Integrated use of multi-mode and multi-angle SAR data for land cover identification in tropics

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Abstract

L-band SAR backscatter data have predominantly been used for land-cover identification. Adding coherence data improved the accuracy. However, coherence data are not readily available due to technical constraints but the application of multi-polarimetry and multi-squint-angle data may result in identical accuracies as the combination of backscatter and coherence data. Further improvements may be achieved by adding coherence data to the combination of multi-polarimetry and multi-squint-angle data and we expect that a combination of all data may yield to the same order of accuracy as with optical sensors. In our study area in Singapore we want to analyze if ALOS PALSAR data with multi-polarimetry and multi-squint angles can improve the accuracy in land-cover identification in the tropics. Applying Maximum-Likelihood, all data combinations will be classified using the same training areas derived by high resolution optical satellite imagery. The accuracies of all classifications will be analyzed to evaluate the best performing combination.

Keywords: ALOS, L-band, land cover identification, multi-mode, multi-angle, SAR, tropics

1. INTRODUCTION

Tropical deforestation increased tremendously in the past two decades [1] while Southeast Asia's rainforests are experiencing the highest rate of deforestation worldwide [2], thus effective monitoring systems are needed. Due to frequent cloud coverage as well as haze and smoke due to annual fire events in this region, optical satellites are severely restricted for land cover identification in the tropics. Therefore researchers have turned to cloud-penetrating radar imagery due to their all weather capabilities. Most notable are the mosaics of the tropical forests worldwide using JERS-1 data [3].

While backscatter data by satellite based SAR sensors have predominantly used for land cover identification, the use of coherence data has also been experimented both on C and L-band. ERS SAR coherence images have been used successfully for burn scar detection in Indonesia [4]. Coherence data in combination with backscatter data proved to be very useful to improve the accuracy in land cover identification as compared to the corresponding backscatter data alone [5]. The same order of accuracy was achieved using the combination of backscatter data on C- and L-band [6]. However, coherence data are not readily available because of different causes: satellites have to be operated in tandem mode to secure a pair of suitable images for interferometry and the repeat-pass interferometry is often not feasible due to a large base line distance between two orbits.

The integrated use of multi-mode and multi-angle backscatter data is readily feasible. In January 2006 the Japanese Advanced Land Observation Satellite (ALOS) was successfully launched. One of the promising features of the Phased Array type L-band Synthetic Aperture Radar (PALSAR) instrument is the ability to acquire data in quad polarimetry (HH+HV+VH+VV) during experimental mode. In our study we want to analyze if the integrated use of ALOS data in multiple polarimetry modes and multiple squint angles can improve the accuracy in land cover identification in the tropics.

2. METHODS

2.1 Study areas

Though very small in extent, the study area of Singapore and some area north of it shows a wide range of land cover classes, from primary and secondary forests, agricultural areas and plantations to urbanized areas. Singapore was chosen because of a high amount of available ground truth data.

2.2 Satellite and ancillary data

Geocoded ALOS PALSAR L-band data with different incident angles were used to analyze their suitability for land cover classification in the tropics. In our study we used two ALOS PALSAR products: 1) Fine beam data with HH polarization, 6.25m spatial resolution and 34.3 degree incident angle dating from 21-12-2006 (shortened: FB-HH). 2) Polari metric mode data with 12.5m spatial resolution and 21.5 degree incident angle which was recorded on 01-06-2007 (shortened: PM-HH, PM-HV, PM-VH, PM-VV).

The Shuttle Radar Topography Mission (SRTM, http://srtm.usgs.gov/) 90 m resolution elevation data was used for geometric correction of the ALOS data with different incident angles.

The training areas for the supervised classification algorithm were set according to different vector files of recent ground truth data superimposed on very high resolution satellite data (source: Google Earth).

A high resolution Landsat 7 ETM+ satellite image dating from 28-04-2000 in combination with recent ground truth data was used for validation purposes.

2.3 Preprocessing

Using the ASF COVERT BETA tool from the Alaska Satellite Facility Geophysical Institute at the University of Alaska Fairbanks (http://www.asf.alaska.edu/softwaretools/), we applied a radiometric and geometric correction to the ALOS PALSAR data. For analyzing the synergistic effects of SAR data with different polarization and incident angles it is essential to work with geometric highly referenced data. After converting DN to Sigma-nought to obtain radar backscattering coefficients we calculated a geometric terrain correction using SRTM data to prevent relief displacement. The elevation data has been resized to 6.25m spatial resolution using cubic convolution as resample method to fit the high resolution ALOS PALSAR data.

After testing several filters we applied a Median filter with a 9x9 kernel size for speckle suppression. A subset of the common study area of both ALOS PALSAR scenes was created.

2.4 Classification

For land cover classification we used a supervised Maximum Likelihood classification. Every single acquisition mode as well as data combination (ALOS L-band backscatter data in multiple polarimetry and squint angle) were classified using the same training areas derived from ground truth observations and high resolution optical satellite data. Training areas were set to distinguish pristine forests, plantations, bare soil and water.

Polygons of the classification results which were smaller than 1 ha were filtered and replaced by the attribute of the majority of attributes of the surrounding polygons.

2.5 Validation

In total 500 randomly selected points over the whole study area were visually interpreted using high resolution Landsat 7 ETM+ satellite data and in-depth knowledge about local land cover. The overall accuracy and the kappa coefficient accommodating for effects of chance agreement [7] of the different classifications were determined. The producer’s and user’s accuracy was calculated to determine the accuracy of individual land cover types.

3. RESULTS

3.1. Accuracies of single band data

According to the trainings areas we analyzed the single band data concerning their accuracy for land cover classification. Almost all bands showed similar kappa coefficients between 0.3313 and 0.3761, whilst the VV polarization with 21.5 degree incident angle only offered a kappa coefficient of 0.1331 (Figure 1).

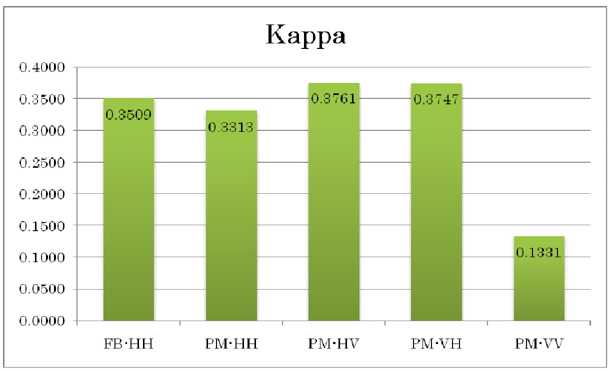

Figure 1. Kappa coefficient per single band

Figure 2 and 3 show the errors of omission and commission per land cover type – analyzed for each single input band.

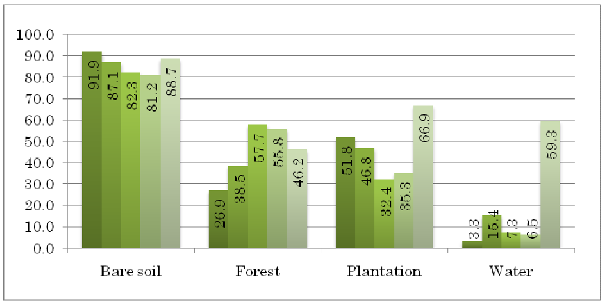

Figure 2. Error of omission (%) per landcover type (from darker green to lighter green color: FB-HH, PM-HH, PM-HV, PM-VH, PM-VV)

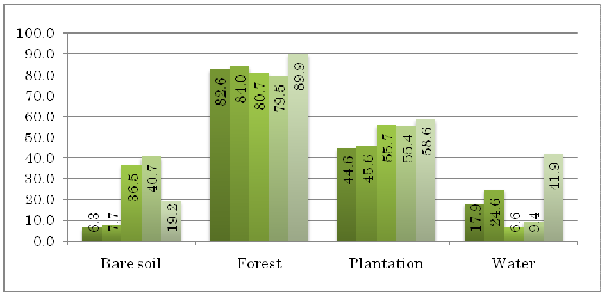

Figure 3. Error of commission (%) per landcover type (from darker green to lighter green color: FB-HH, PM-HH, PM-HV, PM-VH, PM-VV)

3.2. Accuracies of multi-mode and multi-angle data

An increase of the overall accuracy and the kappa coefficient could be detected when using multi-angle data (Fine beam data in combination with Polari metric mode data; overall accuracy: 58.00%; kappa coefficient: 0.4671) in comparison to single-angle data (only Polari metric mode data; overall accuracy: 56.20%; kappa coefficient: 0.4429).

Our results also show a reduction of the errors of omission and commission when multi-angle data was used (Figure 4 and 5).

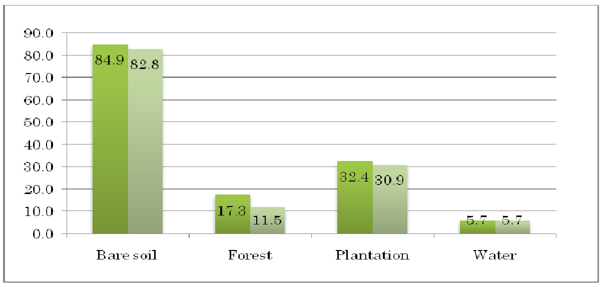

Figure 4. Error of omission (%) per landcover type (single-angle data in darker green and multi-angle data in lighter green color)

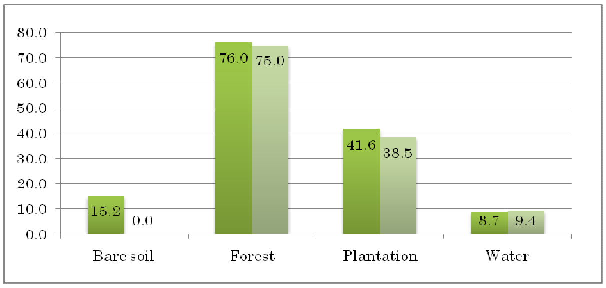

Figure 5. Error of commission (%) per landcover type (single-angle data in darker green and multi-angle data in lighter green color)

4. DISCUSSION AND CONCLUSIONS

According to former research we were expecting to be able to distinguish closed canopy forest, plantations as well as bare soil [5]. All classification results were analyzed according their overall accuracies and single accuracies per land cover type. Thus, the best performing data combination was evaluated, providing insights about the operational use of integrated SAR data for the sake of land cover identification in tropical areas.

It has to be noted that the two ALOS PALSAR data scenes were obtained about half a year apart from each other. Due to the geographic position of Singapore, which is situated slightly north of the equator, no intra-annual effects in vegetation cover were expected to bias the classification results. However, other factors might have had decisive impact on the quality of the investigation: 1) Local weather conditions at the acquisition dates and thus different backscatter characteristics due to changes in the complex dielectric constant. 2) Differences in water level as well as urbanistic changes might also have occurred.

To analyze the synergistic effects of different polarization and incident angles the satellite data has to be highly referenced. One of the problems we were facing was the geolocation error between the different ALOS products (Fine beam data and Polari metric mode data) as well as to the orthorectified Landsat 7 ETM+ scene. Due to relief displacement of the SAR data with different incident angles we applied some geometric correction using the ASF COVERT BETA tool from the Alaska Satellite Facility Geophysical Institute at the University of Alaska Fairbanks. Thus the ALOS PALSAR data was orthorectified based on SRTM elevation data, which almost eliminated the discrepancies between the two ALOS scenes. The discrepancy to the optical Landsat data however still exists and became in some areas even more severe.

Concerning the amount of information content for land cover classification the single bands show the following order: PM-HV, PM-VH, FB-HH, PM-HH and PM-VV. The classification of the single PM-VV band showed the lowest accuracy of all single bands. Especially the class of water and plantation were not detected correctly.

Analyzing the accuracies of the single band input data in comparison to the multi-mode data we clearly detected synergistic effects in the use of multi-mode data, showing an increased accuracy in land cover identification. After combining multi-mode with multi-angle data we were able to further increase the accuracy for land cover classification. Concerning the accuracy of the land cover classification it has to be noted that the class of bare soil showed a high error of omission and a low error of commission in both data sets, resulting in an underrepresentation of that class. For the forest class the situation was inversed with an overestimation in both data sets.

The capability of discriminating different forest classes such as mangrove forest, peat swamp forest and lowland dipterocarp forest has to be examined in a future study using a highly vegetated study area offering different kinds of forest types. However, even using the combination of multi-angle and multi-mode data different stages of vegetation such as park areas or low density residential areas with vegetated surrounding and forest areas outside Singapore were difficult to distinguish. Plantations were detected on bare soil inside the town as well as inside forested areas especially on hillsides facing towards the sensor. Due to foreshortening effects in hilly areas these areas exhibit a brighter appearance, similar to real plantations. Water was also detected on bare soil. Due to their surface smoothness water as well as plain areas of bare soil act as specular reflectors. Thus, these areas show almost no return signal and therefore are difficult to distinguish.

The integrated use of multi-angle and multi-mode ALOS PALSAR L-band data proved to increase the accuracy in land cover identification in the tropics in comparison to single-angle and single-mode L-band data. According to [8] low L-band frequency SAR data is more sensitive to above-ground biomass than other C-band data. A future analysis has to show the capabilities of the ALOS PALSAR sensor in comparison to C-band data (e.g. RADARSAT) to differentiate between different forest classes and forest degradation stages – a very decisive qualification for land cover identification in the tropics.

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