MISSISSIPPI STATE UNIVERSITY

Characterizing Levees using Polarimetric and Interferometric Synthetic Aperture Radar Imagery

Lalitha Dabbiru, James V. Aanstoos, Khaled Hasan, Nicolas H. Younan
Mississippi State University

AGU 2011
paper number: NH13E-1431
Contact: James V. Aanstoos
Box 9652, Mississippi State, MS 39762
Email: anstoos@gri.msstate.edu

INTRODUCTION

Monitoring the physical condition of levees is vital in order to prevent flooding due to levee failure. The dynamics of subsurface water events can cause damage on levee structures which could lead to slough slides, sand boils or through seepage. Synthetic Aperture Radar (SAR) technology, due to its high spatial resolution and soil penetration capability, is a good choice to identify such problem areas so that they can be treated to avoid possible catastrophic failure. The radar polarimetric and interferometric data is capable of identifying variations in soil properties in areas which might cause levee failure.

STUDY AREA AND DATA USED

The study area encompasses portion of levees of the lower Mississippi river in the United States. This area was chosen for analysis because multiple (8) slough slides formed in this area, identified with the assistance of the US Army Corps of Engineers (USACE). Two sources of SAR imagery are used: a) quad-polarized, L-band data from Uninhabited Aerial Vehicle Synthetic Aperture Radar (UAVSAR) for polarimetric classification, and b) high resolution dual-polarized TerraSAR-X data for interferometric analysis. NASA's UAVSAR imagery acquired in 2011 are used for the polarimetric analysis and DLR (German Space Agency) TerraSAR-X high resolution spotlight mode single-look slant range complex (SSC) imagery acquired on 10th March and 23rd April 2011 are used for interferometric analysis.

METHODOLOGY

The methodology of this research is mainly categorized into two streams: 1) polarimetric data analysis and classification, and 2) interferometric analysis.

Polarimetric analysis and classification

The backscattering properties of the target are described by [S] which represents the reflectivity of the area being observed at a given radar wavelength. This 2x2 coherent backscattering matrix with complex elements can be expressed in a vector form as:

$$\textbf{Scattering Matrix } [S] = \begin{bmatrix} S_{HH} & S_{HV} \\ S_{VH} & S_{VV} \end{bmatrix}$$

where H indicates horizontal polarization and V indicates vertical polarization

The scattering matrix is vectorized using Pauli spin elements to obtain the coherency matrix which is shown below

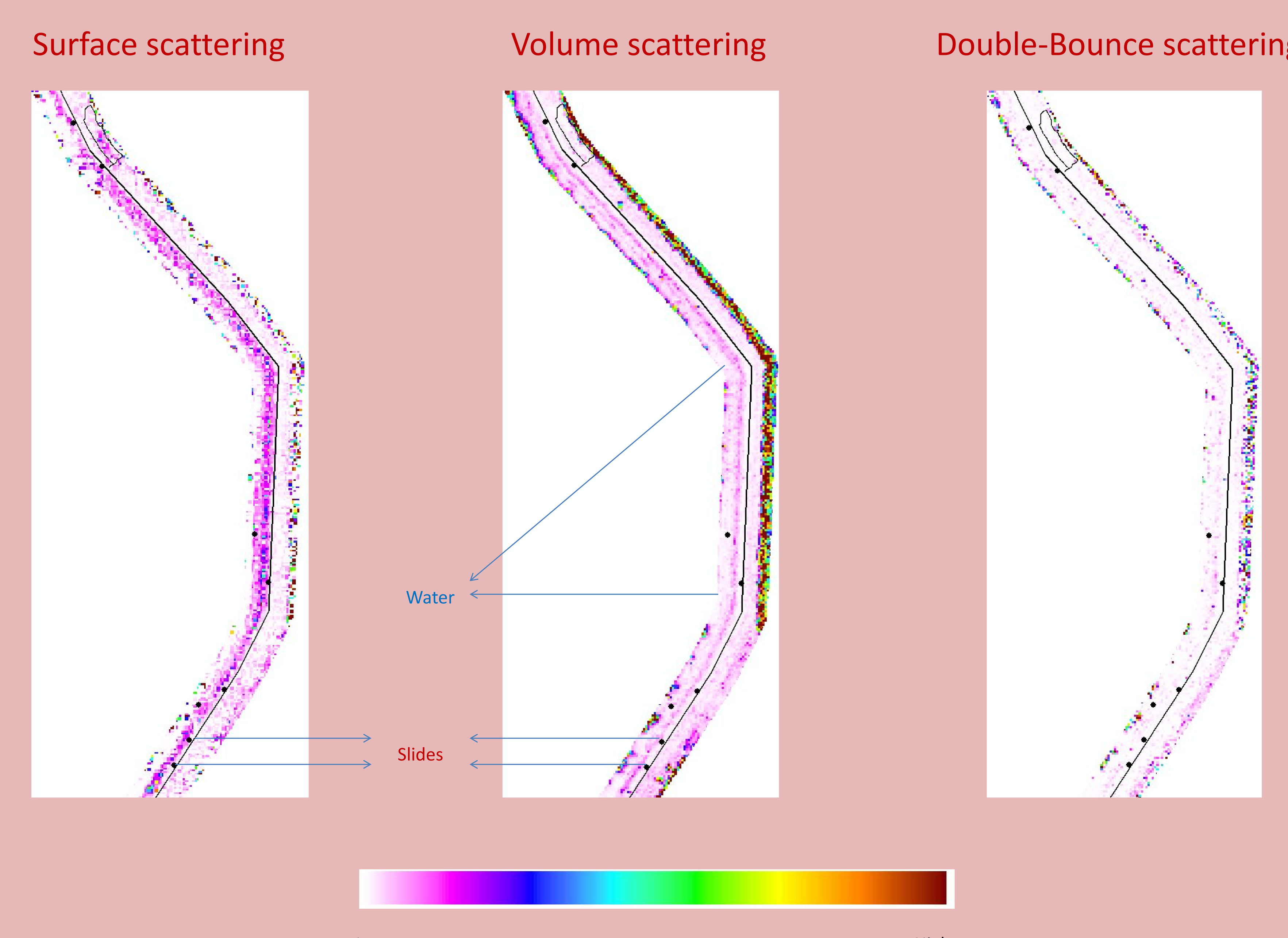
$$\textbf{Scattering Matrix } \vec{K}_p = \frac{1}{\sqrt{2}}\begin{bmatrix} S_{HH}+S_{VV} \\ S_{HH}-S_{VV} \\ 2S_{HV} \end{bmatrix} \quad (S_{HV} = S_{VH} \text{ due to symmetry})$$

$$\text{Coherency Matrix } [T] = \vec{K}_p \,.\, \vec{K}_p^{*T}$$

$$T = \langle \vec{K_p} . \vec{K_p^{*T}} \rangle = \frac{1}{2}\begin{bmatrix} \langle |S_{HH}+S_{VV}|^2 \rangle & \langle (S_{HH}+S_{VV})(S_{HH}-S_{VV})^* \rangle & 2\langle (S_{HH}+S_{VV})S_{HV}^* \rangle \\ \langle (S_{HH}-S_{VV})(S_{HH}+S_{VV})^* \rangle & |S_{HH}-S_{VV}|^2 & 2\langle (S_{HH}-S_{VV})S_{HV}^* \rangle \\ 2\langle S_{HV}(S_{HH}+S_{VV})^* \rangle & 2\langle S_{HV}(S_{HH}-S_{VV})^* \rangle & 4\langle |S_{HV}|^2 \rangle \end{bmatrix}$$

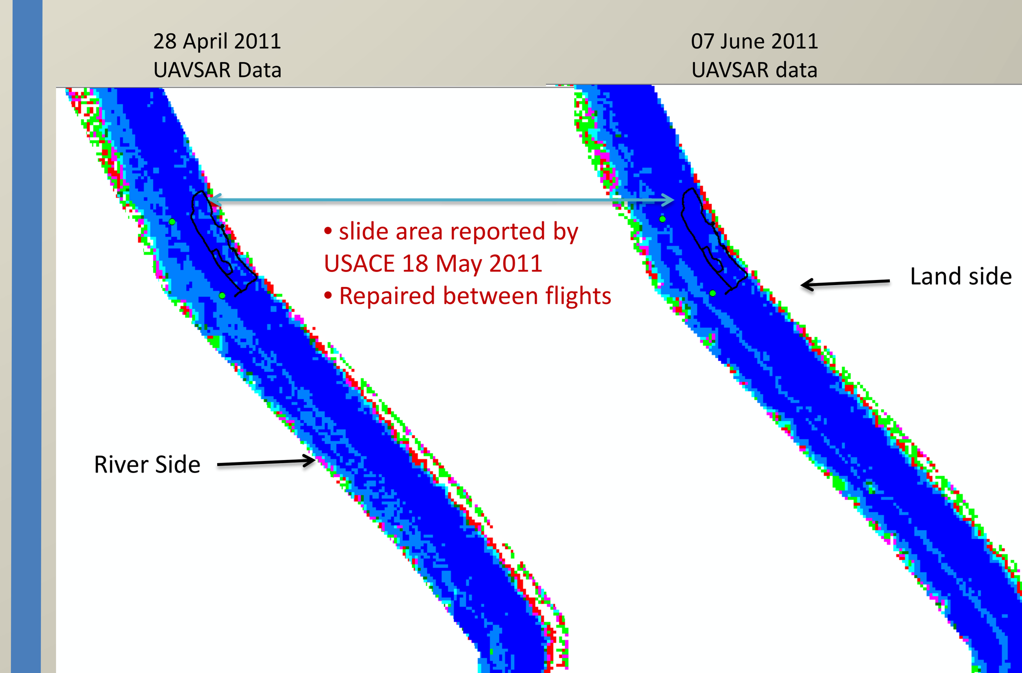
Freeman-Durden Decomposition

For land slide detection and prediction the retrieval of soil roughness and moisture are very important. Using Freeman – Durden decomposition the covariance / coherency matrix obtained from the UAVSAR L-band backscatter data of 22nd June 2011 is decomposed into three scattering components: surface, double-bounce, and volume scattering. The results show that the surface scattering component has higher values in the slide areas due to the higher roughness caused by the slough slides. Due to the vegetation on the levee the volume scattering component has higher values compared to the smoother surfaces like levee road and water.



Wishart H-Alpha Classification

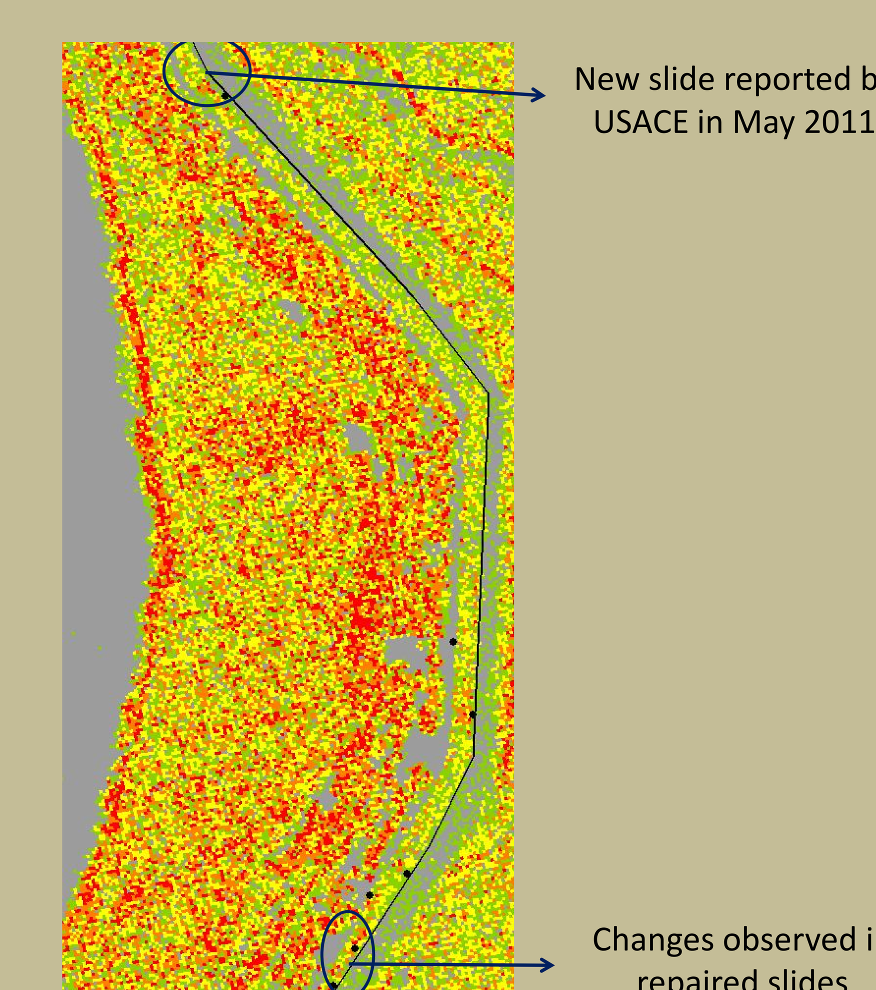
The polarimetric classification is performed based on the decomposition parameters: entropy (H), anisotropy (A) and alpha (α). The Wishart classification is based on the Cloude-Pottier H- α classification. The eight classes resulting from the H- α classification are used as training sets for the unsupervised Wishart classifier initialization and the clusters of the first iteration are used as training sets for second iteration and so on. The final classification has eight clusters with improved classification details.



A new slide and seepage area on the land side of the levee was reported by USACE on 16 May 2011 during rising flood waters. The polygon shows the slide using coordinates taken during our field trip to this area. The 28 April 2011 classification result shows a unique class in this land slide, even before USACE reported discovering it. The slide might have occurred by 28, April 2011 or the H- alpha classification might be predicting the slide before it actually formed as an active slide.

Interferometric Analysis

TerraSAR-X high resolution spotlight mode single-look slant range complex (SSC) imagery acquired on 10th March and 23rd April in the year 2011 are combined into pair to exploit the phase difference of the signals. The interferometric information is used to find evidence of potential small-scale deformations which could be pre-cursors to levee failure. The figure below is the amplitude / phase mixed image of the interferogram.



Funded by the NASA Applied Science Program, and the Department of Homeland Security Southeast Regional Research Initiative (SERRI) at the Department of Energy's Oak Ridge National Laboratory.
TerraSAR-X image provided by and is copyright of DLR (2011)