A Multibaseline-InSAR-based Water Level Estimation Method for Mekong River

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Introduction

The Mekong River (MR) is the twelfth-longest river in the world and the biggest river in Southeast Asia flowing through six countries (China, Lao PDR, Myanmar, Thailand, Cambodia, and Vietnam). The importance of MR to local people's livelihood is more than apparent as inhabitants in MR Basin have been extensively relying on the resources from the MR as their major food supply and source of income by developing fresh water fishery and floodplain agriculture. Here, we try to refine our previous multibaseline (MB)-based three-pass differential synthetic aperture radar (SAR) interferometry (InSAR) (DInSAR) method (named as the MTDA method [1]) to estimate the water level changes of MR. Usually, the traditional InSAR technique does not work well over smooth open water surface because SAR system adopts side-looking geometry which causes little energy backscattered to the SAR antenna. Furthermore, the traditional InSAR is ill-posed since it needs to obey the phase continuity assumption, which is the fundamental limitation of the technique. However, the MB InSAR [2] is a new radar interferometry technique, which is based on the repeated observations with different system parameters. To be specific, MB InSAR can take advantage of the baseline diversity to significantly increase the ambiguity intervals of interferometric phase, and thus MB InSAR can avoid the phase continuity assumption.

MB-DInSAR Methodology

Assume that there are N interferograms (they share the same master), $\varphi_i(s)$ is the wrapped phase of the sth pixel in the ith interferogram. $k_i(s)$ is the ambiguity number of the sth pixel in the ith interferogram, $\Delta_h^m (m=1,2,\cdots,N)$ is the surface deformation between interferogram1 and interferogram m, B_i is the normal baseline length and λ is system wavelength.

$$\frac{\varphi_1(s)+2k_1(s)\pi}{B_1}=\frac{\varphi_2(s)+2k_2(s)\pi+\frac{4\pi}{\lambda}\Delta_h^2(s)}{B_2}=\cdots=\frac{\varphi_N(s)+2k_N(s)\pi+\frac{4\pi}{\lambda}\Delta_h^{N-1}(s)}{B_N} \quad (1)$$

Subtracting Eq. (1) of pixel $s-1$ from that of pixel s, i.e.,

$$\begin{aligned}\frac{\Delta_{\varphi_1}(s,s-1)+2\Delta_{k_1}(s,s-1)\pi}{B_1}&=\frac{\Delta_{\varphi_2}(s,s-1)+2\Delta_{k_2}(s,s-1)\pi}{B_2} \\ &=\cdots=\frac{\Delta_{\varphi_2}(s,s-1)+2\Delta_{k_2}(s,s-1)\pi}{B_N}\end{aligned} \quad (2)$$

where $\Delta_{\varphi_i}(s,s-1)=\varphi_i(s)-\varphi_i(s-1)$ and $\Delta_{k_i}(s,s-1)=k_i(s)-k_i(s-1)(i=1,2,\cdots,N)$.

Through choosing some special $B_i(i=1,2,\cdots,N)$, Eq. (2) can be solved by Chinese Remainder Theorem (CRT). Afterwards, we can compute the MB residue (residue is the loop-integration value of the gradients of any 2 × 2 neighboring pixels) through using the solutions of Eq. (2). Then, the SB PU method could be used to obtain the final absolute phase. We choose the Minimum-Cost Flow (MCF) SB PU method for our experiment.

Interferograms of the study area in Mekong

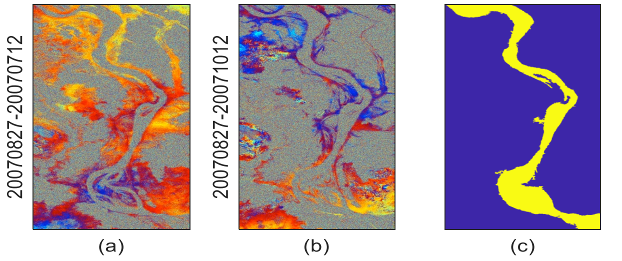

Figure 1. The interferograms in the Mekong study area. (a) ALOS PALSAR interferogram 1. (b) ALOS PALSAR interferogram 2. (c)The mark of the river area.

Mekong River Water Level Estimation Result

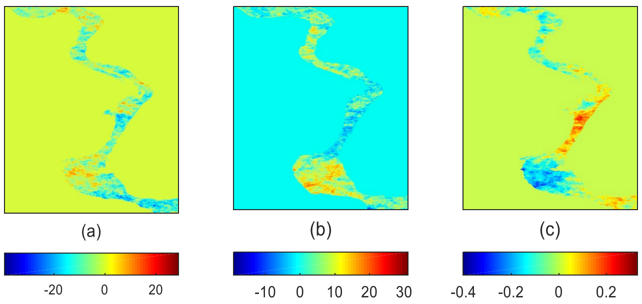

Figure 2. The river water level estimation in Mekong area. (a) MB InSAR phase unwrapping result of Figure 1(a). (b) MB InSAR phase unwrapping result of Figure 1(b). (c) The water level change between 20070827 and 20071012, in which the unit is meter.

Interferograms of the study area in Congo

Besides the Mekong area, we also test our algorithm on Congo river water level time series. In addition, we use the measurement obtained by radar altimetry as the ground truth. Radar altimetry is initially designed to determine the ocean surface topography, but the recent research shows that it also has accuracy advantage on measuring the water level of inland water area.

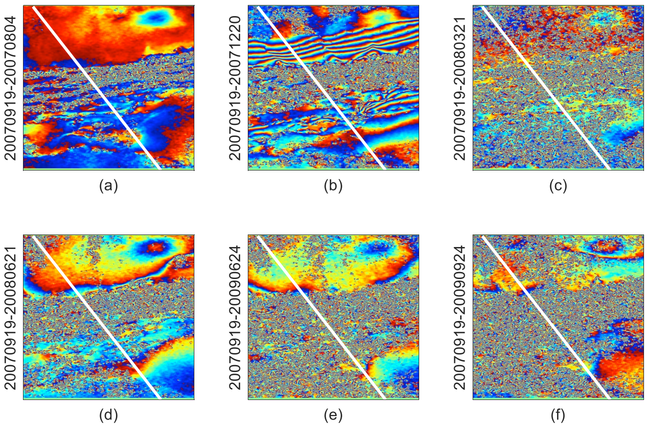

Figure 3. The interferograms in the Congo study area, which is the floodplain along the middle reach of the Congo mainstem, near the city of Lisala. The white line in the interferograms is the Envisat altimeter track. The instrument corrections, media corrections including troposphere and ionosphere corrections, and geophysical corrections including solid Earth and pole tides are also applied in the altimetry measurement.

Congo River Water Level Estimation Result

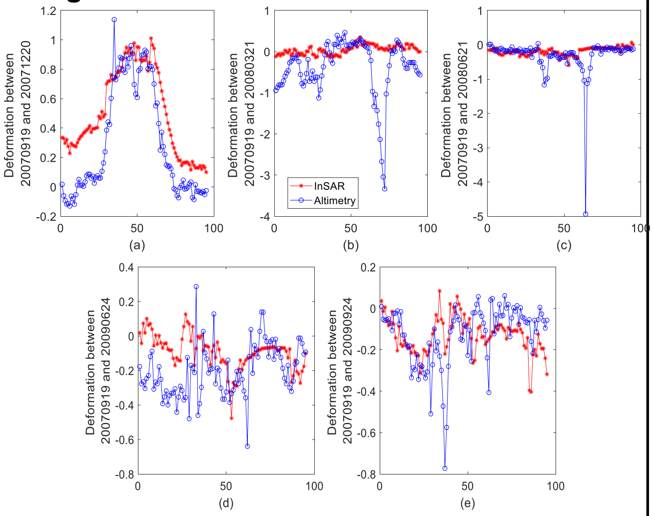

Figure 4. Deformation profiles on the altimetry track (Unit:m). The river range is from point 30 to point 60. Because there is no ground control point information in this study area, InSAR can only obtain the relative deformation information between neighboring pixels, which means that there should be an offset between InSAR and Altimetry results. Ideally, the profile of estimated deformation from MTDA should be parallel with that of altimetry, i.e., the more parallel with the deformation result of altimetry, the better the performance

Conclusions

The conventional three-pass DInSAR technology is not applicable to over smooth open water surface because SAR system adopts side-looking geometry which causes little energy backscattered to the SAR antenna. Furthermore, the traditional DInSAR technique is ill-posed since it needs to obey the phase continuity assumption, which is the fundamental limitation of the technique. In this study, the MTDA MB InSAR methodology based three-pass terrain deformation estimation approach is applied in Mekong and Congo river water level estimation. The experimental results demonstrate that the MTDA method can combine multiple interferograms to potentially increase the signal strength of the river areas through taking advantage of the baseline diversity, so that some information of the water level could be obtained.

References

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[2] Hanwen Yu and Yang Lan. “Robust two-dimensional phase unwrapping for multibaseline SAR interferograms: A two-stage programming approach.”. IEEE Trans. Geosci. Remote Sens., 54(9):5217 – 5225, Sep 2016.

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