Integration of ALOS PALSAR and Landsat-7 ETM+ data for buried lineaments extraction at the Farafra Oasis, Egypt

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Abstract

In the last few years, ALOS/PALSAR (L-band) (HH, HV, VH and VV) images have been widely used due toits ability to penetrate the surface in certain conditions for example of low moisture or dry friable sandysoil. Images from ALOS-1 sensor have been applied to delineate subsurface structures. Optical imagessuch as Landsat-7 ETM+ data are used to discriminate between scatterings from earth surface andsubsurface materials. Thus, Farafra desert is an optimal environment for L-band microwave penetration.Therefore, this research involves mapping and interpretation of lineaments, surface and subsurfacestructures. The interested four spots at Farafara sand sheets display many structures that not have beentraced in the Egyptian official geological maps. Speckle noise is found in radar images due to many reasons, for example, when an object stronglyreflected between itself and the spacecraft causing noise. Refined LEE Filter (RLF) is applied for specklenoise reduction; speckle noise near strong edges is not strongly filtered, leaving the center of the pixelunfiltered, so, this procedure is an essential step in processing of polarimetric data to improve theaccuracy of the data and enhance resolution. ALOS/PALSAR data are processed into circular polarizationfor providing the best viewing of morphological and subsurface lineaments. The ellipse shape governed bytwo axes; semi-major axis 'a' and semi-minor axis 'b'. Orientation angle(ψ) is measured frompositive horizontal axis X counter clockwise direction, orientation angle range from 0° to 180°. Ellipticity(χ) is a shape parameter defined by the degree of oval shape, defined by χ=arctanb/a and can takevalues between -45° to +45°. As, the circular polarization yielded best outputs of subsurface structure indifferent trends, full polarimetric ALOS/PALSAR images (PLR) are transformed into circular polarization, bychanging both angles into orientation angle ψ=0° and elliptical angle χ=45°. Full polarimetric images arerepresented in Pauli RGB. Landsat-7 ETM+ data are freely uploaded with the same date and location ofALOS/PALSAR images. Bands 1, 2, 3, 4, 5 and 7 are merged together, then bands (R:2, G:4, B:7) arechanged to obtain best spatial resolution. Landsat-7 images have some gap areas, which is essentially befilled with Landsat-7 data acquired at the same time of the year by histogram matching technique to fillthe missed pixels of the interested target scenes according to Landsat 7. The obtained rose diagramshows two trends of dominant and secondary; the most dominant direction is North West (NW 330°),while the secondary trend is North (North 10°). This result is confirmed by the field survey. The dominantdirection of lineaments extracted from ALOS/PALSAR images is well fitted with the secondary direction ofthe geological structure in the study area. This work represents a stage of achievement in detecting buried lineaments covered by sand sheets byusing ALOS/PALSAR and Landsat-7 ETM+. Surface and subsurface

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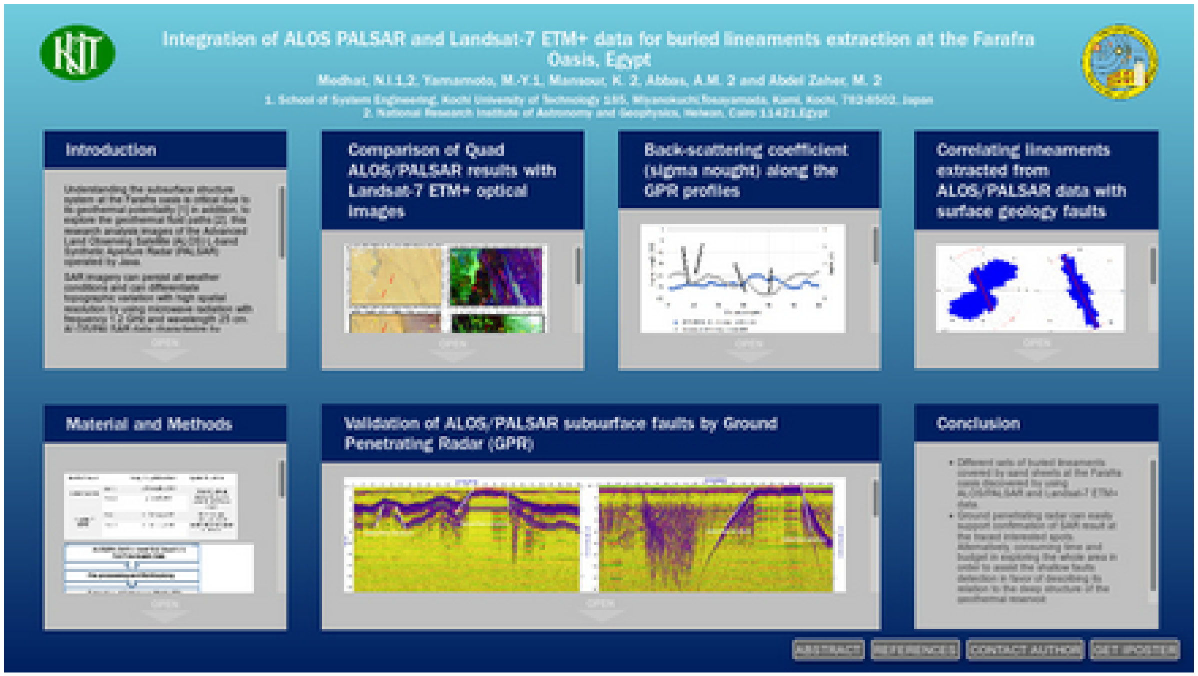

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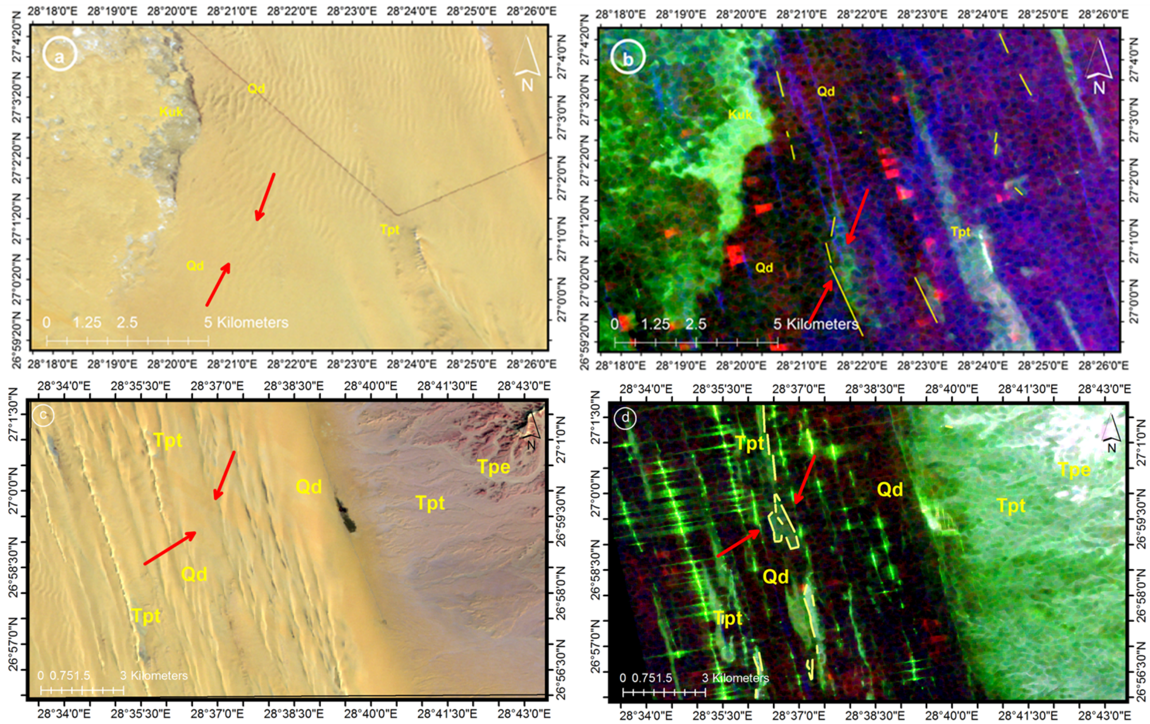
INTRODUCTION

Understanding the subsurface structure system at the Farafra oasis is critical due to its geothermal potentiality [1] in addition, to explore the geothermal fluid paths [2]. this research analysis images of the Advanced Land Observing Satellite (ALOS) L-band Synthetic Aperture Radar (PALSAR) operated by Jaxa.

SAR imagery can persist all weather conditions and can differentiate topographic variation with high spatial resolution by using microwave radiation with frequency 1.2 GHz and wavelength 25 cm. ALOS/PALSAR data characterize by optimal condition of penetration in the desertic areas depending on grain size, moisture and roughness of the surrounding geology and radar backscattering mechanism [3].

Ultimately, we used Ground Penetrating Radar (GPR) as a ground truth tool in order to ensure the result obtained from ALOS/PALSAR images.

COMPARISON OF QUAD ALOS/PALSAR RESULTS WITH LANDSAT-7 ETM+ OPTICAL IMAGES



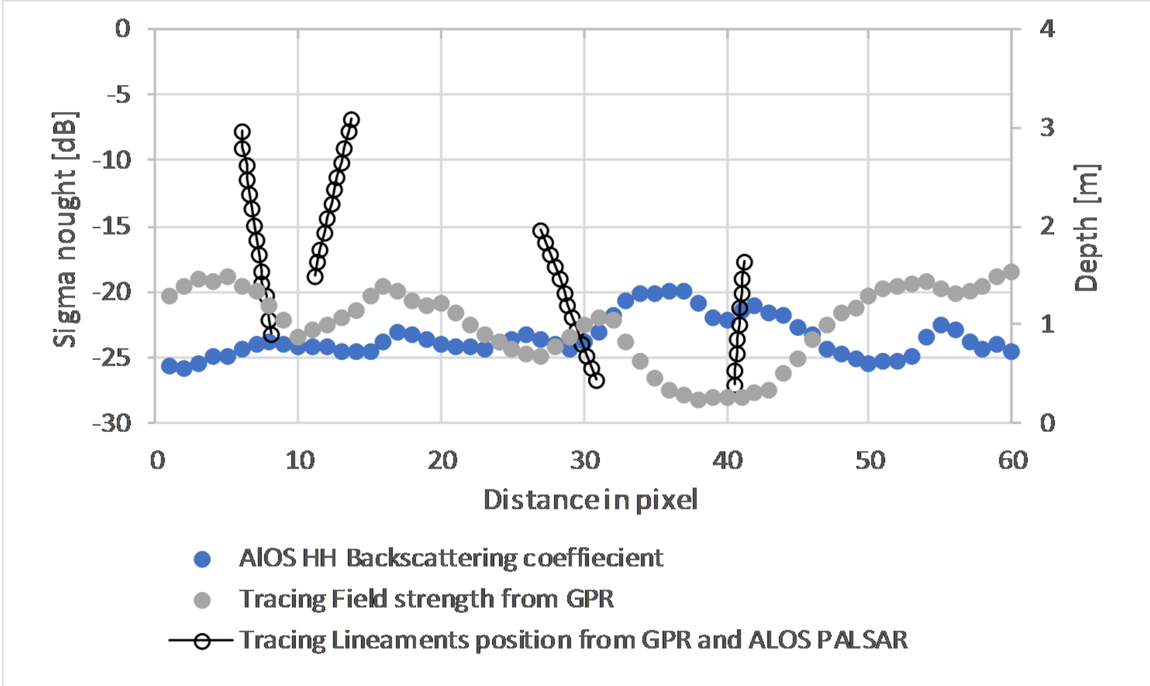
Legend
Qd: Sand dunes
Tpt: Tarawan Fm., white neritic chalk and chalky limestone.
Kuk: Khoman Fm., white massive neritic chalk and chacky limestone.
Tpe: Esna Fm., greenish-grey open marine shale. Limstone facies representing upper part of Esna shale (Ain Dalla Fm.)
Tpt: Tarawan Fm., white neritic chalk and chalky limestone.

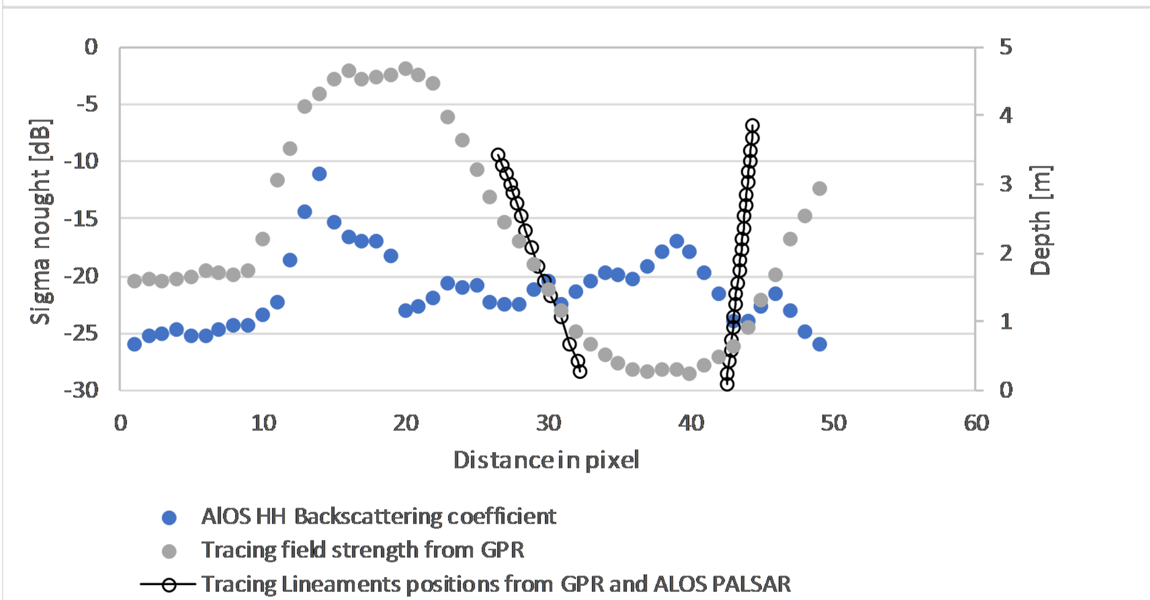
Initially, Full polarimetric images are represented in Pauli RGB , then, the interpreted features in the two areas of interest, The buried subsurface features exist in radar images, while remain unobserved in optical image. The distribution of subsurface features are strongly linked with backscattering coefficient.

However, when radar wave penetrates into subsurface and part of the wave is scattered in the interface between surface and subsurface zone such as subsurface traced features that exit only in radar images and disappear from optical images, generally linear features are located in sand sheets (Qs), bright areas as in Esna Formation (Tpe) and Khoman Formation (Kuk) interpreted as high backscattering including outcrops with a large radar cross section [3]. After careful visual analysis, subsurface lineaments features can be extracted in sand dunes and sand sheets.

Linear features precisely picked out by PCI Geomatica software with respect to the fundamental parameters for not introducing noises, avoiding more than one line linked and compatible to pixel size values [7].

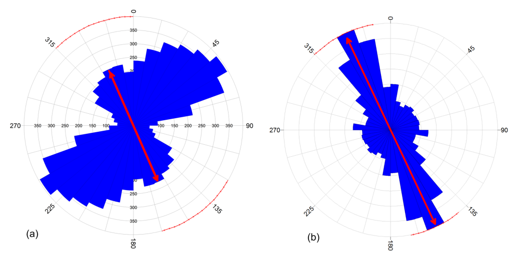
BACK-SCATTERING COEFFICIENT (SIGMA NOUGHT) ALONG THE GPR PROFILES





- The single polarized (HH) data especfically calibrated sigma nought bevaiour in the case of lineaments position were well fitted with the subsurface faults discovered by GPR reflected signal.

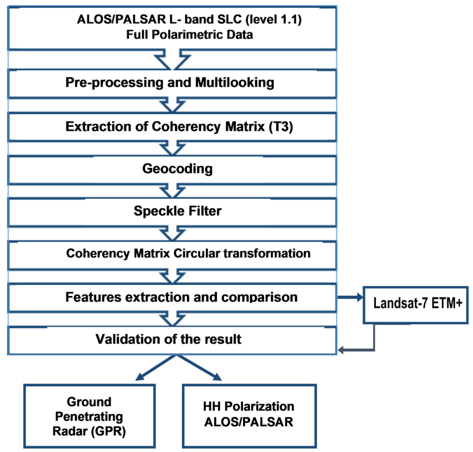
CORRELATING LINEAMENTS EXTRACTED FROM ALOS/PALSAR DATA WITH SURFACE GEOLOGY FAULTS



- The geological and morphological situation of the study area has been evaluated by generating rose diagram of all lineaments that were detected by using ALOS/PALSAR images.
- The dominant direction of lineaments extracted from ALOS/PALSAR images is well fitted with the secondary direction of the geological structure in the study area [1].

MATERIAL AND METHODS

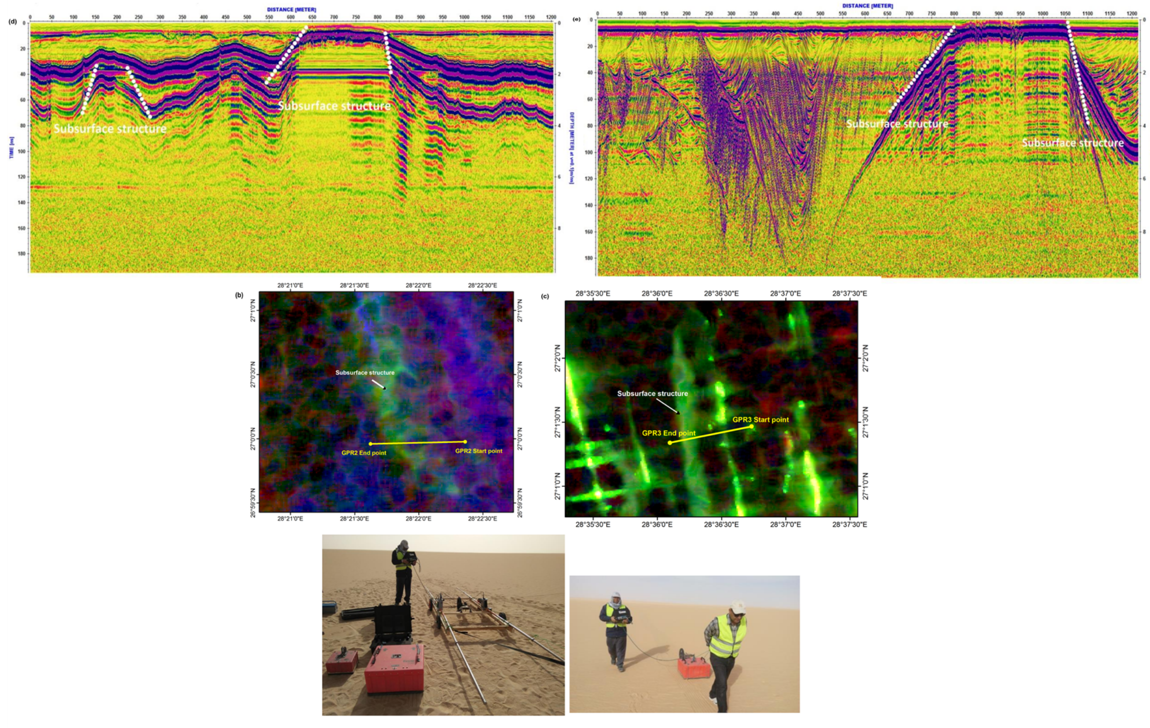
Satellite Sensor		Image Acquisition Date	Spatial Resolution
AlOS/PALSAR	Area 1	10 November 2009	9 m pixel spacing resample to 23 m in azimuth and 28 m in range
	Area 2	23 April 2009	
Landsat-7 ETM+	Area 1	11 February 2009	Six visible and shortwave infrared bands with 30 m spatial resolution
	Area 2	11 February 2009	



ALOS/PALSAR L-band full polarimetric data have been described in Table 1.

- ALOS/PALSAR (PLR), single look (SLC) level 1.1 images are converted into level 1.5 from raw (SLC) to Geoceoded terrain (GTC) and finally into Multi-look Intensity (MLI).
- Refined LEE Filter (RLF) is applied for speckle noise reduction, 7×7 edge aligned window for optimum display of fine details and well preserving of linear features [4].
- As, circular polarization obtained best outputs of subsurface structure in different trends [5], full polarimetric ALOS/PALSAR images (PLR) are transformed into circular polarization, by changing both angles into orientation angle=0 and elliptical angle=45 degree [5].
- Landsat-7 ETM+ data were freely uploaded from U. S. Geological Society (USGS) with the same date and location of ALOS/PALSAR images bands (R:2, G:4, B:7) were changed to obtain best spatial resolution. Moreover, Landsat ETM + data processed by histogram matching algorithm to fill the missed pixels of the interested target scenes [6].
- GPR profiles were utilized exactly on the same features extracted from Quad polarimetric PALSAR data.
- Single polarization of ALOS-1 (HH) correlated with GPR reflected signal.

VALIDATION OF ALOS/PALSAR SUBSURFACE FAULTS BY GROUND PENETRATING RADAR (GPR)



The GPR method was used to verify the resulting image products of ALOS/PALSAR and determine how deep electromagnetic waves at L-band can penetrate and detect near-surface areas covered by dry sand. The GPR profiles acquisition were acquired perpendicular to the subsurface faults, subsequently, processed in the time domain.

The GPR profiles show clearly visible offsets in the subsurface layers (reflectors), which are generated by set of geological structures of normal faults. These subsurface layers displacements are covered by dry and loose sand sheet with a thickness ranging from 1 to 3 m. The ALOS/PALSAR L-band waves can propagate up to 4.75 m deep (skin depth) and practical terms it can detect buried faults at 1.25 m depth (radar observation depth).

CONCLUSION

- Different sets of buried lineaments covered by sand sheets at the Farafra oasis discovered by using ALOS/PALSAR and Landsat-7 ETM+ data.
- Ground penetrating radar can easily support confirmation of SAR result at the traced interested spots. Alternatively, consuming time and budget in exploring the whole area in order to assist the shallow faults detection in favor of describing its relation to the deep structure of the geothermal reservoir.

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ABSTRACT

In the last few years, ALOS/PALSAR (L-band) (HH, HV, VH and VV) images have been widely used due to its ability to penetrate the surface in certain conditions for example of low moisture or dry friable sandy soil. Images from ALOS-1 sensor have been applied to delineate subsurface structures. Optical images such as Landsat-7 ETM+ data are used to discriminate between scatterings from earth surface and subsurface materials. Thus, Farafra desert is an optimal environment for L-band microwave penetration. Therefore, this research involves mapping and interpretation of lineaments, surface and subsurface structures. The interested four spots at Farafara sand sheets display many structures that not have been traced in the Egyptian official geological maps.

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This work represents a stage of achievement in detecting buried lineaments covered by sand sheets by using ALOS/PALSAR and Landsat-7 ETM+. Surface and subsurface lineaments that can be extracted in Farafra formations. May be due to its geological nature and spatial resolution that well fit to ALOS/PALSAR radar wave. Extracted orientation of the lineaments: especially in sand sheets proved great correlation with the secondary trend of the geological structure at Farafra map. Ground penetrating radar can easily support confirmation of ALOS/PALSAR result at the traced interested spots: alternatively, consuming time and budget in exploring the whole area. In addition, parameter analysis of soil samples from field survey will be carried out, if possible.

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