Interferometric synthetic aperture radar coherence constraints in heavily vegetated tropics

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Interferometric synthetic aperture radar coherence constraints in heavily vegetated tropics

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Abstract. Success of Interferometry Synthetic Aperture Radar (InSAR) technique for deriving digital elevation model (DEM) in the heavily vegetated humid tropic using Sentinel-1 SAR has been controversial, owing to the difficulty in achieving good coherence. Yet achievable coherence with Sentinel-1 SAR over the heavily vegetated humid tropic has rarely been reported. Consequently, this paper evaluates coherence achievable with Sentinel-1 SAR over the heavily vegetated humid tropic. Twelve Sentinel-1 SAR over part of Johor selected based on perpendicular and temporal baselines considerations, were used as pairs of six reference and secondary images respectively and processed using Sentinel Application Platform (SNAP) to derive coherence maps and analysed accordingly. The result shows that regardless of image pairs baseline characteristics, coherence of above 0.6 over the heavily vegetated humid tropic with Sentinel-1 SAR can only be achieved in barely 10% of the study area. This result shall serve as eye-opener to geoscience community, especially SAR enthusiast looking forward to leveraging on SAR clouds penetrating ability; and Sentinel-1 SAR open access and short revisit circle to apply Sentinel-1 SAR in deriving DEM over heavily vegetated humid tropical environment. However, future studies shall focus on assessing consistency of good coherence patches and their usability in acquiring elevation.

Keywords: InSAR , Coherence, Sentinel-1, Vegetated humid tropic

1. Introduction

Coherence measured on a scale of 0 to 1, is a parameter that characterises the degree of similarity between two complex Synthetic Aperture Radar (SAR) images [1]. Good coherence is a basic requirement for good interferogram and InSAR DEM derivation. Factors such as weather conditions during data acquisition, image baselines, image acquisition geometry and landcover can affect the coherence between SAR data pairs used for interferometric analyses [2,3]. Thus, due to volume scattering and wind-induced changes in radar signal dielectric properties [4,5], coherence is generally low in vegetated surfaces [6,7].

However, the difficulty of obtaining good coherence over a vegetated environment increases with lower frequency bands, and coherence decreases rapidly as the time between paired data in interferometric analyses increases [8]. [9], who modelled InSAR observations of forested environment with ERS-1 with temporal interval of just three days, concluded that InSAR observations at reasonably high frequencies are better for getting reliable interferometric height measurements in densely vegetated environments. Due to this coherence challenge over vegetated environments, the success of InSAR DEM derivation over heavily vegetated humid tropics with especially Sentinel-1 SAR has been largely controversial, with varying accuracies reported hinged on poor coherence [10,11]. Yet achievable coherence with Sentinel-1 SAR over the heavily vegetated humid tropic has rarely been reported. Against this backdrop, this paper evaluates coherence achievable with Sentinel-1 image pairs in heavily vegetated humid tropics.

The Sentinel Application Platform (SNAP) was used for the SAR image processing to generate coherence maps, while subsequent evaluation of coherence was done using ArcMap. The result reveals the extreme difficulty in achieving good coherence with Sentinel-1 SAR over heavily vegetated environment and shall serve as an eye-opener to the geoscience community, especially SAR enthusiasts looking forward to leveraging on SAR clouds penetrating ability; and Sentinel-1 SAR open access and short revisit circle to apply Sentinel-1 SAR in deriving InSAR-DEM over the heavily vegetated humid tropic.

2. Materials and methods

2.1. Study area

This study was conducted over an area of 4939 km^2 in Johor, Peninsular Malaysia. The area has a humid climate with two monsoons separated by two inter-monsoons and is situated within Latitude 1^0 15' and 2^0 0' N and Longitude 103^0 30' and 104^0 15' E (Figure 1). Forest, oil palm, and rubber plantations cover a significant part of the area [12].

2.2. Data acquisition and processing

Sentinel-1 level-1 SAR data were used for this study. Two image pairs over the same location, acquired along the same orbit track but at different sensor positions and times, are required for SAR interferometry with mono-static satellites such as Sentinel-1. The time intervals between paired images acquisition and sensor positions during the respective data capture establish the temporal and perpendicular baselines necessary for interferometry. The Alaska Satellite Facility's (ASF) online baseline computation tool (https://search.asf.alaska.edu) was used to determine appropriate image pairs, especially in consideration of the recommended perpendicular baseline of between 150 and 400m for interferometric analysis. Six image pairs with perpendicular and temporal baseline ranges of 155m and 228m, and 11 day and 228 days respectively were downloaded from ASF. Details of the Sentinel-1 image pairs used are presented in

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Table 1

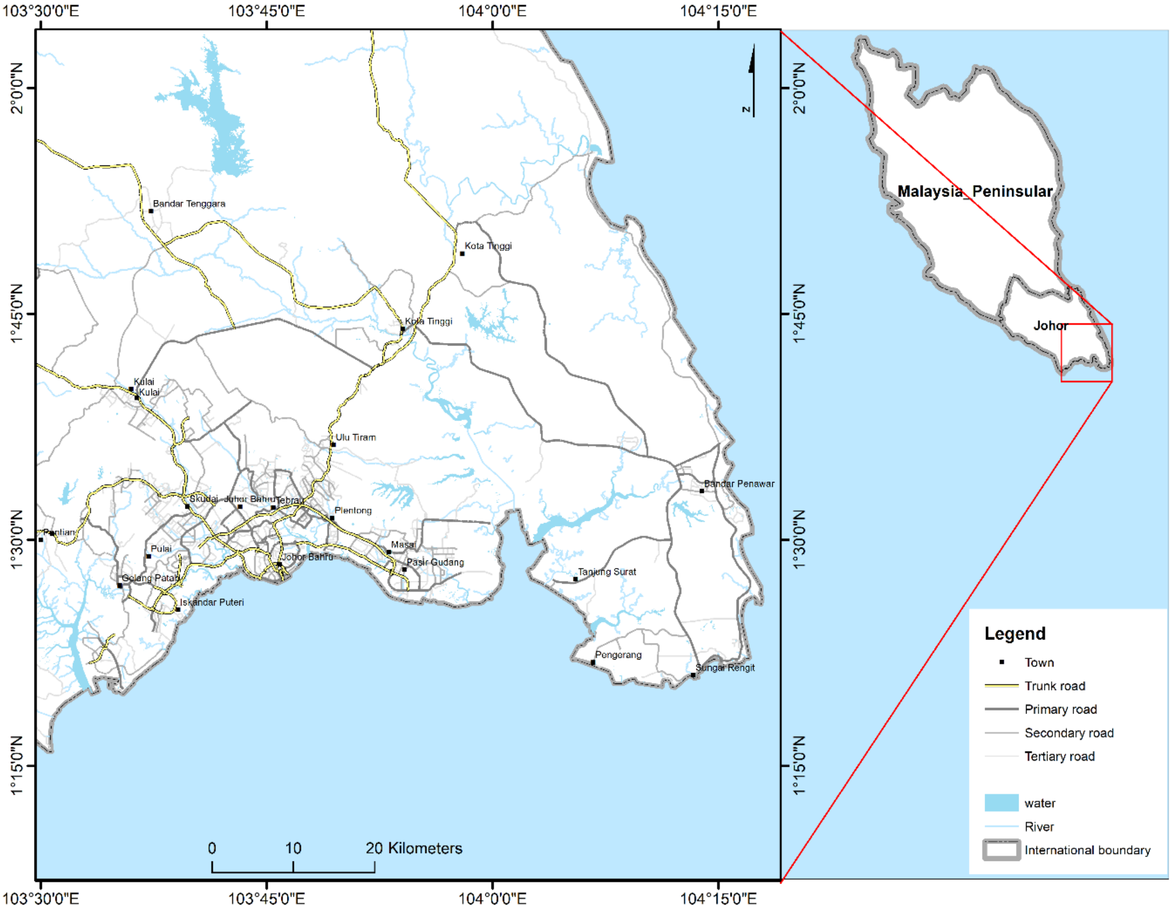

Figure 1: Study area

Table 1: Datasets characteristics

Code	Master ID	Slave Scene ID	Orbit	*T_B (Days)	*P_B (m)
A	S1A_IW_SLC__1SSV_20150626T112501_20150626T112528_006543_008B41_C971	S1A_IW_SLC__1SDV_20150708T112451_20150708T112519_006718_008FEA_710C	Asc	11	228
B	S1A_IW_SLC__1SDV_20150121T112448_20150121T112515_004268_005312_67FD	S1A_IW_SLC__1SSV_20150226T112455_20150226T112522_004793_005F51_B066	Asc	36	176
C	S1A_IW_SLC__1SSV_20150109T112456_20150109T112523_004093_004F43_716F	S1A_IW_SLC__1SDV_20150214T112447_20150214T112514_004618_005B11_1A69	Asc	35	155
D	S1A_IW_SLC__1SSV_20150109T112456_20150109T112523_004093_004F43_716F	S1A_IW_SLC__1SDV_20150708T112451_20150708T112519_006718_008FEA_710C	Asc	179	201
E	S1A_IW_SLC__1SDV_20150614T112451_20150614T112519_006368_008645_14A0	S1A_IW_SLC__1SSV_20160128T112456_20160128T112523_009693_00E252_6B53	Asc	228	188
F	S1A_IW_SLC__1SSV_20150602T112500_20150602T112527_006193_008131_656A	S1A_IW_SLC__1SDV_20150708T112451_20150708T112519_006718_008FEA_710C	Asce	35	202

*Note: *T_B = temporal baseline; *P_B = perpendicular baseline

The downloaded image pairs were coregistered, enhanced by applying range and azimuth shift corrections. Amplitudes of the respective image pairs were cross multiplied, deburst, filtered and multilook to obtain seamless coherence layers (Figure 2). The coherence layers were then terrain corrected to obtain coherence maps for all the six image pairs typical of Figure 3. Coherence is evaluated using Equation 1. $< >$ denotes the ensemble average operator. The processing to obtain the coherence maps were carried out in SNAP, and Environmental Systems Research Institute (ESRI) ArcGIS software was used for subsequent evaluation and all mappings. Details of procedure for obtaining coherence between two SAR image pairs using SNAP, which is part of InSAR DEM derivation workflow can be found in [2,13]

$$\rho = \frac{|<h1 * h2>|}{\sqrt{<|h1|^2> * <|h2|^2>}}$$ --Equation 1 [1]

3. Results and discussion

Coherence, a scale that indicates how similar image pairs are pixel by pixel, ranges from 0 to 1, as shown in Figure 2. High coherence values indicate a strong correlation between image pairs and vice versa. Figure 4 quantitatively depicts achievable coherence with image pairs A, B, C, D, E, and F. Coherence of above 0.6 is achievable in barely less than 10% of the whole study area irrespective of the perpendicular or temporal baselines, with over 80% the study area having less than 0.5. The high coherence areas are found around the built-up areas, while the low coherence areas are found in the heavily vegetated regions, as indicated in Figure 3.

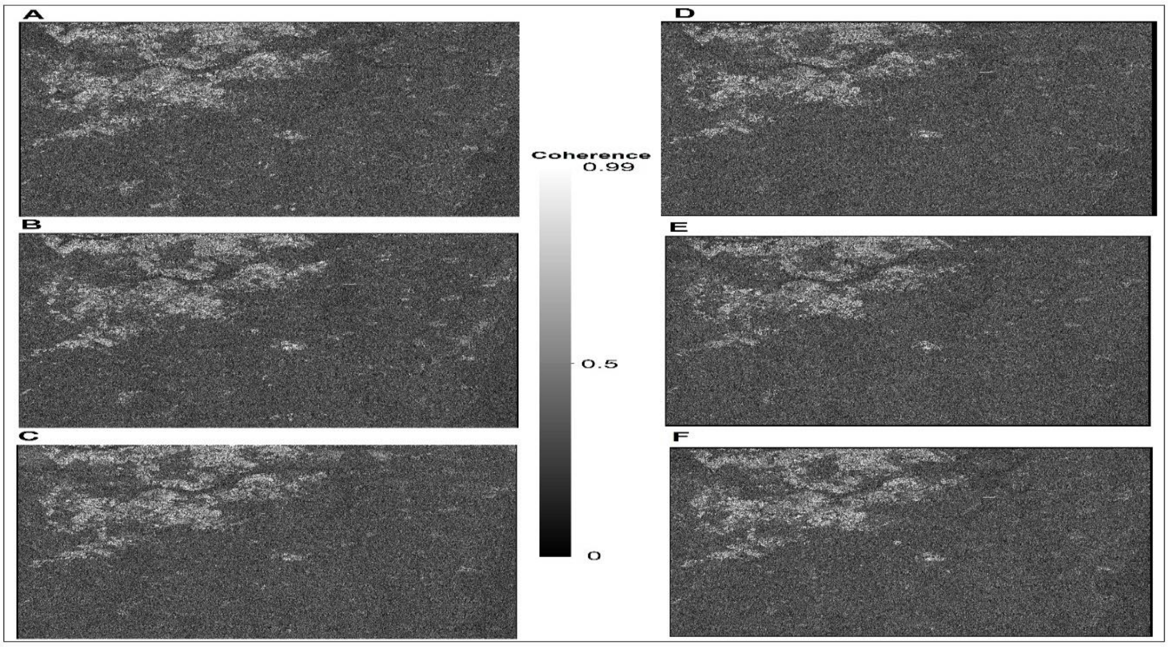

Figure 2: Un-terrain corrected coherence image of Sentinel-1 image pairs A – F

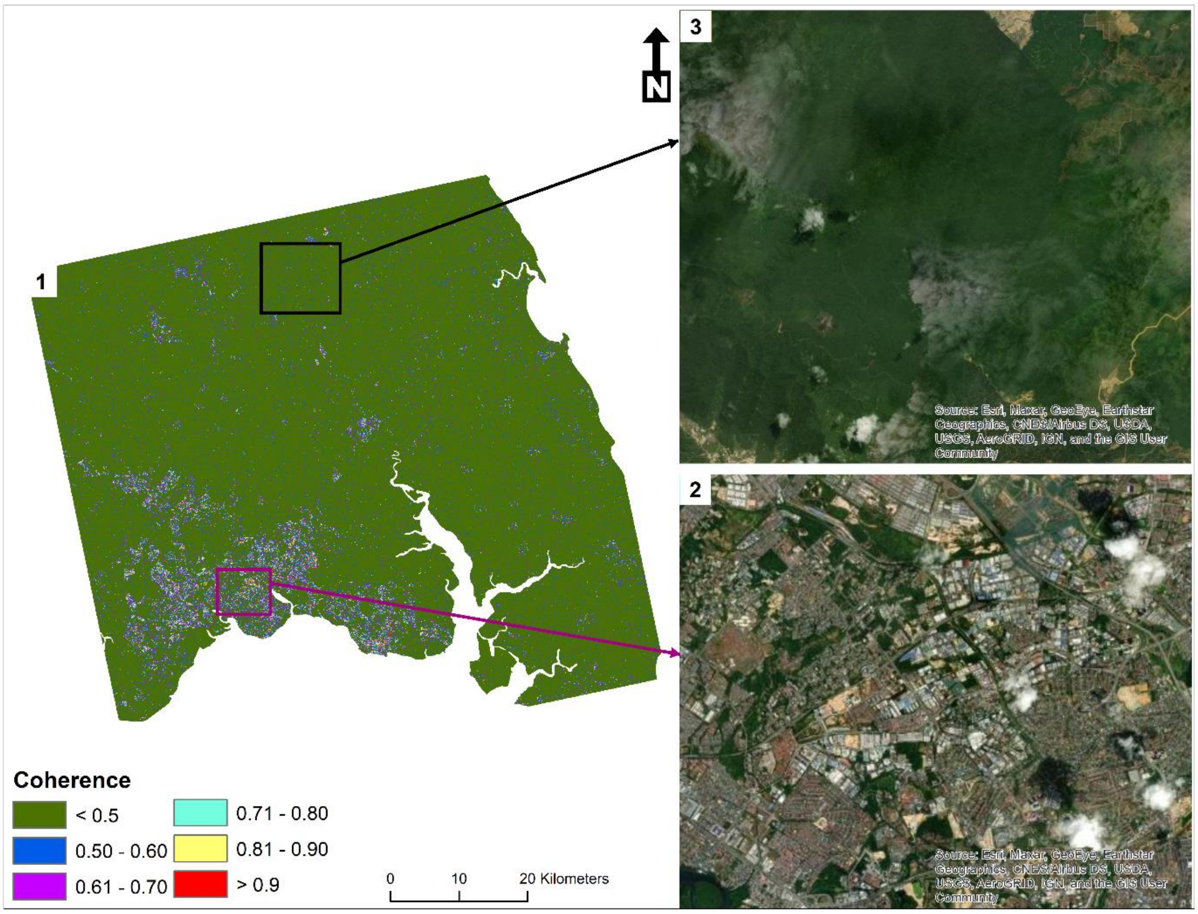

Figure 3: Terrain corrected coherence map of image pair A

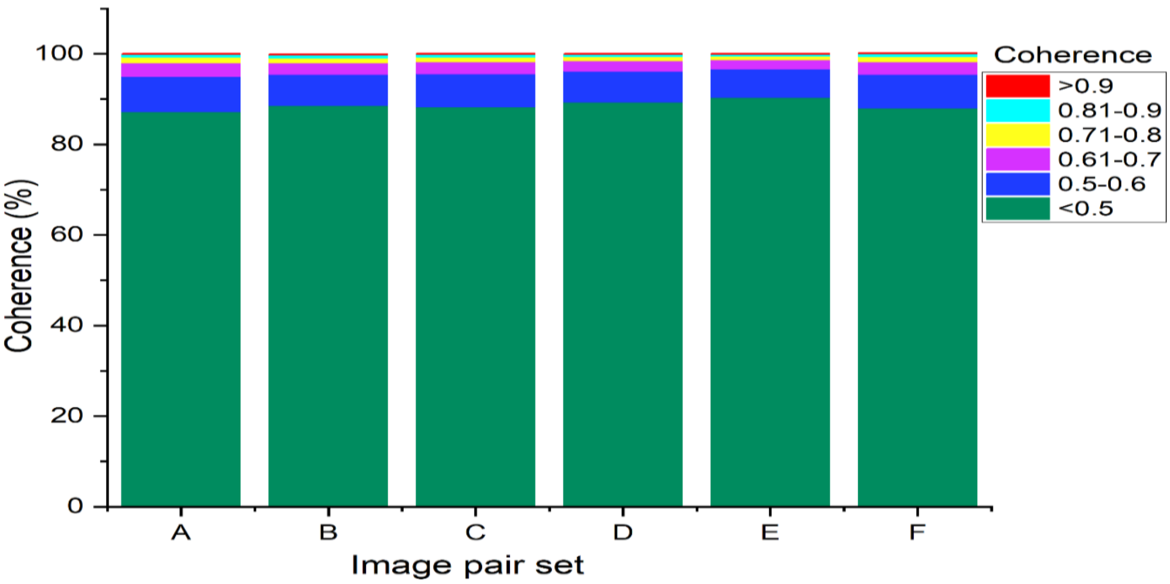

Figure 4: Coherence of image pair A – F

4. Conclusions

The achievable coherence with Sentinel-1 SAR images over heavily vegetated humid tropics have been evaluated. This study reveals that irrespective of baseline characteristics, achieving good coherence in the humid tropics with Sentinel-1 SAR image pairs for deriving InSAR-DEM is extremely difficult, if not impossible, due to heavy vegetation cover. However, patches of good coherence are found within the abundance of poor coherence. Thus, future studies will assess good coherence patches' consistency and their usability for elevation extraction.

Acknowledgments

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