Improved Topographic Mapping Through Multi-baseline InSAR with MAP Estimation

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SAR interferometry (InSAR) has long been recognized as an effective tool for large-area topographic mapping due to its unique capability of all-time all-weather imaging and sensitivity to terrain relief. However, its application is usually limited by temporal/geometric decorrelations and atmospheric phase screens (APS). Moreover, there is an inherent contradiction between the geometric decorrelation and the sensitivity of height measurement for InSAR topographic mapping with a single data pair. A normal baseline of proper length is required to keep a balance between the two issues. Nevertheless, this is a difficult task in practical applications, especially for InSAR observations acquired in repeat-pass mode. A promising solution to this problem is the so-called multi-baseline InSAR analysis.

The basic principle of multi-baseline InSAR is to derive an optimal height estimate by joint analysis of multiple phase measurements from a few interferograms with various normal baselines. Compared with single-baseline InSAR, the major benefit of using multi-baseline InSAR is the possibility of exploiting multiple redundant topographic phase observations with various topographic phase gradients due to differences in normal baseline to limit the errors of phase unwrapping, or even avoid phase unwrapping processing.

In this study we developed a maximum a posteriori (MAP) estimation method for multi-baseline InSAR topographic mapping. Following the generic framework of MAP estimate, we derived the probability distribution of interferometric phase and defined a prior distribution of target elevation from a low-resolution auxiliary DEM. Afterwards a systematical data processing flow was established to make the MAP

estimation method applied to real spaceborne SAR data. Three key issues were solved, including: 1) the combination of interferometric pairs and image co-registration; 2) elevation and phase transformation model; 3) Calculation and quick search of elevation's likelihood probability.

As a show case, we selected four interferometric combinations from six L-band ALOS/PALSAR images considering both time and space baselines and generate DEM with spatial resolution of 20m through multi-baseline InSAR processing. Using the Chinese national DEM of scale 1:25000 as reference, we evaluated vertical accuracy levels of the multi-baseline InSAR DEM as well as the original single-baseline InSAR DEMs. The results show that multi-baseline InSAR processing could significantly improve the DEM quality compared with single-baseline InSAR and avoid phase unwrapping process. The quality of ALOS/PALSAR multi-baseline InSAR DEM can meet the DTED-2 standard.