Detection of huge deformation by SAR interferometry with split-spectrum method

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SAR interferometry is used as one of the useful tools to detect surface deformation caused by earthquake, volcanic activity, and so on. However, even though coherence is obtained, it may not be possible to convert to crustal deformation due to difficulties in phase unwrapping, when huge deformation occurs. For example, in the 2016 Kumamoto Earthquake on April 16, 2016 (M_{JMA}7.3), fringes with high coherence were obtained near the fault by SAR interferometry using PALSAR-2 (e.g., Ozawa et al., 2016), but conversion to slant-range change was difficult due to large phase gaps exceeding π radians. In this presentation, we mention a technique for detecting crustal deformation in such regions using the split spectrum method.
Generally, phase difference obtained by SAR interferometry $\Phi_{total}(f)$ is discribed as

$$\Phi_{total}(f) = 4\pi\ \Delta\rho_{non\text{-}disp}\ f/c + 4\pi\ K\ \Delta TEC/cf + cnst$$

where $\Delta\rho_{non\text{-}disp}$ is non-dispersive slant-range change (e.g., crustal deformation, orbital contribution, atmospheric delay), ΔTEC is valiation of the total electron content along the radar propagation path. The first and the second terms on the right hand side are called the non-dispersive and the dispersive components, respectively. f is radar frequency, c is speed of light, and K, cnst are constants. Dispersive and non-dispersive components can be divided by the split-spectrum method. Its method makes two SLC pairs with high and low frequency applying the band pass filter and divides their components based on the difference in response to the frequency difference in two interferograms made from them (e.g., Rosen et al, 2010; Gomba et al.,2016; Wegmüller et al., 2018). Double difference of two frequency intrefergrams after removing dispersive component is described as

$$\Phi_{diff} = 4\pi\ \Delta\rho_{non\text{-}disp}\,(f_{high} - f_{low})/c + cnst.$$

It corresponds to interferometric phase obtained by radar frequency of $f_{high} - f_{low}$. For example, in a case that SM1 mode data of PALSAR-2 (80MHz bandwidth) is used, $f_{high} - f_{low}$ is 40 MHz (the wavelength is 7.5m). In most cases, this interferometric phase is small value within $-\pi$ and $+\pi$ radians, even if a large crustal deformation occurs. Therefore, the phase unwrapping is not necessary.
Applying this method to interferometric pair for the 2016 Kumamoto Earthquake (PALSAR-2, SM1), phase difference exceeding π radian was obtained due to huge crustal deformation. Then, we created three sub-band SAR images from original SAR images, and estimate phase difference between high and low sub-band interferograms, connecting phase differences for high-mid-low sub-band phases.
Comparing slant-range changes obtained from this method and offset-tracking method, they are almost consistent. While the offset-tracking method using a correlation window deteriorates the resolution, this method can obtain the slant range change with the same spatial resolution as the normal SAR interferometry. In this method, noise due to decorrelation is amplified, so its application is limited to data pairs with high coherence. However, if the application condition is good, there is a possibility that the crustal deformation distribution can be obtained with high accuracy even when large crustal deformation has occurred.

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