論文の内容の要旨

Spatio-temporal analysis of flooding on global scale using microwave remote sensing

(マイクロ波リモートセンシングを用いた

グローバルな洪水の時空間解析）

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Global warming combined with human activities has caused flooding to become the most frequent and devastating natural disaster. The total number of floods worldwide has more than tripled over the last 15 years. Moreover, for the issue of global warming, it is documented that the average temperatures worldwide has risen since the end of the 19th century. In order to discuss and learn about flooding issue, at least 30 years of data should be traced back based on scientific view of global warming. Additionally, in order to meet the needs of government and enterprises, making use of large historical database of Land Surface Water Coverage (LSWC) will be a valuable, economical and necessary way to obtain accurate information and estimate flooding. Among different kinds of sensors, AMSR-E, which belongs to passive microwave remote sensing, can provide long time series of daily global coverage data. PALSAR, which belongs to active microwave remote sensing, has high spatial resolution without cloud interruption. They are in trade off relationship.

In order to better understand the flooding from this large historical database, land cover change and precipitation are incorporated and analyzed. Land cover change is known to influence both surface water hydrology and soil properties. Rainfall also seriously influences open water and soil moisture and thus plays an important role in flooding researches. Making clear the relationship among LSWC, precipitation and land cover change not only for a certain watershed or a single region but also for the global range is of great significance.

The purpose of this study is to conduct more precise calibration of AMSR-E by PALSAR. Secondly, to build nearly 30 years of LSWC database by SSMI, AMSR-E, WindSAT and AMSR2 and to estimate the historical tendency of land surface water coverage of each river basin. Thirdly, to analysis the effects of land cover change and rainfall on the global LSWC during 1987-2015 derived from passive microwave remote sensing.

Firstly, the incidence angle effect to the backscattering for PALSAR ScanSAR mode was investigated. It was found that the change of incidence angle brought backscattering variation in PALSAR ScanSAR images. However, the standard deviation of σ^0 (dB) against incidence angle of ascending and descending scenes in Australia and Colombia were 0.36 and 0.56, smaller than 1dB. Within small range of incidence angle, the effect of incidence angle is within the acceptable σ^0 (dB) variation of PALSAR in this study. Then, spatial correspondence was discussed between AMER-E NDFI/NDPI LSWC and PALSAR LSWC. There was a good agreement among them. At the same time, it was also found in AMSR-E image, there is some blur at the edge of inundated area because of the different spatial resolution and mechanism of PALSAR and AMSR-E. By applying the least squares method. It was found that the determination coefficient reached more than 0.8, the exponential regression curve could precisely represent the scatter points and the RMSE of NDFI is smaller than that of NDPI. AMSR-E NDFI showed a better performance than AMSR-E NDPI on land surface water coverage estimation. Using more precise AMSR-E calibration by PALSAR, the availability and potential of AMSR-E LSWC for large scale flooding detection was indicated.

Secondly, taking into account population density of the world, 68 major river basins were delineated continent wise all over the world using HYDRO1k data. LSWC derived from SSMI, AMSR-E, WindSAT, AMSR2 was mapped and cross calibration among them in the alternate process of sensors was conducted for all the 68 river basins by making a linear regression model. Based on 68 calibration equations, the original database was modified so that getting the cross-calibrated LSWC database. By conducting temporal analysis using cross-calibrated database. It was found that the LSWC during the flooding in specific year significantly exceeds the average and the LSWC value of latest 15 years was found greater than the value of latest 30 years. It was indicated a growth trend in LSWC during last 30 years. Finally, the histogram and cumulative distribution function of each pixel was made by integrating nearly 30 years of LSWC database. It was found that from wetland, forest, agriculture, to barren land, with the increase of aridity, the probability with high LSWC in one year decreases. Moreover, cumulative distribution functions (CDF) of all pixels in global area were created to estimate the cumulative distribution of each LSWC value in global scale.

Thirdly, after integrating nearly 30 years of global LSWC daily data, the daily change of water area corresponding to monthly change of precipitation from the year 1981 to 2014 in each river basin was computed and plotted. It was found the surface water area change pattern basically coincided with rainfall pattern, showing a seasonal variation characteristic in each year. What's more, based on the least squares fitting the annual average change of water area in each river basin was computed which showed an increasing trend. In all 68 basins, most of them showed obvious growth trend. In general, river basins of almost no water area change accounted for only 18%, the small growth trend basin accounted for 34%, the large growth trend basin accounted for 48%.

Moreover, STL time series analysis was carried out to make clear the long-term trend relationship between precipitation and LSWC, it was found that the seasonal trend between each other was very coincide but the long-term trend of them was not identical, LSWC almost presented increasing trend whereas precipitation had no significant trend. In addition, the interactive correlation coefficients of long-term trend between precipitation and LSWC in Mekong river was smaller than 0.6. There is no significant correlation between long-term trend in LSWC and precipitation. Rainfall was indicated not the only factor that brings about the change in LSWC.

In addition, by calculating 4 kinds of land cover change including cropland, forest, urban and water body in each river basin, it was found that the change in urban area was very strong in many river basin, especially in Yangtze basin and Huang he basin in China from 2000 to 2012, changed from 0.08% to 0.83% and from 0.17% to 2.21%. Due to global warming, the Himalayan snowmelt increased year by year, causing water in Brahmaputra river increased significantly. Besides, there was no clear trend feature in forest cover change. In addition, the proportion of cropland increased significantly, especially Ganges basin increased by 40%, grew to nearly 70%. Meanwhile, it was found the cropland presented consistent growth situation along with LSWC. The correlation coefficients between cropland and LSWC change was more than 0.85. It is expected that the widespread expansion of cropland might bring about LSWC increasing. Finally, by detecting the anomaly of LSWC the potential floods can be detected. Anomaly map of each year was made and the monthly flooding development was extracted during nearly last 30 years in global scale, which showed a great increasing trend on frequency since last 15 years especially in nearly 5 years.