Research Advances

Quantitative Estimation of Groundwater Leakage from Namco Lake by SAR Monitoring

CHEN Jiaqi[1,2,*], DENG Yunkai[2], LI Ning[2], WANG Yu[2], LIU Zhongling [2] and ZHANG Shilin[1]

1 *Computer and Information College, Hohai University, Nanjing 210098, Jiangsu, China*
2 *Department of Space Microwave Remote Sensing System, Institute of Electronics, Chinese Academy of Sciences, Beijing 100190, China*

Objective

This study focused on the Namco, the largest lake on the Tibet plateau as well as the highest large lake in the world. A large imbalance between water input and output of this lake has attracted great attention in the field of hydrogeology during recent years. As there is no surface outflow from Namco, the large water imbalance can only be explained by water seepage. Synthetic aperture radar (SAR) image data were used for the first time in combination with hydrological data actually measured in the field and meteorological station data, to quantitatively acquire the information of surface fluctuation, water storage variation, and to estimate groundwater leakage from Namco Lake. The results provide theoretical support and data for further understanding the processes and extent of water resource response to global climate change, and also provide a scientific basis for rational development and utilization of water resource in the Tibetan Plateau.

Methods

As Namco is a closed lake without subsurface outflow, the water balance of this lake in a given period can be given by: $L=P+R+G-E$, where P is the precipitation over the lake, which can be acquired from Tropical Rainfall Measuring Mission (TRMM) Multisatellite Precipitation Analysis (TMPA) products assimilating with independent rain gauge networks located within the Namco Basin; R is the runoff into the lake and E is the evaporation of the lake, which both could be obtained by nine field observations; L is the lake level change, and can be obtained by calculating the changes of lake area. A four-step approach was proposed for the calculation of lake area: (1) orthorectification and data coregistration; (2) speckle filtering; (3) segmentation of SAR images; and (4) water area detection and calculation. G is groundwater flow into the lake. This amount of water seepage can be obtained from the water balance equation, while the other mentioned four parts were known.

Results

The main progress of this research is the accurate measurement of the lake area change by utilizing high resolution SAR data. TerraSAR-X is an X-band polarimetric SAR capable of imaging up to 1 m resolution in spotlight mode. As narrow observation area is the expense of high resolution in SAR imaging, scene size of TerraSAR-X high-resolution spotlight mode is only 5 km´10 km (azimuth´range). Therefore, for a great lake around 2000 km^2 such as Namco, the selection of observation position is very important for assessing the resolution accuracy. Based on the lake bathymetric survey data, the most obvious water level fluctuations of Namco is located in the northeast corner, which is also the most relatively gentle terrain of the whole lake. After accurate water area detection, all temporal SAR images were mapped by the above mentioned processing steps. The integrated images of the detection water area in two days (2014.07.11 and 2014.08.02) were stacked on one map (Fig. 1), in which the water area of Namco Lake was extracted and interpreted as black parts in the figure. The divergence between temporally distinct water surfaces, which were highlighted with a red color along the shoreline, indicates a significant augment tendency of Namco Lake. The water area of Namco was calculated utilizing the corresponding mapped technique to be 32982205 m^2 and 33253869 m^2 in high-resolution spotlight mode (1m´1m), respectively. The largest area change part is located in the valley region, marked in red box, with lake area increasing by 79824 m^2. In accordance with the prior investigation and meteorological data set, the average precipitation, glacial meltwater supply, as well as runoff reaches the maximum of the whole year in the duration from June to September on Tibet Plateau were determined. Thus, it is easy to understand the extensive

* Corresponding author. E-mail: cjq19840130@163.com

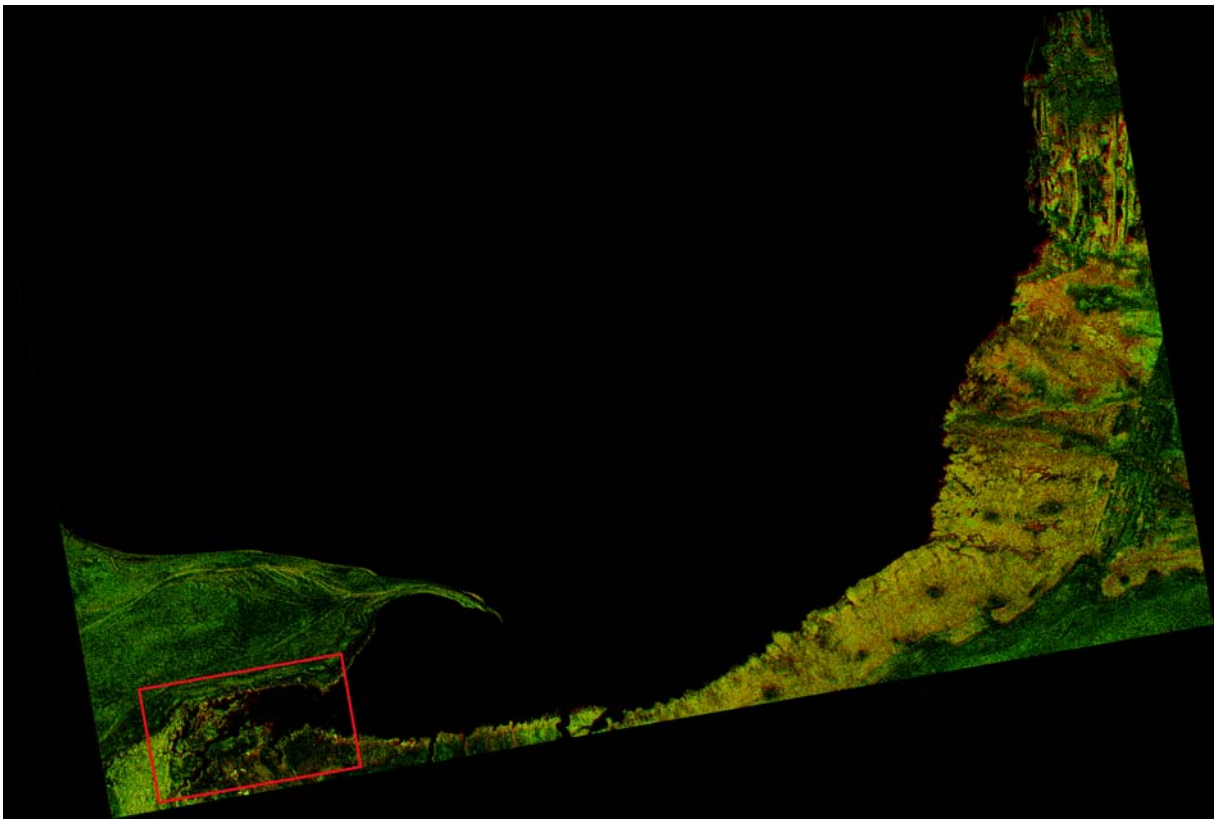

Fig. 1. Pseudo-color result of two SAR images acquired on July 11st, 2014 and August 2nd, 2014 for the study area in Namco Lake.

tendency of the lake. Combined with ground measurements and historical data, available water level vs. lake area curve was gained, and the lake level changes were analyzed.

Conclusion

High-resolution TerraSAR-X spotlight mode images were utilized to monitor groundwater leakage from Namco in the central Tibetan Plateau. To extract the water body of Namco Lake from temporal SAR images, a set of image processing method was exploited before quantitative calculation of the accurate area and its changes. The comparison image of 2-days' integrated results demonstrates the extensive trends of water area, which is quite consistent with prior research for meteorology and climate mechanism during summer time. Thence experiment results indicate high-resolution TerraSAR-X system has huge potential for annual accuracy monitoring of groundwater seepage in the field of hydrogeology.

Acknowledgement

This work was financially supported by the National Natural Science Foundation of China (grant No. 61301025), the Jiangsu Provincial Natural Science Foundation of China (grant No.BK20130853), the Fundamental Research Funds for the Central Universities (grant No.2016B07114).