SAR Remote Sensing Technology Development and Application in China

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Remote sensing technology is one of the most powerful tools for human to know the nature and their living environment. However, before microwave remote sensing was developed and applied, remote sensing application was limited strongly by weather and time. Microwave remote sensing technology solves the problem. It makes us to have the capability to acquire information at all time of the day and under all weather condition, and make remote sensing technology be used in more wider area. Microwave remote sensing system include mainly Synthetic Aperture Radar (SAR), Microwave Radiometer, Microwave Scatterometer, and Altimeter (ALT). As SAR can acquire image whose spatial resolution is similar with visible and infrared image, it is paying much attention to and playing a more and more important role in earth observation. In recent year, the development of new SAR technology (multi-band and multi-polarization technology, InSAR technology, D-InSAR technology, and so on) makes SAR remote sensing go to an new stage, and its application area become more and more widely.

The first Synthetic Aperture Radar (SAR) in the world appeared in 1960. After that, SAR and its application all developed very fast. Some radar satellites launched and run (include Seasat-A in 1978, ERS-1 in 1991, JERS-1 in 1992, Radarsat in 1995, and so on) promote SAR research and application in world greatly. China began to develop its SAR sensor and research SAR application in 1970s. After more than 30 years' research, it get some important development in sensor development, data processing method, and application. Some operational systems have been used and play an important role. This paper will introduce the development of SAR technology and its application in China.

1. Data Acquisition and Processing

A lot of research and development work have been done on data acquisition and processing, which provide reliable foundation for further application.

1.1. Sensor

The research and development of SAR sensor in China was begun in 1970s. After some research and technical preparation in several years, China began to develop its airborne SAR system at 1977. The first experiment system fulfilled air remote sensing experiment and got the first airborne SAR image in 17 September 1979. In 1983, the single band and single polarization system was fulfilled. It is an operational airborne SAR system, and works in X-band,

HH polarization, 10 m x 10 m spatial resolution. Multi surveying band and multi polarization system, named CAS/SAR, was fulfilled in April 1988. Its working wavelength is 3 cm, and can get HH, HV, VV, VH polarization images. Spatial resolution is 10 m x 10 m, surveying band width is 35 km. Their application promote SAR research and application in China effectively, and get very good application result. For example: in summer 1989, CAS/SAR was used to monitor the flood in Yangtze River, and got a lot of images (include in night and raining weather). It was a great help for disaster control agency to know the situation and developing process of the flood and make the decision.

L-band airborne SAR system (named L-SAR) was also be developed successfully in 1990s. Its developing is not only for developing of operational airborne SAR system, but also for developing of satellite SAR system. It has two polarization way: HH and VV, spatial resolution 3m x 3m, and has multi working modes. It has been used widely in various application area, especially flood monitor. At same time, satellite SAR system also be developed. Its prototype system has been finished in a few years ago. Now the system is developed further, and will be installed in first radar remote sensing satellite of China soon.

Some new SAR technologies (for example: Spotlight SAR, Curvilinear SAR) have been researched and developed. Spotlight SAR can get image with very high spatial resolution, and has wide application foreground. Some technical research for Spotlight SAR has been done, include antenna beam control, movement compensation, imaging algorithm, and so on. Based on research, L-SAR was used to do Spotlight SAR experiment and got image with 1.5 m resolution. The further research for higher resolution is doing. Curvilinear SAR (CLSAR) technology born only a few years. It can get 3-D information with only one antenna, however, the movement compensation and imaging algorithm are much difficult than normal SAR. It has been researching and has got some results.

1.2. Real Time Data Transmission System and Processing System

The successful development and application of the airborne SAR make us to get a lot of SAR data. In China, the most important application of airborne SAR is for disaster monitor. It is needed for final user to get the data and know the situation about the disaster as soon as possible. In order to make the final user get SAR image in time, real time transmission system for airborne SAR was begun to researched and developed from 1980s. The first system was used in 1990. Then the system was developed and modified continuously. In 1996, an operational real time data transmission system, named Airplane – Satellite – Ground System, was established and applied. It is a comprehensive space – ground system. After airborne SAR got data, the system in airplane will process and compress data (use wavelet method to compress data. The compress ratio is over 1/60 and still can get high quality image), then transmit compressed data to ground receive station directly by communication satellite. It was used to establish an disaster monitoring system with L-SAR and be circumstantiated as a very useful system. When the first time airborne SAR was used to know flood situation in 1985, it needed more than 20 hours from airplane arrive the flood area to that the disaster control center in Beijing saw SAR image. Use the real time communication system, no matter where disaster area is, the image can be shown in

the screen in Beijing only a few second after airborne SAR began to work. It make the disaster control center can know the situation in real time, and make decision betimes.

SAR data imaging and data processing is quit different with other remote sensing data. It needs some special data processing algorithms. These algorithms have been researched, and some new data analysis methods like wavelet, fractal, neural network, have been used for SAR data processing. Some new algorithms have been developed (for example: adaptive filter based on wavelet analysis and based on fuzzy analysis). Based on the algorithm research, the software system, which was used specially for SAR data processing, has been developed, and already be used in various application projects.

As SAR data volume is large and data processing is complexity, it often needs more time to process SAR data. However, for some important application like disaster monitoring, user often requests to get result as soon as possible. Using large computer often cost much. Based on parallel algorithm, an image processing software system has been developed. Its hardware environment is the network made up of 5 to 8 PC computer, operational system is Linux or Window NT. It can process large volume SAR data fast by general PC computer (it process ERS SAR original data to get one standard scene ERS image need about 5 minutes) rather than expensive large computer, and get higher process speed with lower cost.

2. Application

SAR application research in China began at 1970s. Since then a series of SAR research and application projects have been done, included some international cooperation projects. It promotes SAR research and application, and makes more and more agencies use SAR image in their professional work. Now SAR data has been used widely in various aspects in China, include mainly:

2.1. Flood Monitoring

China is a country where the appearing frequency of various natural disasters is quit high, and often face to be menaced seriously by flood, typhoon, drought, earthquake, forest fire, and so on. The economic loss per year caused by the natural disasters is several million dollars, and trend to increase with the growth of economy every year. Among these disasters, flood is most serious. In recent year, the economic loss caused by flood is about 70% of all loss caused by natural disasters, and be 3% - 6% GNP. For example, in 1998 summer, The economic loss caused by flood along Yangtze River and Nenjiang-Songhuajiang River area in 1998, is over 3 billion dollars! It has been one of the important factor which affects national economic growing and regional sustainable development seriously. Therefore, central government and local government in various levels are all pay much attention to avoid flood and reduce loss caused by flood. In China, the most important SAR application is to monitor flood.

In August 1985, the big flood appeared in the Liao River basin, and bullied some important cities, factories and oil fields serious. Airborne SAR was used to monitor the situation

of the flood. As SAR can work and get clear image in the bad weather, it was almost the only way to know situation about flood area. It got SAR image covered more than 110,000 km.sq, and provided accurate information for the flood control center to make correct decision, and played an important role in the flood control. It is the first time in China that SAR image was used to monitor flood in real time, and get very successful result, even if the data transmission and processing still need longer time. The successful application make our government pays much attention to develop and apply SAR in flood monitoring. It becomes the indispensable tool for flood disaster relief. In recent year an operational flood monitoring and evaluation system has been established. It consists of the remote sensing airplane with airborne SAR, Airplane-Satellite-Ground System, and ground processing and decision-making support system. In 1998 summer, it was used to get SAR image covering 200,000 km.sq. At same times some satellite SAR images were also got. The data was analyzed in the ground processing and analysis system in the flood control center. The analysis and evaluation result was sent to central government and local governments. It plays a very important role in decision-making of flood control. Now SAR application in flood control is considered as the most successful and most valuable application of remote sensing technology in China.

2.2. Agriculture

In agriculture research, SAR images are used mainly to identify different landuse types and vegetation types, especially crop types. Some methods have been used to increase classification precision, include: data fusion of SAR image and other image; using multi-band, multi- polarization and multi-time data; using grain information in SAR image extracted by wavelet analysis and fractal analysis, and so on.

It is one of the most important applications to identify rice land and measure its area. As it is often rainy or cloudy on main rice area in China, especially in Zhujiang Delta where are the most important rice area, SAR image is indispensable for rice area measure and changing monitoring. A series of research has been done. In theory, one research is to simulate and analyze the dielectric constants from different rice growth stages by Debye-Cole dual-dispersion mode of vegetation. The growing period of rice crop is divided into five major stages: transplant, seeding developing, ear differentiation, heading and mature period. Analysis shows that rice crops of different growth stages have the various dielectric constants, and the dielectric constants of early and late season rice crops show the diverse changes. The parameters, including frequency, gravimetric moisture content of rice, temperture and bulk density of dry vegetation materials, have the influence on dielectric constant, but salinity has no effect on the dielectric constant. Another research is to establish microwave backscatter model for some crops (include rice) based on Monte-Carlo method and Vector Radiative Transfer Theory (VRT). It can simulate microwave backscatter coefficient of rice and its variations with date, incidence angle, wave band, and polarization change. These analysis results will be helpful in theoretical and methodological guidance for using SAR data to make rice field mapping, rice growth monitoring and rice production forecasting more effectively.

In application, multi-time ERS images have been used to identify rice, measure rice area,

and monitor its change in different year in Zhujiang Delta area, and got good classification result the identified precision for rice area can be higher than 90% in flat area, and 88% in other area. Now the method has been used for whole Guangdong province, and got good result. Similar method also be used other crops. SAR image is also used to measure moisture in soil and find ground water in arid and semi-arid region.

2.3. Application of InSAR and D-InSAR Technology

In recent year, SAR Interferometry (InSAR) and Differential SAR Interferometry (D-InSAR) technology are developed and applied fast. They use SAR phase information to get 3-D information of earth surface and detect its change with high precision, which is important information for research and application. Scientists in China pay much attention to study and apply InSAR and D-InSAR technology. Using SIR-C/X-SAR images, DEM in Xinjiang Province have been got by InSAR technology. Compare with topographical map with 1:100,000, DEM from SAR data show more detail then topographical map. In Tibet, ERS-1/2 SAR images Were used to do the same work, and got same result. InSAR also be used to identify forest and forest mapping, and got good result.

China is one of the countries with frequent earthquake occurrences. It often cause serious loss. For example: Tangshan earthquake on 28 July 1976 (Ms = 7.8) cause more than 200,000 death and 10 billion immediate property loss. Therefore, earthquake is pay much attention. On 10 January 1998, an earthquake (Ms = 6.2) occurred in the Zhangbei-Shangyi region of Hebei Province. It was the strongest earthquake near Beijing since Tangshan earthquake on 28 July 1976. The coseismic displacement field of the Zhangbei-Shangyi earthquake was measured using ERS-1/2 SAR data by the three-pass D-InSAR method. Based on a standard elastic dislocation model for seismic displacement, the focal mechanism of the earthquake is estimate from the D-InSAR measurement of surface deformation. Through the relation between the focal parameters and displacement in the line of sight direction measured in the radar interferogram, the optimum focal parameter set is derived. It was used to analyze the focal mechanism and earthquake-induced structures.

Land subsidence is another serious problem in China. It has occurred in near 50 cities of 16 provinces. Suzhou City is one of the most remarkable cases of urban land subsidence in China with regard to the extent of the subsiding area and to the velocity of the vertical movement. There is a strong demand for accurate and economical method to monitor land subsidence. D-InSAR technology has been used in Suzhou City, Jiangsu Province. Eight ERS-1/2 SAR images from 1993 to 2000 is collected and to create seven interferograms, and three differential interferograms (1993 – 1995; 1995 – 1998; 1998 – 2000) are produced by three-pass method. They show the spatial distribution of land subsidence clearly. The deformation maps are validated by leveling surveys, the correlation coefficient and standard deviation between them are 0.943 and 0.1706 respectively. Based on seven benchmarks, the subsidence rates are estimated, the overall trends are in close agreement with analysis result by SAR images.

2.4. Other Application

As microwave has good penetrability for vegetation and dry soil, geological character can be seen clear in SAR image. Therefore, it is very suitable to geological survey. In China, SAR image has been used to identify rock type and various geological structures, and help to modify geological map. Some new faults have been found after using SAR data, which can't be found in both geological map and other remote sensing images. SAR data is also used in research on engineering geology and gold mine.

Marine study is another important application area in China. SAR has been used to study sea surface character, extract information of wind vector, identify sea ice type, monitor oil pollution, detect the ship wake, and so on.

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