Geostructural and Hydrogeological Setting of the Gallaba Plain in West Aswan, Egypt, as revealed by ALOS/PALSAR Subsurface Imaging

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Summary

About 96 percent of Egypt is covered by deserts. These include the western desert, the eastern desert, and the Sinai Peninsula. Groundwater is an important factor to be considered for their development and utilization. Thus, we proposed to use ALOS data in a range of arid land applications including water resources assessment in the western desert. This topic is currently being addressed by ongoing research in an area West of Aswan, Egypt. Reconnaissance fieldwork has been carried out in the study area and some field measurements will be carrying out in March 2011 for validating the processed PALSAR results. The ALOS/PALSAR data have been used to image the near-surface buried faults under the dry sand of the western desert. This was achieved by transforming the PALSAR full polarimetric information to circular polarized for better visualization of the buried faults that strike in various directions. Preliminary results of this work have been presented in the ALOS PI Symposium 2010 in Tokyo, Japan and new results will be presented in the upcoming IGARSS 2011 conference in Sendai, Japan.

Keywords: desert sand, buried faults, water resources assessment, ALOS data.

1. STUDY SITE AND PROBLEM STATEMENT

The Gallaba plain is located west of Aswan between the cities of Kom Umbo and Edfu in Egypt (Fig. 1). It is a sedimentary basin and its origin is possibly attributed to the delta system of the ancestral Nile River (protonile). Geo-structurally, the Gallaba basin is believed to represent the western extension of the Kom Umbo graben which means that it has been affected by the same structural deformation processes that shaped the Kom Umbo basin. Recently, two productive oil fields have been discovered in this area, which are of great importance for future land development plans. However, the geo-structural and hydrological setting of Gallaba plain is still not well understood, and therefore, its groundwater potentials remain largely unknown.

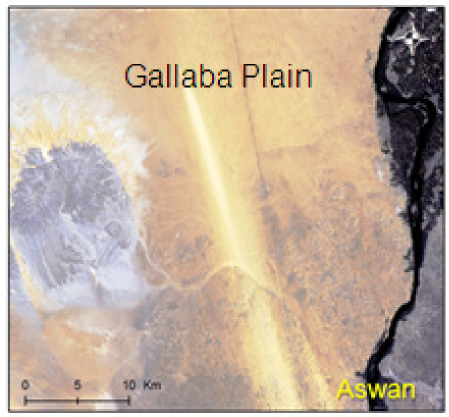

Fig. 1. ALOS/AVNIR-2 image of the study area

2. RESEARCH PLAN

The ALOS/PALSAR sensor provides high resolution imagery with variable incidence angles, and a much improved noise equivalent (σ0 NEσ0) value of around -23dB, which is a crucial parameter for achieving better subsurface imaging since buried structures are likely to have a low backscattering return. In addition, PALSAR L-band is capable of penetrating very dry sand and together with its quadrature polarization mode has the ability to collect and measure information on polarimetric scattering properties of buried targets. PALSAR L-band data with its multi-polarization channels have been used in this study to detect concealed fault structures striking in various directions as potential areas for groundwater accumulation in a desert area west of Aswan, Egypt.

3. RESEARCH IMPLEMENTATION

A DEM produced from the void-filled seamless SRTM data (available from http://srtm.csi.cgiar.org/) has been used to delineate and calculate surface runoff and quantity of water reaching the study area. For this the D8 flow direction algorithm has been employed for generating the surface flow directions and delineating the drainage network [1] (fig. 2). The study area is receiving a large amount of surface runoff during the rainy season.

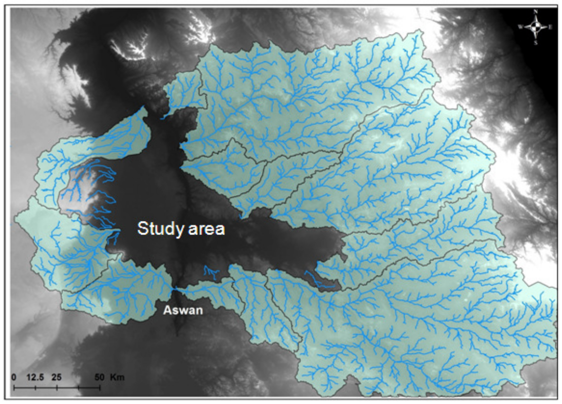

Fig. 2. Drainage patterns and watersheds surrounding the study area

Furthermore, ALOS/AVNIR-2 optical data together with field information have been used to generate a supervised classification map using the minimum distance technique [2]. This supervised map shows that the study area is mainly covered by very dry, relatively flat and homogenous sand and, thus, shows optimal conditions for microwave penetration (fig. 3).

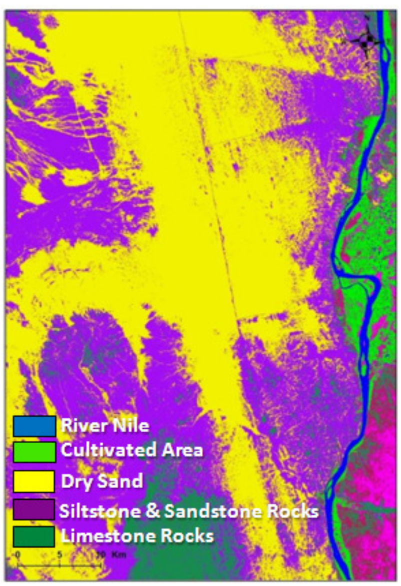

Fig. 3. ALOS/AVNIR-2 supervised classification map

Different polarization transformations have been applied on the ALOS/PALSAR full polarimetric data by changing both the orientation and elliptical angles to delineate the subsurface structures (fig. 4).

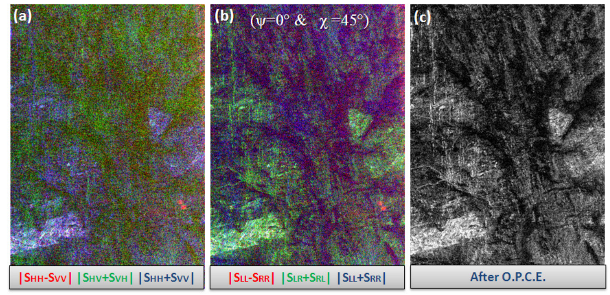

Fig. 4. Images of (a) Pauli decomposition, (b) circular polarization transformation and (c) polarization filtering

The circular polarization information has revealed better results, thus, such derived circular polarization images were further enhanced by applying the Optimal Polarization Contrast Enhancement (O.P.C.E) method [3] to maximize the ratio of backscattered strength between faults and the surrounding sedimentary material by calculating the power of any target as follows:

$$P = \vec{g}^T [K] \vec{h}$$

$$\vec{g} = [1, g_1, g_2, g_3]^T \quad \text{and} \quad \vec{h} = [1, h_1, h_2, h_3]^T$$

Where g and h are respectively the stocks vectors of the transmitter and receiver, and [K] is the Kennaugh matrix which can be calculated at each pixel from the full polarimetric ALOS/PALSAR. The proper polarization states which optimize the enhancement factors of target (K_A) and target (K_B) have been calculated using the following equation;

$$c = \max \frac{\vec{g}^T \langle K_A \rangle \vec{h}}{\vec{g}^T \langle K_B \rangle \vec{h}}$$

$$s.t.\ \ g_1^2 + g_2^2 + g_3^2 = 1$$

$$h_1^2 + h_2^2 + h_3^2 = 1$$

The initial contrast between the buried faults and the surrounding sediments was 1.047321e+000 and has been enhanced to be 2.153422e+000 after 8 iterations (Fig.4). The proper stocks vectors of the transmitter and receiver have been calculated (table 1) from the previous equations and plotted on the Poincare sphere to determine the best polarization states for imaging the buried faults in the study area as clutter, because they have lower backscattered returns than the surrounding sediments which have been represented as clutter (Fig.5). From the Poincare sphere, it can be inferred that the VV polarization is the best to image the buried faults in the study area, because unlike the surrounding sediments it is HH polarization.

Table 1. The proper stocks vectors for O.P.C.E

Optimal Transmit Polarization		Optimal Receive Polarization	
g0	1.000000e+000	h0	1.000000e+000
g1	9.928611e-001	h1	-9.832537e-001
g2	1.098681e-002	h2	-1.133955e-001
g3	1.187688e-001	h3	1.426660e-001

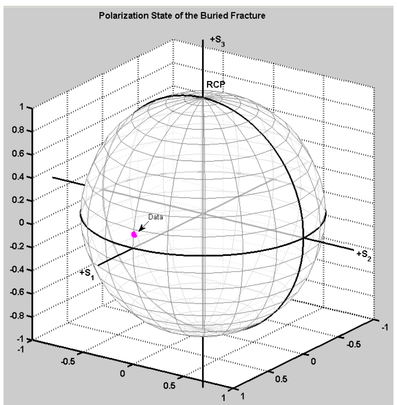

Fig.5. Faults (Svv) and surroundings (Shh)

Subsequently, the enhanced PALSAR data has been geo-coded and mosaicked in order to digitize the linear features that represent faults to produce a final fault network map (Fig.6). Moreover, the fracture density map has been calculating to map the highly fractured areas as potential areas for groundwater accumulation in the study area.

The circular polarization information has revealed better results for imaging the subsurface faults in various strike directions with clearly defined fault zone boundaries than the results from linear and elliptical polarizations. The Optimal Polarization Contrast Enhancement (O.P.C.E) method which maximizes the ratio of backscattered strength between faults and the surrounding sedimentary material significantly enhanced the boundaries of fault zones. Many buried faults could therefore be mapped from the PALSAR processed data which were not reported on the last version of the official geologic map (REF. ??). Some of these remotely extracted faults will be examined in the field using GPR for high resolution subsurface imaging and validation. Such highly fractured zones are potentially favorable for groundwater accumulation and constitute a promising resource in the Western Desert, Egypt.

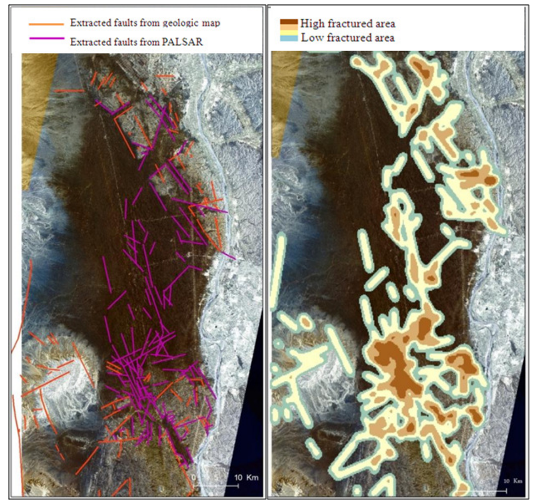

Fig.6. Network of extracted faults from the processed PALSAR data and the highly fractured areas

4. LIST OF ACQUIRED ALOS DATA

The following ALOS data sets have been used so far for work in the study area.

AVNIR-2 data
2 scenes imaged on 5/20/2008 and 5/23/2009
Mode: 1B2R

PALSAR data
4 scenes imaged on 5/24/2007 and 29/11/2007
Mode: 1.1 PLR 21.5 (level 1.1)

2 scenes imaged on 2/22/2008
Mode: WB2 24.6 HH3scan (level 1.5)

5. DISSEMINATION OF RESULTS

We recently submitted an abstract to the IGARSS 2011 conference in Sendai, Japan and the 4th ALOS PI symposium in Tokyo, Japan in 2010. As our research work progresses we intend to submit additional conference/journal papers in the near future.

6. REFERENCES

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