IMAGING RADAR IN THE MOJAVE DESERT – DEATH VALLEY REGION.

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The Mojave Desert – Death Valley region has had a long history as a test bed for remote sensing techniques. Along with visible-near infrared and thermal IR sensors, imaging radars have flown and orbited over the area since the 1970's, yielding new insights into the geologic applications of these technologies. More recently, radar interferometry has been used to derive digital topographic maps of the area, supplementing the USGS 7.5' digital quadrangles currently available for nearly the entire area.

As for their shorter-wavelength brethren, imaging radars were tested early in their civilian history in the Mojave Desert - Death Valley region because it contains a variety of surface types in a small area without the confounding effects of vegetation. The earliest imaging radars to be flown over the region included military tests of short-wavelength (3 cm) X-band sensors [1]. Later, the Jet Propulsion Laboratory began its development of imaging radars with an airborne sensor, followed by the Seasat orbital radar in 1978. These systems were L-band (25 cm). Following Seasat, JPL embarked upon a series of Space Shuttle Imaging Radars: SIR-A (1981), SIR-B (1984), and SIR-C (1994). The most recent in the series was the most capable radar sensor flown in space and acquired large numbers of data swaths in a variety of test areas around the world. The Mojave Desert – Death Valley region was one of those test areas, and was covered very well with 3 wavelengths, multiple polarizations, and at multiple angles.

At the same time, the JPL aircraft radar program continued improving and collecting data over the Mojave Desert – Death Valley region. Now called AIRSAR, the system includes 3 bands (P-band, 67 cm; L-band, 25 cm; C-band, 5 cm). Each band can collect all possible polarizations in a mode called polarimetry. In addition, AIRSAR can be operated in the TOPSAR mode wherein 2 antennas collect data interferometrically, yielding a digital elevation model (DEM). Both L-band and C-band can be operated in this way, with horizontal resolution of about 5 m and vertical errors less than 2 m.

In arid regions, it has been recognized that the weathering habit of a rock outcrop will determine its appearance in a radar image. Resistant, jointed rocks tend to appear bright, while fissile easily comminuted rock types appear dark. In one of the classic early radar studies, Schaber et al. [1] explained in a semi-quantitative way the response of an imaging radar to surface roughness near the radar wavelength. This laid the groundwork for applications of airborne and spaceborne radars to geologic problems in arid regions. Thus radars produce images of the physical nature of the surface, complementary to the compositional information produced by optical sensors. A secondary characteristic of the surface, its dielectric constant, which is strongly affected by moisture content plays a much smaller part, but can sometimes be seen to affect image tone around springs and after a rainfall.

When the wavelength is long and the dielectric constant is low (e.g. very dry soil) surface penetration may occur and subsurface horizons may be imaged. This was surprisingly demonstrated by SIR-A in 1981 over the Sahara Desert [2]. Bedrock and alluvial gravels covered by several meters of well-sorted, dry sand were clearly imaged at L-band (25 cm). A few sites in the Mojave Desert – Death Valley region have also demonstrated penetration at L-band and P-band (67 cm) [3, 4, 5].

Another useful application for imaging radar is mapping of surficial deposits and processes. Many surficial geomorphic processes act to change the roughness of a surface. In the southwest US, the most common processes are salt weathering (near salty playas), aeolian deposition, and desert pavement formation. Daily et al. [6] found that combining Landsat optical images with airborne radar images were useful for mapping several alluvial fan units, based on desert varnish formation in the optical wavelengths and desert pavement formation in the radar images. Taking this further afield, Farr and Chadwick [7] applied a similar approach to map fan units in a high valley in western China. These results make a case for the possibility that different surficial processes leave diagnostic signatures in multi-sensor remote sensing data, a possibility that will require much more extensive tests for uniqueness in different environments.

A more quantitative attempt at connecting radar images with surficial processes was undertaken by Farr [8]. Building on the work of Dohrenwend et al. [9] and Wells et al. [10], roughness changes with age at Cima Volcanic Field were quantified using close-range stereo photography from a helicopter. The results were then compared with radar images inverted to become maps of surface roughness [11]. The helicopter stereo photographs where reduced to profiles for the study. Profiles ranged from 10-30 m long and the points were spaced 1 cm apart. Typically about 15-20 profiles for each stereo-pair were produced. Sites for which helicopter-derived roughness profiles exist include lava flows (Pisgah Lava Flow, Amboy Lava Flow, Cima Volcanic Field, Lunar Crater Volcanic Field), alluvial fans (Death Valley, Silver Lake, Owens Valley), playas (Death Valley, Lavic Lake), and sand dunes (Death Valley). These data form a unique resource for those studying the effects of surficial processes on microtopography and remote sensing response to surface roughness.

References:

[1] Schaber, G.G., G.L. Berlin, W.E. Brown, Jr., 1976, Variations in surface roughness within Mojave Desert - Death Valley region, California: Geologic evaluation of 25-cm-wavelength radar images, Geol. Soc. Amer. Bull., v. 87,

29-41.

[2] McCauley, J.F., G.G. Schaber, C.S. Breed, M.J. Grolier, C.V. Haynes, B. Issawi, C. Elachi, R. Blom, 1982, Subsurface valleys and geoarchaeology of the eastern Sahara revealed by Shuttle Radar, Science, v. 218, p. 1004-1020.

[3] Blom, R., R.E. Crippen, C. Elachi, 1984, Detection of subsurface features in Seasat radar images of Means Valley, Mojave Desert, California, Geology, v. 12, p. 346-349.

[4] Schaber, G.G., J.F. McCauley, C.S. Breed, G.R. Olhoeft, 1986, Shuttle imaging radar: Physical controls on signal penetration and subsurface scattering in the eastern Sahara, IEEE Trans. Geosci. Rem. Sens., v. GE-24, 603-623.

[5] Schaber, G.G., 1999, SAR studies in the Yuma Desert, Arizona: Sand penetration, geology, and the detection of military ordnance debris, Rem. Sens. Env., v. 67, p. 320-347.

[6] Daily, M., T. Farr, C. Elachi, and G. Schaber, 1979, Geologic interpretation from composited radar and Landsat imagery, Photogram. Engr. Rem. Sens., v. 45, p. 1109-1116.

[7] Farr, T.G., O.A. Chadwick, 1996, Geomorphic processes and remote sensing signatures of alluvial fans in the Kun Lun Mountains, China, J. Geophys. Research, v. 101, p. 23,091-23,100.

[8] Farr, T.G., 1992, Microtopographic evolution of lava flows at Cima volcanic field, Mojave Desert, California, J. Geophys. Res., v. 97, p. 15171-15179.

[9] Dohrenwend, J.C., L.D. McFadden, B.D. Turrin, S.G. Wells, 1984, K-Ar dating of the Cima volcanic field, eastern Mojave Desert, California: Late Cenozoic volcanic history and landscape evolution, Geology, v. 12, p. 163-167.

[10] Wells, S.G., J.C. Dohrenwend, L.D. McFadden, B.D. Turrin, K.D. Mahrer, 1985, Late Cenozoic landscape evolution on lava flow surfaces of the Cima volcanic field, Mojave Desert, California, Geol. Soc. Amer. Bull., v. 96, p. 1518-1529.

[11] Evans, D.L, T.G. Farr, J.J. van Zyl, 1992, Estimates of surface roughness derived from synthetic aperture radar (SAR) data, IEEE Trans. Geosci. Rem. Sens., v. 30, p. 382-389.

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