Forest structure information extraction from ALOS PALSAR data: Preliminary Results

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Abstract

In order to investigate the multi-temporal ALOS PALSAR dual-polarization interferometric SAR data processing and forest structure parameters extraction methods in repeat-pass mode, several scenes of level 1.1 SLC data have been acquired for the Tai An test site of Shandong Province, PR. China. The preliminary results for the first phase of this project were reported. Firstly, the GEC geo-coding method and its geo-location accuracy were evaluated with one geo-coded Landsat ETM as reference. Secondly, one high resolution DEM was used for doing GTC processing. The benefit and limitation of GTC for forest mapping were evaluated with one SPOT5 image. Thirdly, entropy-alpha polarimetric segmentation method was evaluated for forest classification. Finally, the coherence images were generated for all the possible pairs of PALSAR images acquired to find out the possibility for studying interferometry based forest structure information extraction methods. The plan for the next phase of the project is presented.

Keywords: PALSAR, Geocoding, Polarimetric classification, Forest structure information

1. INTRODUCTION

The needs for forest structure information are currently increasing because the awareness of forest health status as well as the recognition of the role of forests in reducing effects of global warming. Many studies have been carried out using airborne SAR systems, SIR-C/X SAR, ERS and JERS-1 SAR for forest parameters extraction. It has been observed that the backscattering coefficient of L band had good relationship with forest volume and biomass, and L-VH or HV was better than HH or VV [1]; the cross polarization to co-polarization ration was also very good for forest parameters estimation. Interferometric coherence was related with these parameters very well and had bigger dynamic range. Combining coherence and backscattering coefficient with water-cloud model could improve biomass estimation level and accuracy [2].

The SAR signal saturation problem limits the biomass estimation level below 40-60 Ton/ha for L band and 100-150 Ton/ha for P band [3]. However, reference [4] firstly published one new method to extract forest height from repeat-pass polarimetric interferometeric SAR (POLinSAR) data. Forest biomass can be estimated without saturation through the tree height and some known forest growth models. Forest application is the most important and successful field for POLinSAR technique, specially the L-band POLinSAR; Even with dual-polarization interferometric observation, the RVoG model can be applied for tree height inversion [5].

Except for the SIR-C/X SAR, airborne SAR system is the only data collectors for POLinSAR research until the launch of ALOS. ALOS is the first satellite to own one L-band SAR senor with dual- and quad-polarimetric data acquiring capability. So it is very important to investigate and evaluate the capability and limitation of the space-borne sensor, so as to provide advanced remote sensing tool and forest structure information products for forest management, environment protection both in local and regional scale.

The project objectives are to Investigate the dual-polarization interferometric SAR data processing and forest structure parameters (height, volume and biomass) extraction methods with ALOS PALSAR data acquired in repeat-pass mode, and evaluate the accuracy of the forest tree height, volume and biomass product with detailed ground truth, provide SAR remote sensing based forest inventory technique for forest management and support forest carbon estimation model with quantitative forest parameters. However, PALSAR data preprocessing and classification are the major activities being carried out currently, the preliminary results on these two topics are to be introduced in this paper.

2. TEST SITE AND EO DATA

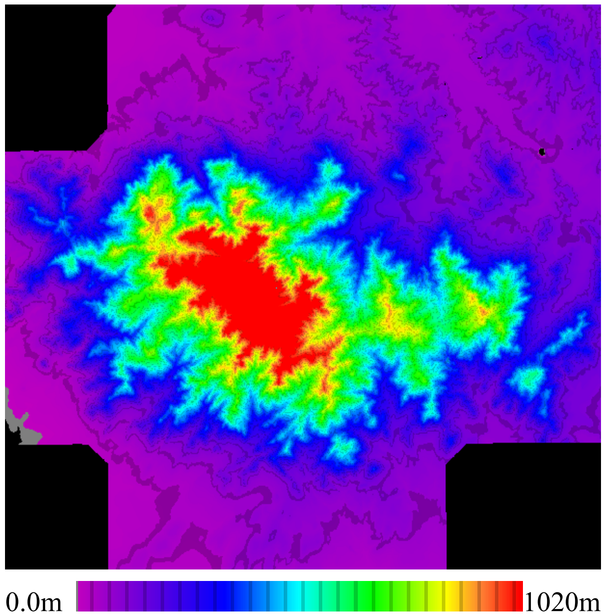
The test site is located in Tan An district of Shandong Province, its geographic coordinate ranges from N35°59′ to 36°5′ in latitude and from E117°13′ to 117°25′ in longitude. The forest covering area of the test site includes Tai Mountain and Culai Mountain, whose forest coverage rate is above 80%.

One regional remote sensing campaign has been carried out here from April to June of 2005, through which above 4.6 TB earth observation data have been collected. The airborne sensor data acquired includes small footprint LiDAR, CCD and Hyper-spectral data (PHI). The space-borne sensor data include ENVISAT ASAR APP and APS (HH and HV) data, EO-1 Hyperion Hyper-spectral data, SPOT-5 (Fig.1 (b)), Quick-bird and IKONOS. Ortho-rectified CCD image for the two mountains was produced separately. The DEM (Fig.1 (b)), forest component maps for Tai Mountain and Culai Mountain, and land use map (Fig.3-(d)) of 1:250 000 for Tai An district have been established.

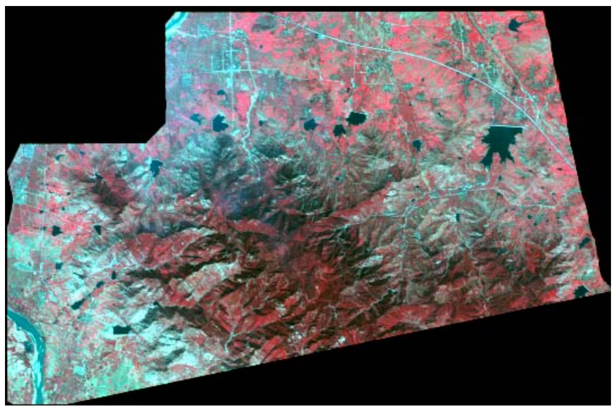
Four scenes of ALOS PALSAR level 1.1 data have been acquired for the test site. The major imaging parameters for the four images were listed in Table 1.

Table 1. Major imaging parameters for the PALSAR data acquired for the test site

Imaging Date	Polarization	Azim/range Resolution	Inc. angle of image center
May 19, 2007	Quad	3.55/9.37m	23.8 deg
June 21, 2007	HH, HV	3.18/9.37m	38.7 deg
July 20, 2007	HH, HV	3.19/9.37m	38.7 deg
Sept 21, 2007	HH, HV	3.18/9.37m	38.7 deg



(a)



(b)

Fig.1 DEM of Culai Mountain (a) & SPOT5 image (b)

3. DATA PROCESSING AND RESULT ANALYSIS

3.1 Geo-coding of PALSAR data and performance analysis

Range Doppler (RD) geo-location model based GEC data processing method of PALSAR level 1.1 products was studied and corresponding program was developed to support the investigation activities of the project. After generating the GEC images of all the data listed in Tab.1 with the same kind of GEC method, the geo-location performance of it was validated with two ways. Firstly, each two of the GEC images was overlapped routinely to check the fitness of image features. It has been found that the three dual-polarization images (Tab.1) of different date can be stacked together with a relative positive bias around 1.0 pixel. However, the location bias between image of MAY (the quad-polarization data) and the other three is around 203m in East-West direction and 64m in North-South direction, the error sources are not so clear. However the GEC results can be directly applied for checking image quality quickly and rough analysis of application possibility of multi-temporal PALSAR dual-polarization images.

The second way is to compare the GEC image with other sensor image already in map projection (geo-coded). One scene of Landsat ETM+ image extracted from USGS EROS GLOVIS server was used as reference to validate the performance of the GEC method. The Landsat ETM+ image was in UTM map project with WGS 84 ellipsoid and datum. The PALSAR images were also geo-coded to the same map project. When we show SEPT image (Tab.1, acquired in Sep. 2007) upon ETM+ image, we found out that the location bias between them is about 200m in East-West direction and 70m in North-South direction.

The absolute geo-location accuracy of the PALSAR level 1.1 products with the developed GEC method can not be validated because of lacking of ground control points of high accuracy. But apparently, we need to generate geo-coded terrain correction (GTC) images in order to integrate PALSAR data acquired from different date, in different descending/ascending orbit with each other or with optical data. Although the absolute geo-location performance of the current geo-location method applied seems not satisfactory, it is good enough for driving topography (DEM) based SAR image simulation procedure and supporting further development of program to generate GTC product. Fig.2 shows the GTC image of the MAY quad-polarization data in Pauli-basis presentation taking HH-VV as red, HV+VH as green and HH+VV as blue. The DEM used and the GTC image are all of pixel size 10m*10m. The image coverage is only of Culai Mountain.

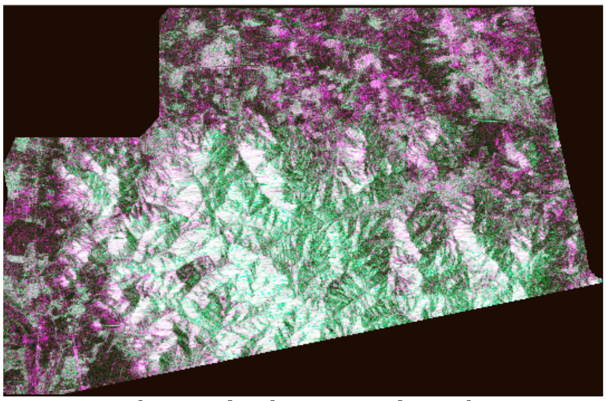
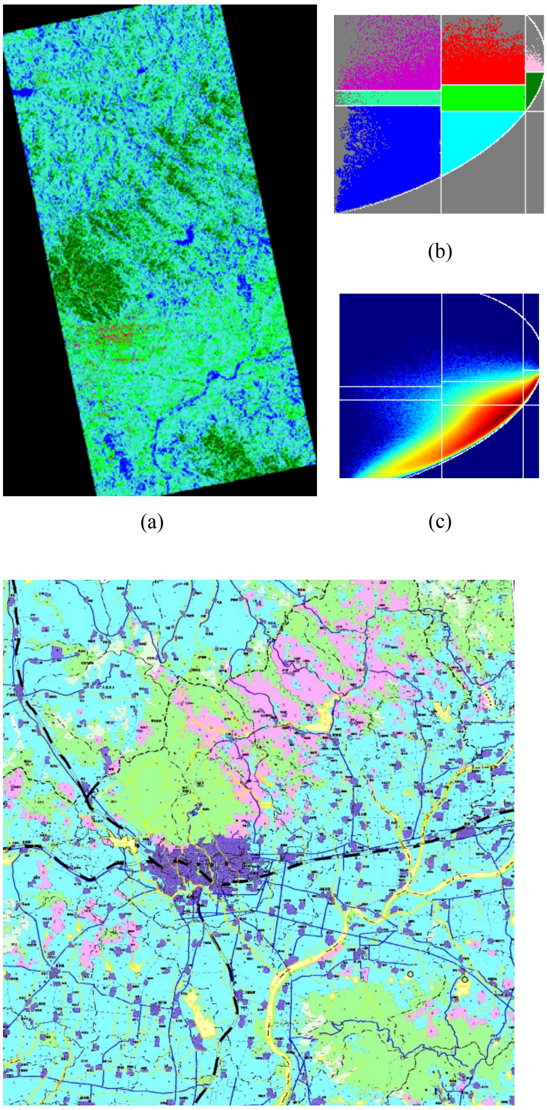


Fig.2 The quad-polarization data shown in Pauli-basis after GTC processing

3.2 Quad-polarization SAR data classification

Cloude and Pottier entropy (H) alpha classification was applied to the multi-look (5 looks in azimuth, 1 looks in range) MAY quad-polarization data (Coherency matrix) in original slant range geometric frame. The land terrain type image generated was geo-coded using GEC method, and Fig.3 shows the resulted segmentation result (a) with corresponding land-use map of this region (d), the color map legend for 8 terrain types (b) and the occurrence histogram for each type (c).

Comparing Fig. 3-(a) with (d), it can be found that dark green class in (a) corresponds to forest cover in (d) of light green color very well. Water bodies were of yellow color in (d), most of them can be detected as blue color of (a). But apparently there are so many small blue areas in the upper mountainous regions where there should not be water bodies according to the true map (d).



(a) (b) (c) (d)

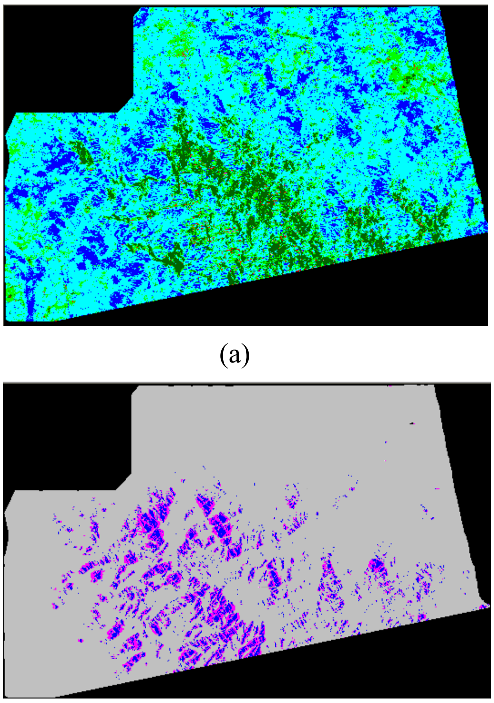
Fig. 3 Entropy-Alpha segmentation result (a), the legend for 8 terrain types (b), the occurrence histogram for each of the 8 types, and (d) is the corresponding land use map as true.

The city Tai An is in dark blue color located in the center of (d) just under Tai Mountain. Apparently the city can not be detected effectively by the segmentation method, only few pixels of purple color in (a) can be safely thought as urban, most of the pixels covered by the city were classified as light green color, which was confused with low vegetation (crop field and shrubs). Most of the forest located in the mountainous region, it seems the segmentation can identify most of the forest covering area effectively through the simple comparison of the entropy-alpha segmentation result with the land use map. But if we want to give a quantitative validation, the topography caused image distortion should be considered.

After applying the GTC processing to the entropy-alpha segmentation result (still in original image coordinate), we get the topography corrected segmentation result in map coordinate (UTM) as shown in Fig. 4. Fig.4 covers most part of the Culai Mountain region, there is large area of forest to distribute continuously according to the SPOT image shown in Fig.1-(b). However, Fig.4-(a) shows only some parts of the forest cover area as forest (Dark green color), near half of them was lost. If compared Fig.4-(a) with (b), the layover (red) and shadow (blue) map, it is easy to find out that the lost forests are really located in these layover and shadow regions. The topography caused layover and shadow destroy polarimetric signal totally, the coherency matrix fall in these region lost their original land cover type's polarimetric signature, these regions should be masked before or after entropy-alpha segmentation. Fortunately, it seems the radiometric distortions caused by topography such as foreshortening other than layover and shadow do not lead to serious problem for physical backscattering mechanism detection using entropy-alpha decomposition and segmentation method. But to what extent can the foreshortening affect the polarimetric segmentation and whether it is possible to correct its effect through radiometric terrain correction (RTC) [6] need to be further studied.

3.3 Multi-temporal dual-polarization SAR data processing results

Image to image auto-registrations were carried out between JUNE image and JULY image, but unfortunately, sub-pixel registration tie points can not be found successfully, so the two images can be thought as lost of coherence totally. With the same registration method, JUNE image were successfully registered to SEPT image with sub-pixel accuracy. All the registration procedures were carried out between two HH polarization images from different dates, the tie-points found were used to establish registration functions for both HH and HV images separately.



(a)

(b)

Fig.4 GTC image of the entropy-alpha segmentation result (a) and the layover, shadow region map (b).

Fig.5 shows the interferometric coefficient image from the InSAR pair of JUNE and SEPT. The maximum, mean and stand deviation of HH-HH coefficient image is 0.98, 0.30 and 0.16 respectively; that of HV-HV is 0.98, 0.23 and 0.13. From HH-HH coefficient image much more pixels of high coherence can be found than from HV-HV. Both of the two coherence images shows high coherence for forest covered mountains, urban area; while shows low coherence for crop covered regions and water bodies. Normally, forest region should have low coherence, but most parts of the two mountainous, where it should be covered fully by forest, were of high coherence. The coherence information should be integrated with intensity images of HH and HV from both date for classification and forest structure parameters extraction in the future.

The inteferometric land use image (ILU) was composed with coherence as red, mean intensity as green and intensity difference as blue separately for HH, HV polarization. It seems there is much more land covers information in the HH-ILU image than HV-ILU image.

4. CONCLUTIONS

The project test site has been established in two mountainous forest regions, and high resolution optical image and DEM are available for classification validation. One scene of quad-polarization and three dual-polarization PALSAR data have been acquired till now. The GEC and GTC processing have been applied to PALSAR level 1.1 products and their geo-location performance has been validated. Although the location bias relative to Landsat ETM+ image, the location bias between quad- and dual-polarization images is around hundred meters, its performance is good enough for generating GTC product based on SAR simulation using DEM. To what extent can the foreshortening affect the polarimetric segmentation and whether it is possible to correct its effect through radiometric terrain correction (RTC) need to be further studied.

Entropy-Alpha segmentation was validated with land use map of this test site as ground true, it has been found that this method can identify forest from the other land cover types in general, but there are serious problems in mountainous regions where layover and shadow happen. These regions should be masked out before or after segmentation. By this way, large part of mountain forest region can not be mapped with the PALSAR data.

Although one pair of the dual-polarization data can be registered precisely for coherence analysis, but the coherence image quality is not so good, the mean coefficient is well below normal value for standard InSAR application. How to integrate this kind of coherence information with multi-temporal intensity images for the development of efficient classification and forest structure parameters method needs to be investigated further.

More images will be acquired and ground true data of forest structure parameters such as forest canopy height, volume density and biomass above ground will be collected through field work, and various kinds of forest mapping and structure information extraction methods will be validated and improved for operational application in year 2008.

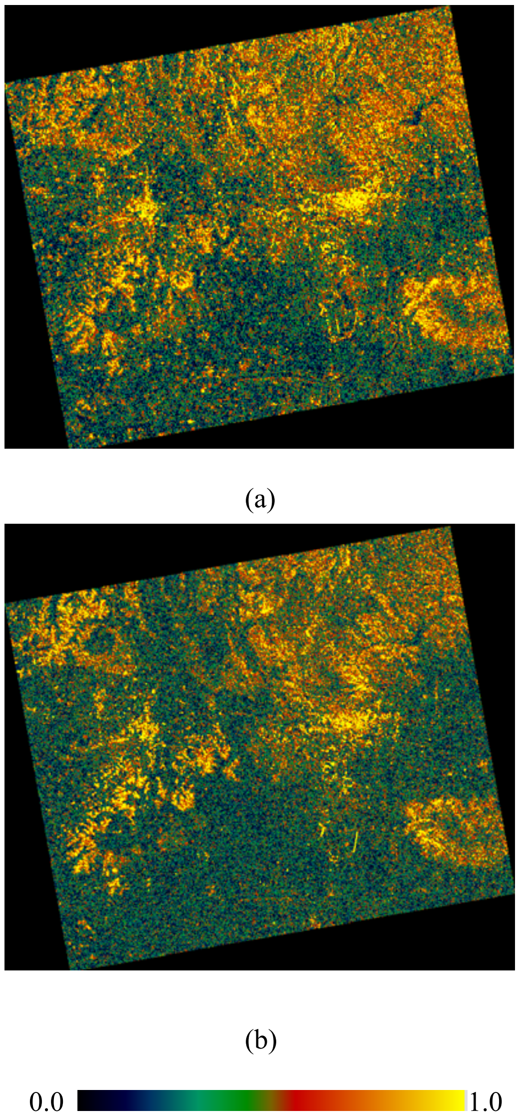


Fig. 5 The interferometric coefficient image of HH-HH (a) and HV-HV (b)

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