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Investigating the backscatter contrast anomaly in synthetic aperture radar (SAR) imagery of the dunes along the Israel–Egypt border

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ABSTRACT

The dune field intersected by the Israel–Egypt borderline has attracted many remote sensing studies over the years because it exhibits unique optical phenomena in several domains, from the visual to the thermal infrared. These phenomena are the result of land-use policies implemented by the two countries, which have differing effects on the two ecosystems. This study explores the surface properties that affect radar backscatter, namely the surface roughness and dielectric properties, in order to determine the cause for the variation across the border. The backscatter contrast was demonstrated for SIR-C, the first synthetic aperture radar (SAR) sensor to capture this phenomenon, as well as ASAR imagery that coincides with complementary ground observations. These field observations along the border, together with an aerial image from the same year as the SIR-C acquisition were used to analyze differences in vegetation patterns that can affect the surface roughness. The dielectric permittivity of two kinds of topsoil (sand, biocrust) was measured in the field and in the laboratory. The results suggest that the vegetation structure and spatial distribution differ between the two sides of the border in a manner that is consistent with the radar observations. The dielectric permittivity of sand and biocrust was found to be similar, although they are not constant across the radar spectral region (50 MHz–20 GHz). These findings support the hypothesis that changes to the vegetation, as a consequence of the different land-use practices in Israel and Egypt, are the cause for the radar backscatter contrast across the border.

1. Introduction

Remote sensing imagery is one of the most powerful tools for studying the surface of the Earth because it is an efficient way to study vast areas, and areas to which access is restricted or difficult. Thus, the mosaic of land use and land cover that make up the different ecosystems on the Earth's surface can be mapped using remote sensing imagery (Rozenstein and Karnieli, 2011; Levin, 2015).

An interesting example for such use of remote sensing can be found in the continuous study of the dune field intersected by the Israel–Egypt border (Fig. 1A) (e.g., Otterman, 1974; Schmidt and Karnieli, 2000; Roskin et al., 2012). While ground access to this study site has been restricted at times due to geopolitical circumstances, this area attracted many remote sensing scientists due to a contrast along the two sides of the political border. The first remote sensing study of the area showed a difference in spectral reflectance between the relatively dark Negev dunes in Israel, and the very bright Sinai dunes in Egypt, based on a Landsat-MSS image from 1972 (Otterman, 1974). This phenomena was considered to be the result of overgrazing of the vegetation in Sinai, and simultaneous recovery of the vegetation in the Negev (Otterman, 1981). However, two decades after the origin of this interpretation, it was rejected, and an alternative explanation was postulated; the lower reflectance in the Negev was determined to be associated with the wide-spread cover of the surface by cyanobacteria dominated biocrusts rather than with higher vegetation, which was considered too sparse to cause this effect on brightness (Karnieli and Tsoar, 1995; Tsoar and Karnieli, 1996). The high reflectance of the Sinai dunes was attributed to the absence of biocrusts due to continuous trampling of the surface by pastoralist activities, preventing biocrust establishment (Meir and Tsoar, 1996). Hence, the high reflectance in Sinai was associated with the bright sands of the relatively bare dunes (Karnieli and Tsoar, 1995; Tsoar and Karnieli, 1996). Moreover, a thermal variation across the border occurs and is also attributed to the same land-use and land-cover differences (Qin et al., 2001; Qin et al., 2002). The relatively dark biocrusts

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absorb more solar irradiance than the bright sands, which results in higher land surface temperatures in the Negev than in Sinai during daytime. In addition to the land surface temperature contrast between exposed and biocrusted dunes, it was shown that because biocrusts are characterized by higher thermal emissivity (Qin et al., 2005), the land surface emissivity of the Negev dunes is higher than the Sinai dunes (Rozenstein and Karnieli, 2015). Recently, spaceborne observations of the fluctuations in the surface emissivity as a result of water vapor adsorption by the topsoil at night, and their subsequent evaporation during the day were also shown to differ between the two environments (Rozenstein et al., 2015).

So far, the exploration of the anthropogenic anomaly created by the contrasting land use practices in Sinai and the Negev utilized different spectral regions along the optical spectrum. A backscatter contrast in synthetic aperture radar (SAR) imagery of the border was previously suspected to be caused by differences in vegetation across the border, but this was not established (Blumberg, 1998). Considering that radar backscatter is affected by very different surface properties than those affecting optical remote sensing images, the contrast appearing in SAR images points to additional differences between the processes occurring in Sinai and the Negev. Radar backscatter is mainly influenced by the surface topography, roughness, and dielectric properties, in combination with the beam incidence angle, wavelength, and polarization (Blumberg and Greeley, 1993). Yet, the topography of the linear dunes does not change significantly across the border, and therefore it is not the cause for the differences in backscatter between Sinai and the Negev. In light of this, the aim of this paper is to explore the factors affecting surface roughness (e.g., the vegetation spatial patterns, and composition) and dielectric properties of the dune surface to determine the cause for variation in radar backscatter across the border.

2. Methodology

2.1. Study area

The study area in the Negev–Sinai erg (sand sea) is characterized by linear dunes arbitrarily intersected by the Israel–Egypt political border. This borderline that runs in an almost straight line from the Mediterranean to the Red Sea is based on the 1906 agreement between the British and Ottoman empires, which later on laid the foundation for a number of agreements between Israel and Egypt. In spite of their appearance from space, the dunes on both sides of the border are of the same pedological unit (Roskin et al., 2011). Since this border was last demarked in 1982 following the peace agreements between Israel and Egypt, this has restricted pastoralist activities to Sinai, as conservation policies were

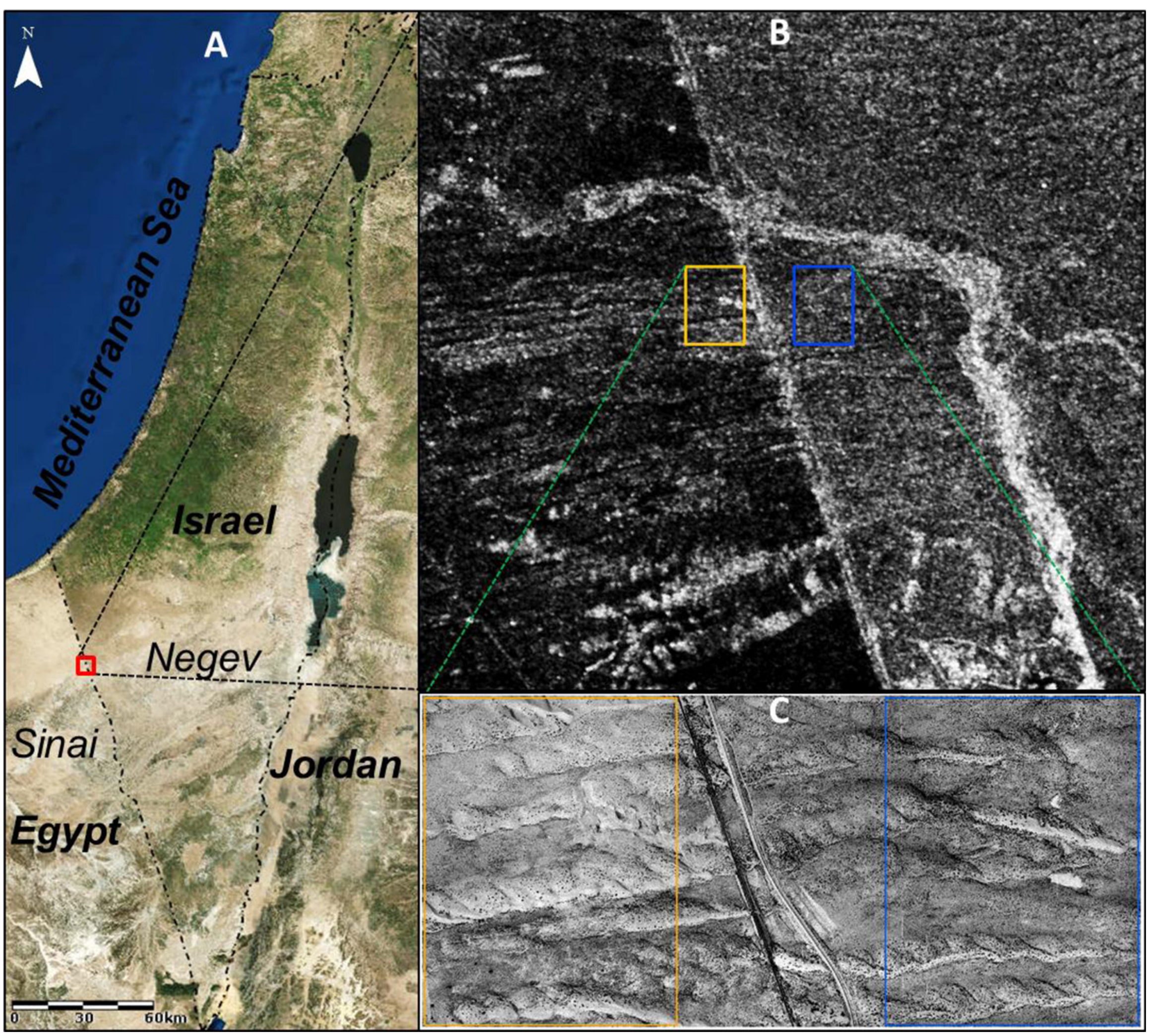

Fig. 1. (A) Location of the arid dunes study site on the Israel–Egypt border; (B) a subset of the SIR-C synthetic aperture radar C-HH band (λ = 5.7 cm) over the southern end of northwestern Negev dunes. The radar backscatter from the Israeli side of the border is higher than from the Egyptian side; (C) a panchromatic aerial image over the southern end of the dunefield. The vegetation patterns in the areas marked by rectangles on both sides of the border were analyzed and compared.