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APPLICATION OF REMOTE SENSING AND GIS

TO FLOOD CONTROL AND DISASTER MITIGATION IN CHINA

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ABSTRACT: China is a country suffered frequently from flood and waterlogging. Flood control and disaster mitigation is a fundamental task for sustainable development of society and economy. This paper illustrates the application of remote sensing and geographic information system to flood monitoring and assessment before, during and after the occurrence of flood, introduces the operational and professional system for flood monitoring and evaluation, as well as its role played in recent years. The new requirement arisen from practical work of flood control and disaster mitigation is also discussed.

1. Introduction

China is a large country with very complicated natural conditions and often suffered from various kinds of disasters, such as flood and waterlogging, drought, earthquake, forest and grassland fire, snow, muddy-flow and so on. With the rapid development of society and economy, the loss resulting from natural disaster increases significantly. For example, the loss caused by floods and waterlogging was 50 billion RMB in 1991 for the whole country, 170 billion RMB in 1994, 150 billion RMB in 1995, 220 billion RMB in 1996, while 270 billion RMB in 1998. Natural disaster becomes one of main constrained factors limiting everlasting development of national economy.

Remote sensing (RS) technology has its special superiority and potentiality for disaster monitoring and assessment, so it has been applied for this purpose for a long time in China, especially for the disaster resulting from floods and waterlogging. A lot of scientific and practical achievements have been obtained in this field. Early in 1983, the Remote Sensing Technology Application Center of the Ministry of Water Resources of China (RSTAC/MWR) investigated the flood occurred in the Raoli River Basin located in the Sanjiang Plain by means of TM image of Landsat. The information on inundated area and the variation of river channel was successfully obtained. In 1984 and 1985, by using the polar-orbit meteorological satellites, the floods occurred in the Huaihe and Liaohe River Basins were investigated separately. During this period, the airborne SAR image was used for monitoring the flood in the Panjing District of the Liaohe River Basin. After scanning, image processing was done by computer. At the same time, airborne infrared remote sensing was applied for the investigation of distribution of obstacles in the channel of New Yongding River and the location of breaching dike in Sanjiangkou of the East Liao River. Especially from 1987 to 1989, through the cooperation among RSTAC/MWR, Chinese Academy of Science, National Bureau of Surveying & Mapping and Chinese Airforce, the application experiment of RS on flood control was early or later carried out in the Yongding River, the Yellow River, the Jingjiang District, the Dongting Lake and the Huaihe River. A system for quasi-real-time and all-weather monitoring flood and waterlogging was established. It played an important role to the monitor of the heavy floods in the Huaihe River Basin as well as the middle and downstream basins of the Changjiang River in the year of 1991.

After 1991, a lot of experts recognized the importance of real- time transmission of image data for reducing the loss to the minimum and suggested to set up the real-time transmission system of airborne remote sensing for disaster monitoring. Through five years' efforts, this system has been established and applied in 1994, 1995, 1996, 1998 and 1999 respectively.

2. System for Flood Monitoring and Assessment in China

2.1 Flood Monitoring

Flood and waterlogging monitoring in China is carried out in four levels of platform: meteorological satellite, high resolution satellite and space-borne SAR, airborne SAR and helicopter, ground observation stations for measurement of discharge and water elevation.

The National Satellite Meteorology Center is in charge of the macro and dynamic monitoring by meteorological satellites. It has three stations located in Beijing, Guangzhou and Ulumuqi, digital image data are transmitted to Beijing by communication satellite and mosaic image product for the whole country is made in Beijing after correction. The Satellite Ground Receiving Station of the Chinese Academy of Science can receive the digital image data of Landsat, Radarsat, ERS, SPOT, CBERS and so on. The reservation of acquisition should be separately made at least one day, two days or three days before and the user can obtain the data after initial correction in 6 six hours. The airborne SAR system is equipped on Learjet 36 with the flight altitude from 10,000 to 13,000 m. It is used for investigation of important water and other projects, such as dam, embankment, railway in urgent cases. The resolution of transmitted image is 3 m. The real-time image digital data is transmitted to RSTAC/MWR. The flood monitoring by helicopter is mainly performed in case of fine weather condition, with the altitude of 900 m. When the helicopter flies along the boundary between water body and land, GPS can record the location.

RSTAC/MWR can access the real-time database of the Ministry of Water Resources. The real-time discharge and water level are useful for the option of alternatives for flood monitoring and also important for estimating loss resulting from flood. All of these data are sent by network or other measures to RSTAC/MWR.

2.1.1 All-weather and Real-time Transmission System of Airborne SAR

This engineering system is the integration of RS, global positioning system (GPS), data transmission and image processing. The image data acquired by radar in aircraft is sent to communication satellite first, the transmitting station on the ground enhances the signal and sends it back to communication satellite, then the user stations can receive it in seconds. The system consists of three subsystems: information acquisition, data transmission and image processing.

The maximum effective distance of the synthetic aperture radar is 55 km, the real-time imager can deal with SAR signals with the resolution of 3 m into the data of SAR image of ground according to the semi survey band (resolution of 3 m) and full survey band (resolution of 6 m). At present, the resolution of transmitted image data is 3 m. GPS is linked with the navigation system. Apart from the allocation of radar image, it can provide the location of aircraft for the antenna servo system to ensure the trace to communication satellite. The GPS data now is transmitted together with image data once every second. So the geometric correction and mosaic of bands would be carried out on the full use of increased GPS data. The airborne station cryptographs, modulates and compresses the data of SAR image from the real-time imager and then sends them to the communication satellite. The transmitting station is mainly for solving the limitation of up link, increasing gain and avoiding the superposition of noises. After demodulation, decompression and decryption, the user station can perform data processing. The subsystem of information processing mainly realizes real-time display of image, real-time record of data and real-time hard copy of image.

The functions and characteristics of the system can be summarized as: all weather, real-time data transmission, flexibility in time and space and high resolution. It made a great contribution for flood monitoring in recent years, especially in 1998 and 1999.

2.2 Flood Assessment

On the basis of the monitoring data sources mentioned above, an integrated system for flood monitoring and assessment is established in RSTAC/MWR. It is a professional and operational center. Its operation starts from this year. The integration of software, hardware, data base and network is the key issue of its successful establishment. It is a distributed operational system, including the sub-centers of meteorological satellite observation and ground hydrological observation. The meteorological satellite monitoring is mainly used for macro and dynamic monitoring on warning level, space-borne SAR for disaster and loss assessment, and airborne SAR for important water and other projects investigation under urgent case. For space-borne SAR, ERS is used for the disaster investigation of local flood and for the rivers along north-south direction, while Radarsat for the floods covering a large area due to its wide scope of 500 km*500 km, or the flood occurred in cities due to its high resolution with its fine modes

As for disaster and loss investigation, main contents are the inundated area of each county and its mapping, including its landuse classification, especially the inundated area of cultivated land and that of residence area. For project investigation, it includes reservoir, embankment, sluice gate, flood basin, retarding basin, bridge, railway, highway, harbor, airport, oil field and so on.

The disaster assessment is performed on the basis of following data sources:
1) GIS including the layer of social-economic data for some of areas flooded frequently,
2) Landuse classification from TM images before or after flood season,
3) Topographic maps mainly used to find geographic control points for geometric correction and extraction of administrative boundary.
4) Other thematic maps

3. Foods in Recent Years and Their Monitoring and Assessment by Remote Sensing & GIS

In China, the heaviest flood since 1954 occurred in 1998, especially on the Changjiang River Basin and Nenjiang-Songhuajiang River Basin. While the highest water level in history and the second highest water level since 1954 occurred on the Taihu Lake and the Changjiang River separately in 1999, the highest water level in history on the Yongjiang River in 2001.

RSTAC/MWR performed flood monitoring and assessment 9 times in 1998, five times for the Changjiang River Basin on 7th and 30th of July, 8th and 3th of August respectively, four times for Northeast China on 4th, 17th, 21st and 30th of August respectively, four times by airborne SAR and five times by space-borne SAR, including Radarsat and ERS-2. The total covering area of investigation is 480,000 km^2. Besides, more than 50 meteorological satellite image products showing the inundated area of different river basins were made during the flood season.

Up to 7th of August, RSTAC/MWR did 6 times of flood monitoring and assessment in 1999, One time for the Taihu Lake Basin on 3rd July, three times for the Changjiang River Basin on 24th and 26th of July, one time for the Yellow River Basin and one time for North-east China on the same day of 7th August, five times by space-borne SAR of Radarsat and one time by airborne SAR. The total monitoring area is 950,000 km^2. Besides, 46 times of monitoring by meteorological satellite were done.

In 2000, heavy landslide occurred in the Eagong River, a branch of the Yaluzhangbu River in Tibet Autonomous. It stooped up the river course like a dam and formed a big lake. With the increase of water storage in the lake, t is very dangerous for the downstream area if the increasing water breaks the landslide body. The best solution is to dig a channel to release the water gradually before the coming raining season. In this case, successive monitoring were made by RSTAC/MWR with CBERS data . Combining GIS, the investigation for the storage of water amount, the expansion of landslide body, the slop of the river course downstream of the landslide body provided some important information for the decision making. Besides, since 2000, the law of flooding basin use with compensation was begun to be carried out. The compensation is decided by the result of remote sensing. So successive monitoring were made for the Nihewa Retarding Basin in the Henan Province in order to catch the largest inundated area.

In 2001, heavy flood due to typhoon occurred in upstream of the Pearl River, highest water level in history occurred in Nanning City, the capital of the Guansi Autonomous, remote sensing also played its important rule again.

The assessment consists of inundated area of each county and mapping, including cultivated area, resident area and other main landuse classification, as well as the situation of reservoir, breaching embankment, number of inundated oil ell, length of inundated highway, the effect of water diversion and so on. All of these were finished within 48 hours. All information was sent to the State Flood and Drought Prevention Headquarter and the Office of State Council as early as possible, providing important data for decision-making on disaster relief and evaluation.

4. Requirement Arisen from Practical Work of Flood Control and Disaster Mitigation

The most important information needed for flood prevention is rainfall, hydrological regime (water level and discharge), water project situation and disaster condition. What we are doing by RS and GIS is limited in the last two aspects. The rainfall measurement by meteorological satellite and Doppler radar and conversion from inundated area to water level with the support of GIS would extend the application of RS and GIS to the first two aspects and become a tool which must be used in flood control.

Flood disaster assessment before the occurrence of flood is more important than that during and after the occurrence of flood, because it can provide important information for decision making and can really reduce the loss due to flood. According to the flood forecasting, GIS-based flood routing can provide the inundated area under different regulation alternatives. Combining with social and economic database the affected population and economic loss can be estimated for different alternatives. It is very important for deciding which alternation will be finally selected under the principle of reducing loss to the minimum. In order to realize this purpose,, the most important thing is to establish GIS for all areas where floods occur frequently. As the first step, the GIS with the scale of 1:100,000 is useful for loss evaluation, then that with the scale of 1:10,000 is necessary for flood routing in order to estimate economic losses resulting from different operational alternatives before the occurrence of flood, so as to provide information for decision-making on water projects' operation and withdraw of resident. Besides, on the basis of long-term historical data including rainfall, runoff, water projects, population, economy, landuse and other factors, the flood hazard zoning with 8 classes and flood disaster risk zoning also with 8 classes in China have been finished. They are also very useful for flood prevention planing and decision-making before occurrence of flood disaster.

5. The Establishment of Professional and Operational System for flood Monitoring and Assessment

As mention above, a professional and operational system for flood monitoring and assessment has been established in RSTAC/ MWR. It is entirely different with scientific research. Through one year's operation, some experiences have been obtained and sum up as follows.

The basic conditions for professional and operational system are:

1) Sufficient and reliable remote sensing data source from different sensors,
2) Sufficient background data,
3) Effective and quick technology for image processing, information extraction and analysis,
4) Well-organized command system,
5) Quick communication,
6) Quality control system.

In any case, RSTAC/MWR must send the information on inundated area, including the inundated area of each county and corresponding thematic map to the State Council and State Flood Control Headquarter within 12 hours after acquisition of satellite image, and finish the assessment, including the inundated cultivated land and resistant area of each county as well as corresponding thematic map, within next 12 hours. The basic conditions mentioned above are fundamental for the success of flood monitoring and assessment.

6. Conclusion

1) Remote sensing and GIS can play important roles to flood monitoring and assessment, it is proved again through the practice for the flood investigation during recent years in China.
2) The establishment of operational system is essential for practical performance of flood disaster mitigation.
3) The extension of application of remote sensing and GIS to decision-making before the occurrence of flood is a significant challenge in the near future.