An Application of the SRTM Dataset in Inland Water Stage Measurement

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1. Introduction

One of the limitations in large-scale water resource management is constructing a database for water stages for uncountable number of lakes. In this case, remote sensing might provide an alternate solution and only microwave sensors such as radar altimeter or imaging radar can fulfil weather-independent missions which are the best for hydrologic applications since they can monitor water bodies periodically regardless of weather conditions. The study objective is to construct fundamental dataset for water resource management such as lake stages and seasonal difference of lake volume with SRTM dataset and to validate the applicability of SAR images in inland water level measurement.

2. Semi-Automated Contouring

A semi-automated procedure was developed to speed up and quantitatively determine the best fit of lake level estimates to gage measurements. First, to incorporate the feasible maximum lake areas, the Landsat-derived water coverage was extended (or buffered) to outside from each lake with a 1200 m-width strip and clipped to avoid the possible inclusion of land areas to lake water. The result is then the corresponding DEM area for each lake with the so-called buffered lake zone. Secondly, the Landsat-derived boundary was converted to the grid (or lattice) form to capture elevations along boundaries. These elevations were highly variable because of two possible reasons. Near the boundary of each lake, the mixture of land and water influenced the radar backscattering possibly causing erroneous elevations along the boundary. Also, the noise over water was not perfectly cleared along the boundary of each lake. In other words, the bumpy noise over water continued to exist to some extension of very near land areas. This elevation variation, however, used to define a domain of lake level. Using a statistical approach (2σ), very low and high elevation outliers were eliminated and an automatic contouring algorithm generated contours at a specific elevation with 0.5 m interval within the defined range of elevations. During this procedure, a number of unnecessary noisy and spotty contours or islands were generated inside a lake due to the noise over water as shown in Figure 2. Therefore, all contours inside of a lake, illustrating the water-type noise, were then deleted by an algorithm in the semi-automated method. For the next step, the area and perimeter of the lake boundaries derived from contouring were calculated. The foundation of this contouring approach was that the lake boundaries were well defined with minimal noise because lake boundaries include land elevations without noise. Therefore, length of a lake boundary should be minimized when compared with a more meandering boundary caused by noise. Inversely, the area enclosed by a noise free boundary should be larger than the comparable lake with a noisy boundary because noise causing a meandering boundary towards the inside of a lake makes the water area more excluded. It should be noted that our assumption was based on the fact that the land has no water-type noise. These derived lake perimeter and area reversely behave as the interval of contours change.

3. Comparison with Stage Readings

The term of ‘masking’ refers to extracting pixel (elevation) values along water boundaries so masks are only ones along water boundary (shorelines) pixels and zeros for all the others. This method requires three types of lake boundary masks: (1) Landsat-derived water coverage, (2) contours and (3) lake outlines by the Canny Edge Detector (CED). Each of them has unique features contributing to the extraction of lake levels when they are combined. Landsat provides actual lake boundaries at the time of the flight of the mission so the classified water coverage from the Landsat portray the most probable lake boundaries if the time of image capture is close enough to the actual time of the shuttle mission. However, the resolution problem of the dataset cannot be resolvable in determining exact lake boundaries. SRTM-derived contours provide the only means to infer hydrologically correct lake margins using the SRTM data with an assumption that the Landsat-derived lake boundaries or other data may or may not be available. In other words, inaccurate elevations around lakeshores may produce banks or openings of lakes if lake boundaries are generated with other datasets (i.e. Landsat) so that inappropriate boundaries can be drawn. However, SRTM-derived contours are the most adapted ones in hydrologic sense based on the dataset itself. Regardless of the constant elevations of contours that may cause erroneous boundaries including or excluding neighbouring land (or water), the CED can detect the best fit of the lake outlines (boundaries) using the most distinguishable differences of elevations in an image. These three approaches to define lake boundaries provide complementary datasets to decide the most probable lake levels. The extracted elevations were then calculated for lake levels by averaging the elevations with the 2σ constraints.

4. Canny Edge Detector

Figure 2 showed the results of contouring methods with masking. Masking determined the estimates with pinpoint accuracy especially for the large lakes (≥10 km^2). Compared with stage readings, the differences of the estimates were mostly within ±0.5 m for the large lakes, illustrating the accuracy of masking. However, the stages were frequently over-estimated regardless of lake size, and the stage differences for small lakes (<10 km^2) were still fluctuated. The problem of this method was the spatial resolution of the datasets (i.e. SRTM and Landsat).

5. Summary

For hydrologic applications, lake levels is very important. As a first step in developing a remote-sensing based approach, lake stage estimation using remote sensing was proposed with the SRTM data from February 2000, which was providing a one-time snapshot. After several steps using contouring, masking, and CED, it was found that iterative contour fitting to a lake outline provided the outstanding result with the operator’s decision. If the lake size is large enough, a constant meter of the difference removal due to bias found by Bhang et al. (2007) might be useful for more accurate estimations for the methods. A lake-level snapshot using SRTM data could provide estimates within 0.5 m level of accuracy for large lakes (>10 km^2) with contouring. Also, even if the processing algorithm is complex, the accuracy was reliable. Overall, we confirmed that this study would provide useful information to ameliorate the quality of the SAR-derived DEMs specifically for water areas and if more expanded, SAR images can fruit result in water monitoring.

6. References

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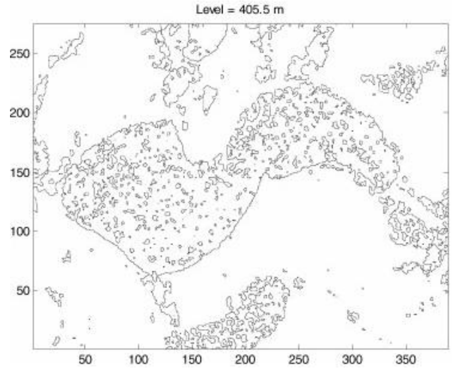

Figure 1. Water shorelines using contours

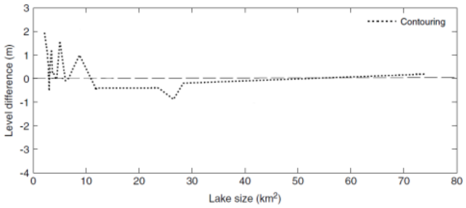

Figure 2. Lake levels extracted by contouring

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