A Novel Co-registration Approach for Sentinel-1 TOPS Data

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1 Background

To overcome scalloping and maintain azimuth-invariant SNR, the antenna beam of Sentinel-1 keeps electronically steering in each bursts of three swaths (Fig. 1) under TOPS [1] mode. Though it ensure every point can be scanned with the entire antenna pattern, the introduced azimuth-independent Doppler centroid difference between consecutive bursts would cause phase discontinuities in overlapping region. The Doppler centroid difference which can be several times larger than pulse repetition frequency (PRF) puts forward a high requirement for the co-registration accuracy of TOPS data.

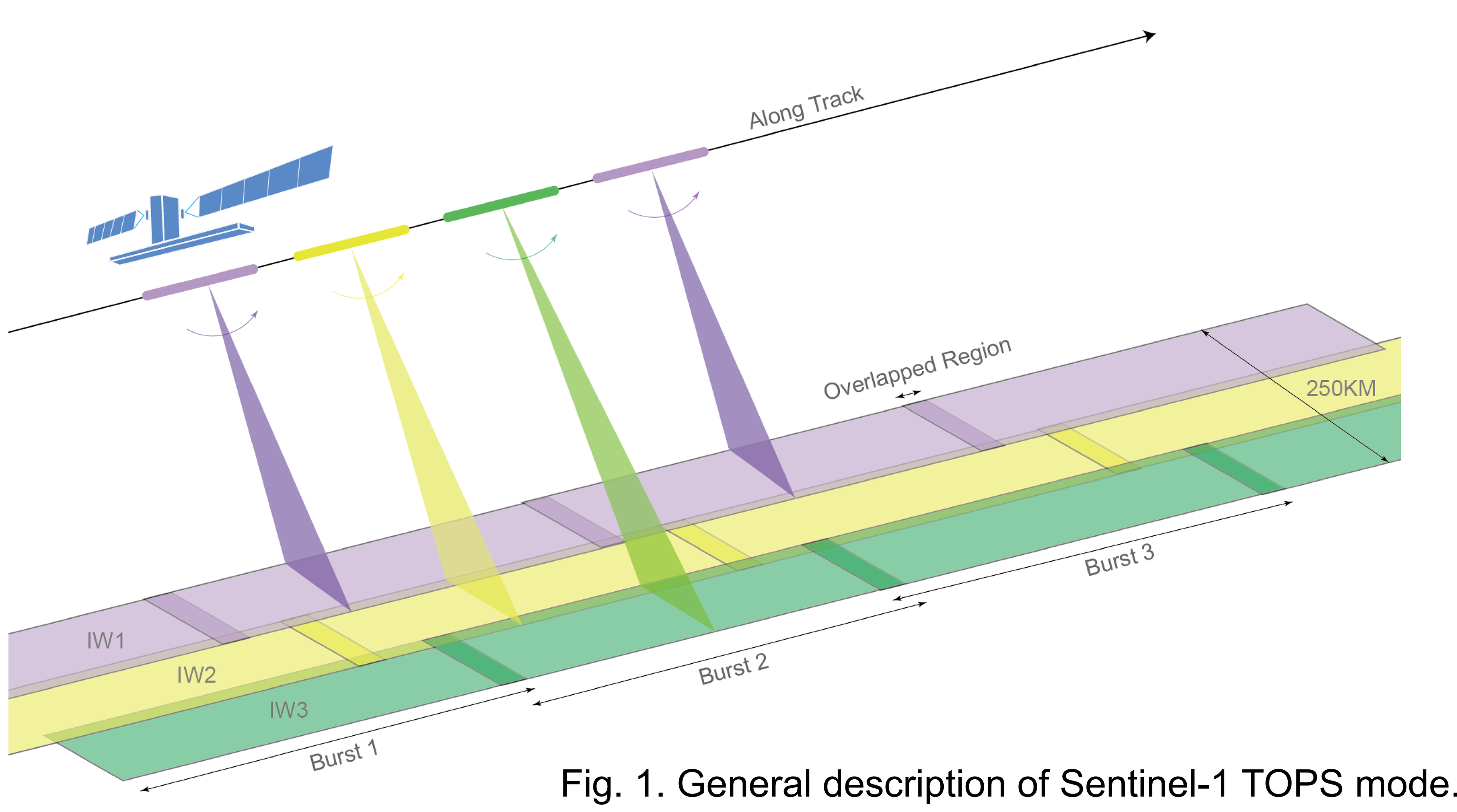

Fig. 1. General description of Sentinel-1 TOPS mode.

2 Methods

1. Enhanced Spectral Diversity [2]
2. Floyd-Warshall Algorithm [3]
3. 2-K Coherence Estimation

1. The residual phase of each pixel can be obtained by the same overlapping area shown in Fig.2
2. As opposed to previous studies that used coherence of a single burst interferogram or averaged coherence over the overlapping area, we combines two consecutive burst SLC samples to reduce both the bias and variance (Fig.2)
3. Besides coherence estimation, construction of image network that minimizes decorrelation is also crucial. It is worth noting that undirected graph generated by Floyd-Warshall algorithm can select the best interferometric pairs to maximize the coherence

1. $$\phi_{ESD} = \angle((m_i \cdot s_i^*) \cdot (m_{i+1} \cdot s_{i+1}^*)^*)$$

2. $$\hat{\gamma}_p = \frac{\left|\sum_{k=1}^{K} s_1^{b1}(k) s_2^{b1*}(k) e^{-j\phi^{b1}} + \sum_{k=K+1}^{2K} s_1^{b2}(k) s_2^{b2*}(k) e^{-j\phi^{b2}}\right|}{2K}$$

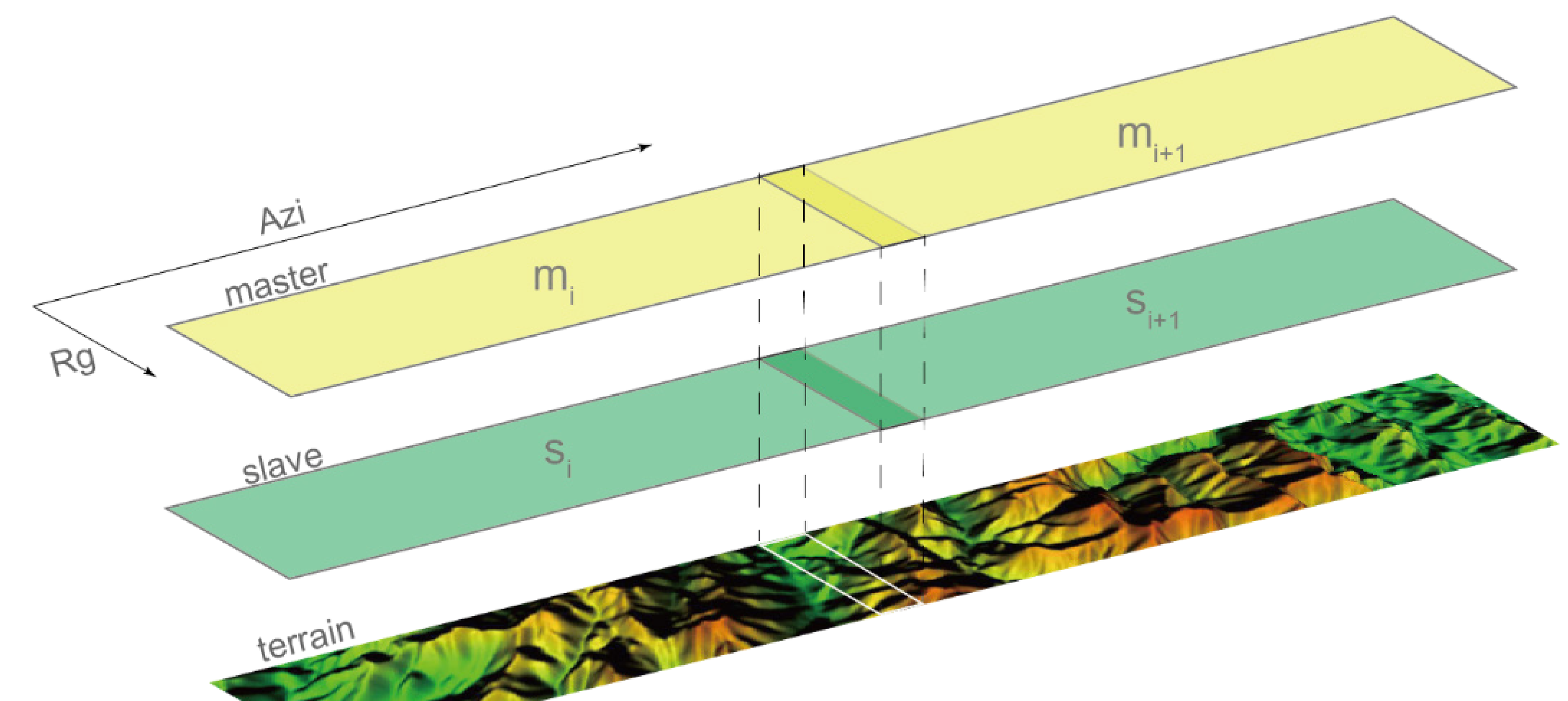

Fig. 2. Overlapping region of the master and slave image.

3 Results

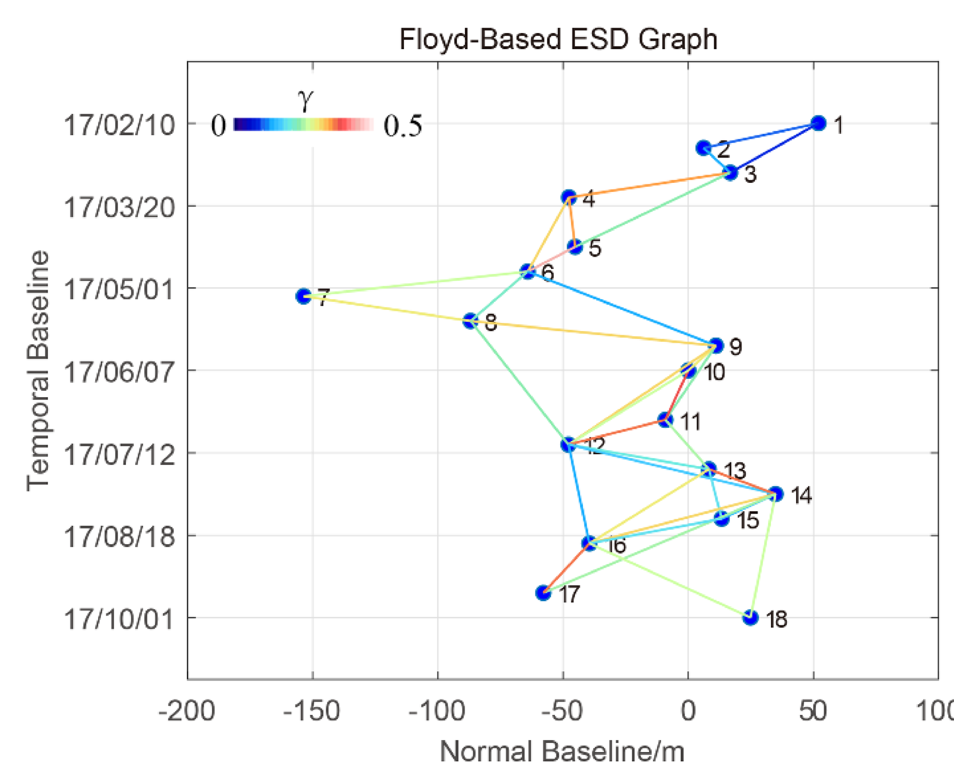

Fig.3. Floyd-Based ESD graph generated by coherence matrix.

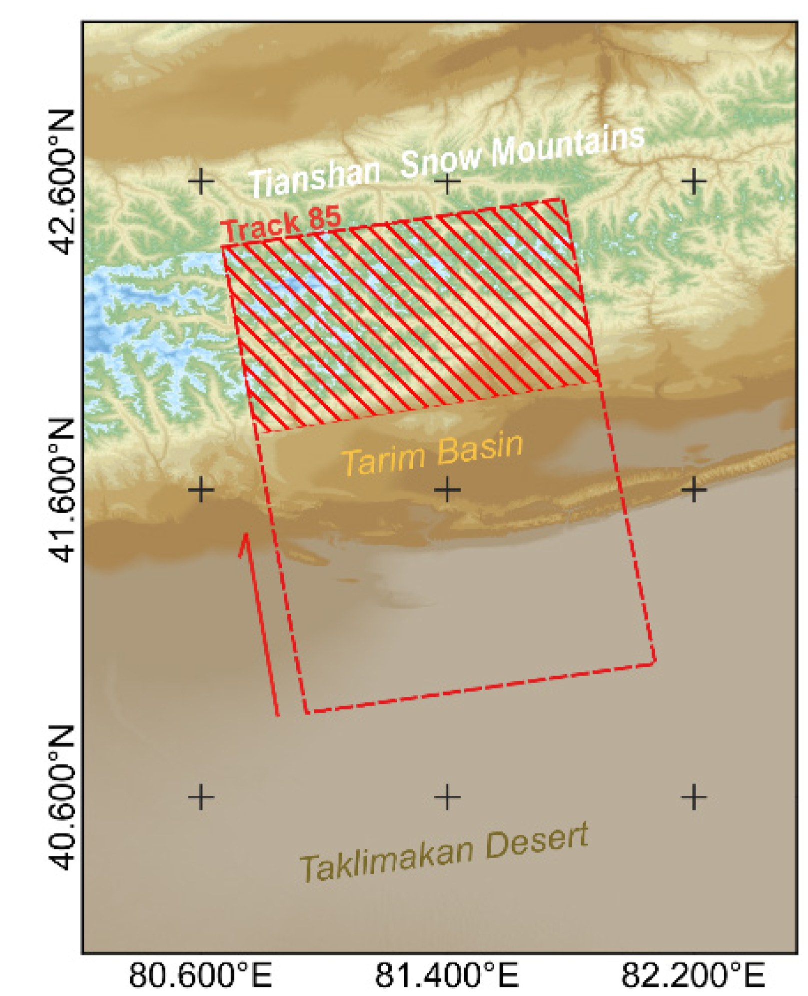

Fig.4. Footprint of Sentinel-1A TOPS acquisitions in Tianshan Mountains, China. The red dashed line denotes the complete coverage of interferogram in Fig. 5 and hashed oblique lines represent the study area we use for the azimuth

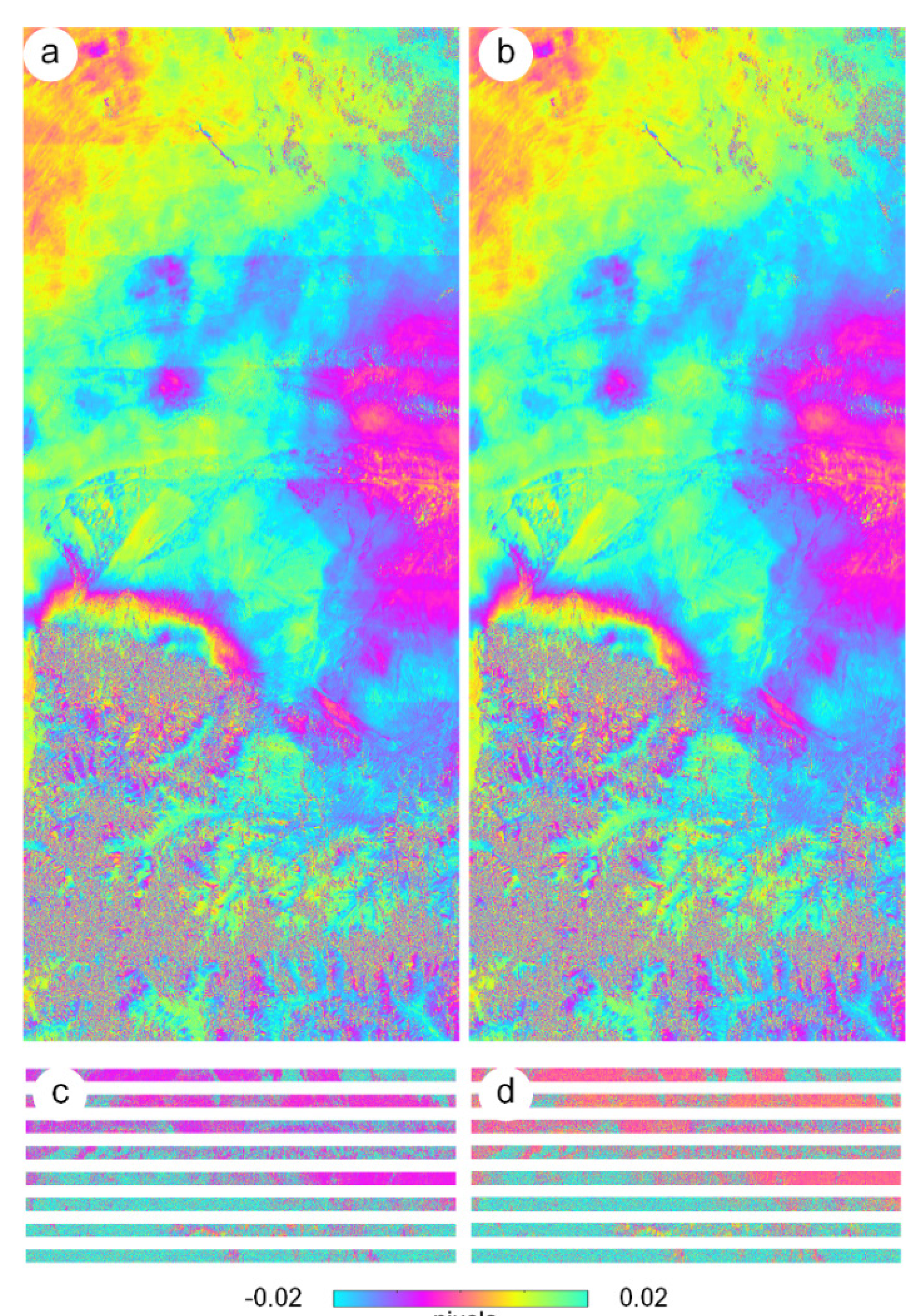

Fig.5. Interferogram (20170209-20170221) with and without the azimuth mis-registration estimated by Floyd-Based ESD. (a) is the interferogram with phase discontinues and (c) is the zoomed-in view of the mis-registration pixels of burst boundaries. (b) and (d) represent the interferogram and burst boundaries after correction respectively.

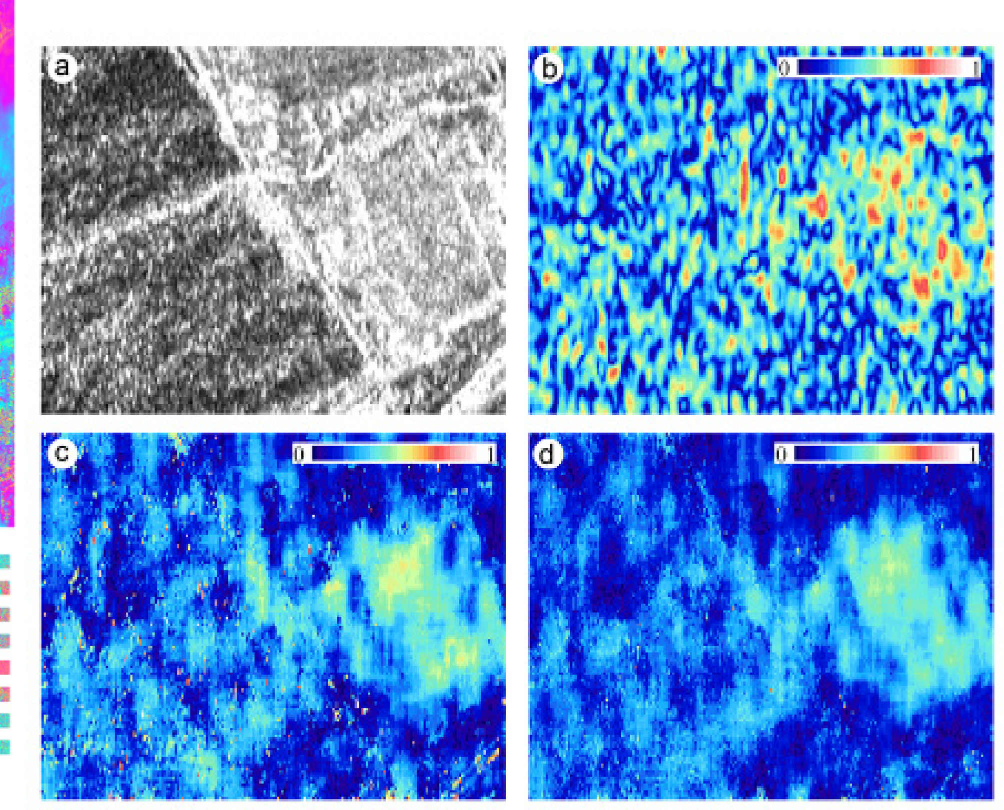

Fig.6. Estimated coherence with different estimators. (a) Intensity map; (b)coherence estimated by 7*7 Boxcar; (c) coherence estimated by estimator with only K samples; (d) coherence estimated by estimator with 2K samples

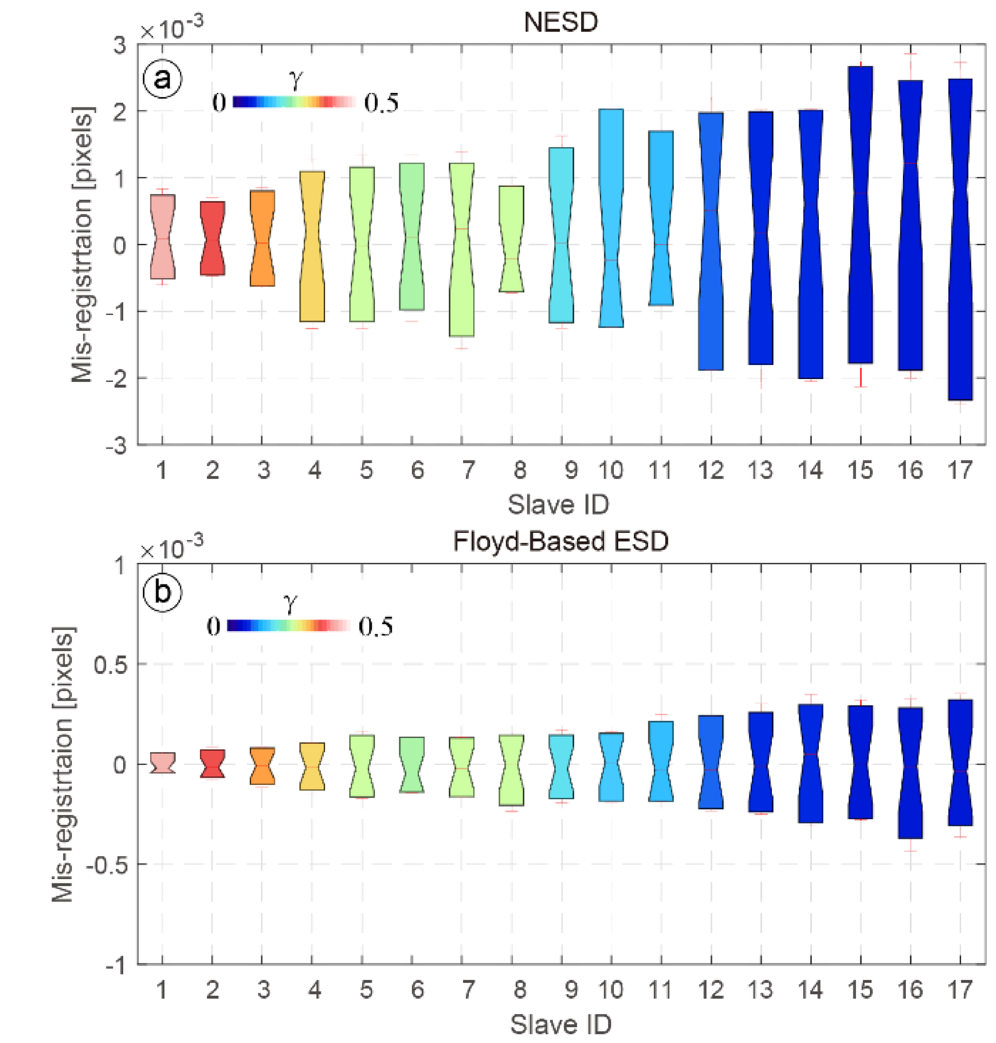

Fig.7. Boxplot of residual mis-registration after performing NESD and Floyd-Based ESD 100 times.

4 Conclusion

To avoid the influence of abrupt loss of coherence over fast decorrelation areas, estimated coherence from SAR dataset is used to replace the empirical decorrelation model. A robust coherence estimator, designed for TOPS image data processing, is presented in Method to mitigate both bias and variance. To achieve better co-registration accuracy, Floyd algorithm is conducted to find an optimal path so that maximum coherence contributes to coherent acquisitions, and weighted least square adjustment is also employed to reduce error propagation induced by complete temporal decorrelation.

Compared with NESD [4], the results from using this method on real data demonstrates the better performance of the Floyd-Based ESD. It also meets the requirement of 0.001 pixels accuracy of co-registration. This increased accuracy will benefit a series of applications that rely on low coherence Sentinel-1 TOPS time series InSAR scenes.

5 References

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