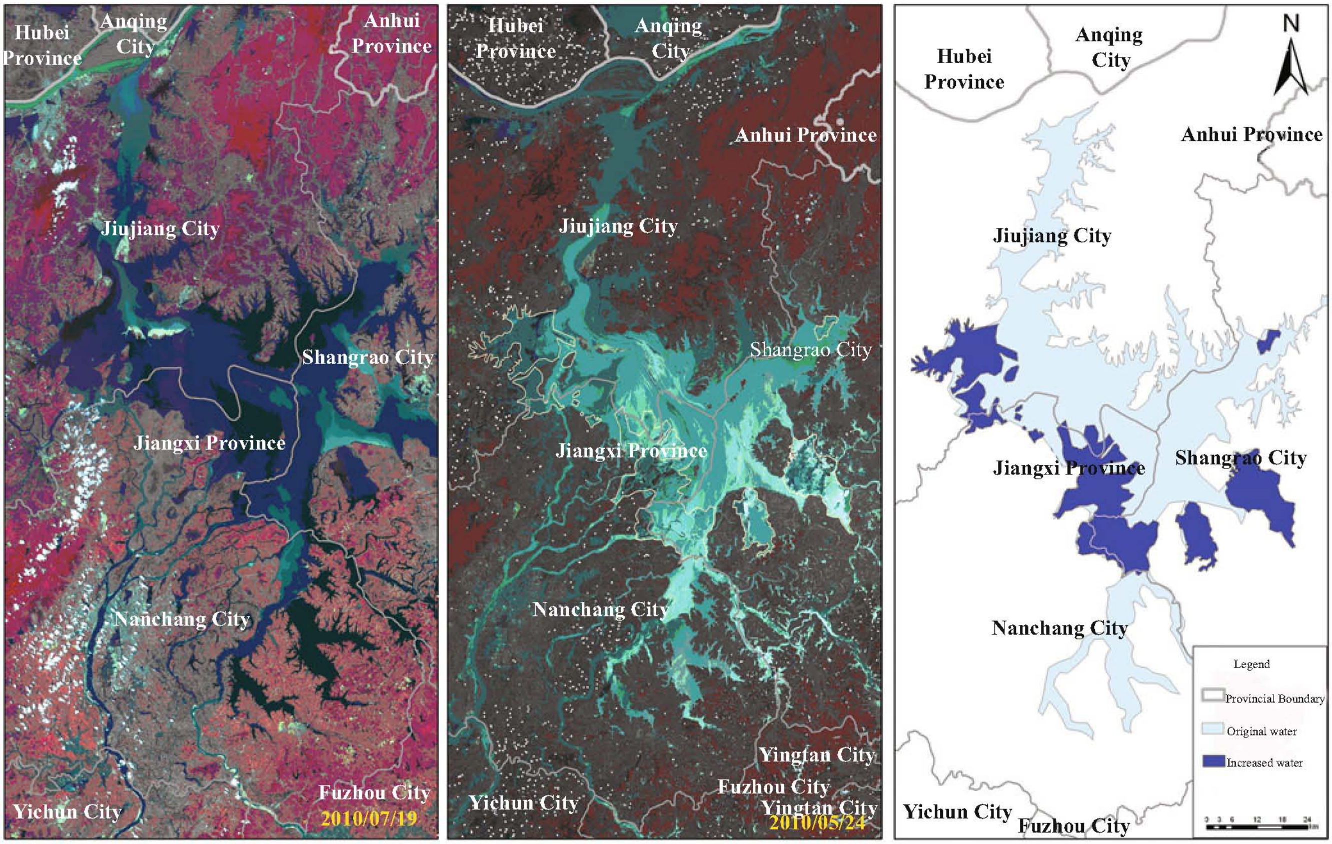

Figure 9. Remote sensing monitoring of the flood in the Poyang Lake area in 2010

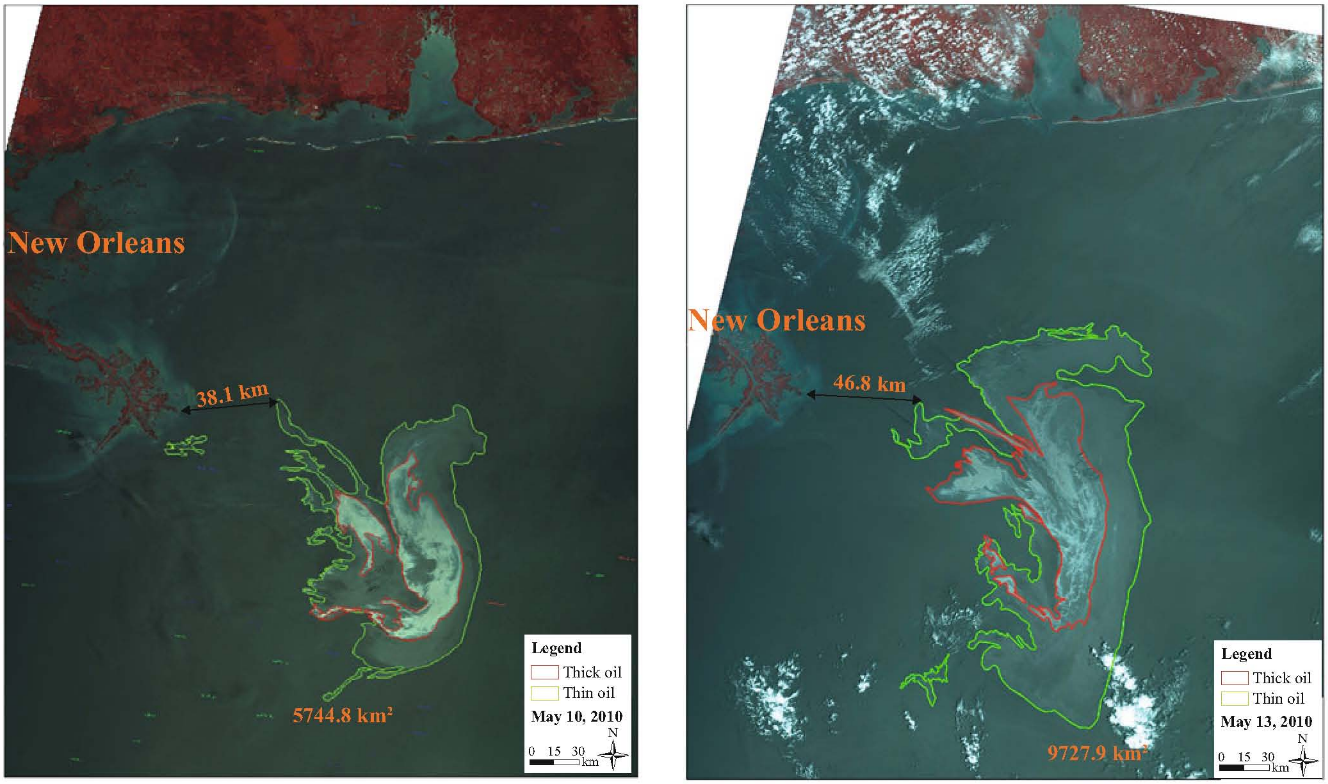

Figure 10. Dynamic remote sensing monitoring of oil spill in the Gulf of Mexico on 10 May 2010 (left panel) and 13 May 2010 (right panel)

monitoring results of the water area of the Poyang Lake and the flooded areas. According to the results, the water level of the shallow water area in the Poyang Lake covering about 941 square kilometers obviously rose on July 19 2010 (left panel) as compared with that on 24 May 2010 (middle panel), and the shoal areas were flooded (right panel).

4.8 International Disaster Responses and Services

During the past two years of on-orbit operation of the HJ-1-A and HJ-1-B, NCDR (NDRCC/SDRCC) has successfully monitored more than 10 major international disasters and provided a great deal of support to international cooperation mechanisms and organizations such as the International Charter on Space and Major Disasters and UN-SPIDER (United Nations Platform for Space-Based Information for Disaster Management and Emergency Response) in the events of the 2009 Australian fire, the 2010 Haiti earthquake, Chili earthquake, Gulf of Mexico oil spill (Figure 10), Iceland volcano eruption, Russian fire, and the severe Pakistan flood (Figure 11). Additional disaster-formative environment monitoring has been conducted for some countries (Figure 12).

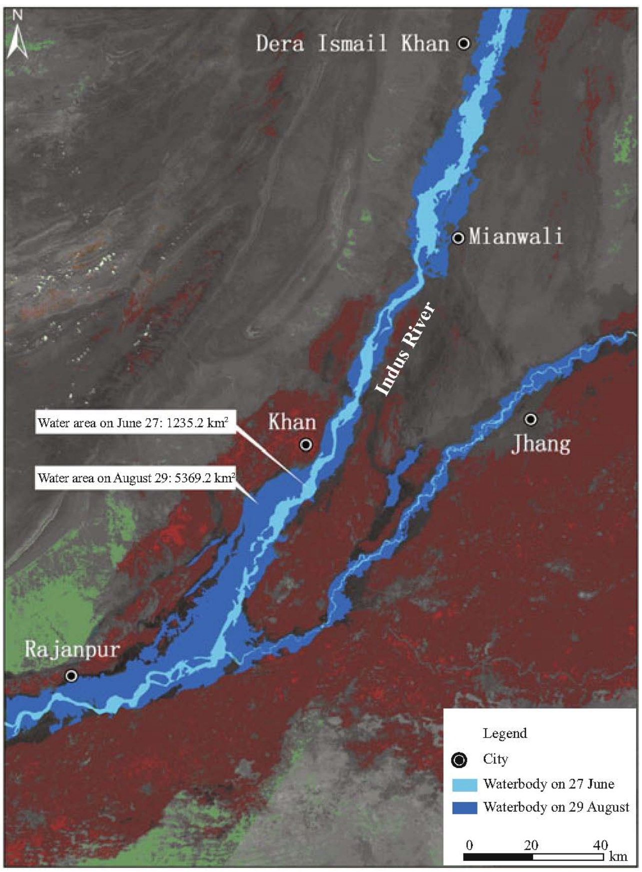

Figure 11. Remote sensing monitoring of the flood in Pakistan on 29 August 2010 as compared with the situation on 27 June 2010

Also continuous monitoring and research have been carried out on land use/land cover change issues linked to global climate changes, and these products may be useful for providing disaster background information upon which future emergency relief and rescue plans could be constructed. By using the data from the HJ-1-A/B satellites, it has been possible to provide support for international disaster reduction communication and information services.

5 Conclusion and Discussions

The environment and disaster reduction small satellite constellation is a remote sensing small satellite constellation of China that is mainly used for disaster management and environmental monitoring. It is an important part of China's earth observation system. Since the launch on 6 September 2008 of the two optical satellites, in the first stage of the constellation, China's NCDR has established a relatively comprehensive system of space technology applications for disaster reduction and in a work mode that varies according to the situation. These applications have incorporated the data of HJ-1-A and HJ-1-B into the national system of disaster reduction and relief, and have successfully coped with recent natural disasters in China including the snow disaster in the north, the Bohai Sea and the Yellow Sea ice events, the Xinjiang melting snow flood, the severe drought in the southwestern region, the Yushu earthquake, the Northeast China fire, and the southern China flood. This system has also provided data support in time to aid the emergency response to major international natural disasters, such as the Australian fire, the Haiti earthquake, the Gulf of Mexico oil spill, the Pakistan

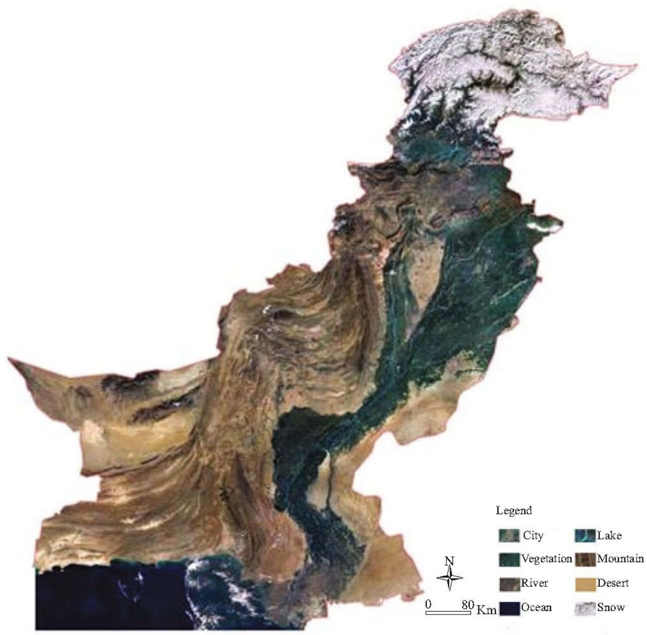

Figure 12. HJ-1-A and HJ-1-B mosaic map of Pakistan

flood, among other large-scale ecological and human disasters.

HJ-1-A and HJ-1-B have the advantages of high revisitation, wide coverage, and fairly high spatial resolution. The related data can play an important decision support role in disaster warning, monitoring, and assessment. Integrated with the synthesized aperture radar small satellite C to be launched in the next few years, they will form a small satellite constellation of "2+1". The constellation will then be able to monitor and evaluate disasters in all weather at all times. With the continuous improvement and development of the constellation, data from these environment and disaster reduction satellites will continue to be the stable primary satellite data source for applications of space technology in disaster reduction in China. They will also provide important support for major disaster response of relevant sectors and institutions in China and in the world.

Acknowledgments

This project is funded by the state Eleventh Five-Year Plan Science and Technology Support Plan Program (No. 2008BAC40B01, 2008BAK50B08), and the State 863 Key Project Program (2007AA120205).

References

Bai, Z. G., Z. Shen, and Z. Y. Wang. 2009. HJ-1A/1B Satellites Technology. *Spacecraft Engineering* 18 (6): 1–11. [In Chinese.]

Liu, S. C., and S. Q. Yang. 2010. Disaster Reduction Application of the Infrared Scanner (IRS) Data of HJ-1B Satellite. *Spacecraft Engineering* 19 (4): 110–14. [In Chinese.]

Yang, S. Q., S. J. Li, T. Tang, P. Wang, and Q. Wen. 2010. Study on the Mode for International Application of the Environment and Disaster Monitoring and Forecasting Small Satellite Constellation. *Spacecraft Engineering* 19 (4): 105–09. [In Chinese.]