Radar observations of planetary dune analogues and assessing their stability using synthetic aperture radar.
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Introduction: Monitoring geomorphic changes on other planets is always a puzzle while on Earth measuring geomorphological dynamics can involve field work, i.e., ground truth. Dunes, wind streaks and other aeolian morphologies have been identified on Earth, Mars, Venus and Titan. These morphologies can be subjected to rapid and continuous changes when the surface is not stabilized by vegetation or crust and the wind is sufficiently strong. Thus, these sand bodies can change rapidly responding to the wind regime, rainfall, and sand particle availability. Identifying these changes by remote sensing (or even on the ground) is not straightforward because the entire surface may change concurrently.

In this paper we demonstrate how synthetic aperture radar interferometry (InSAR) can be used to identify changes in dunes using the coherence which is normally a measure of phase noise prohibiting interferometric studies. We demonstrate this for dunes along the Negev and Sinai border region. This paper will show how ERS data were used to map the stability, and loss of it, over time ranges spanning from 1 day intervals to 2 years when eventually the entire surface changed including the, so called, stable areas. This methodology has advantages as it does not show potential mobility but rather the true mobility or stability. It is applicable to planetary landscapes where there is no other indication of stability. Moreover, the methodology can be used also to measure the stability of surfaces susceptible to other mechanisms of landscape changes.

Synthetic aperture radar: Synthetic-aperture radar (SAR) is a method for the acquisition of images by actively illuminating a target scene with microwaves (λ~ 1 cm to 1 m) and integrating multiple radar images along a flight track to yield higher-resolution images than would be possible by a real aperture radar antenna. SAR amplitude images provide information on the surface geometry including slopes and roughness and the surface dielectric constant.

Spaceborne platforms such as ERS, and Radarsat, and the previously flown 1994 SIR-C/X-SAR exhibit single-look resolutions of 5-8 m in range and 15-20 m in azimuth and new spaceborne platforms such as the German TerraSAR-X, the Israeli TecSAR, and the Italian Comos Sky-med all exhibit resolution capibilities of at least 1 m. Mostly, data are processed to multilook images, which are produced by averaging single images of the same area to create a reduced speckle image (with lower spatial resolution.) Hence, the SAR spatial resolutions is as fine and at times superior to those known on current civilian VIS/NIR platforms and provide complementary information about the target scene. Another advantage of SAR system is the ability to acquire observations during both day and night and through all weather conditions, the results are systematic observation of the area of interest.

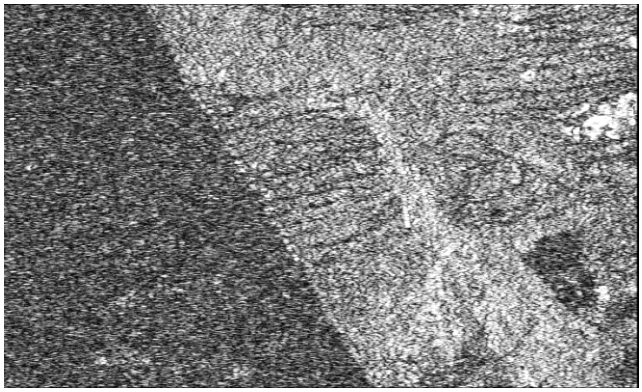
Radar coherence The radar phase is also affected by other factors, which together make the raw SAR phase image essentially arbitrary, with no correlation from pixel to pixel. Coherence is one of the products of the SAR interferometric process and it represents the magnitude of the complex correlation of both amplitude and phase information from two interferometric signals. The coherence is used to measure interferometry SAR data quality. Because each pixel in a SAR image is formed by the coherent sum of the backscatter from thousands of cells on the scale of the radar wavelength, temporal decorrelation can also be caused by the relative motion of the scattering cells within the SAR resolution (for example dunes can do so.)Thus, coherent change detection should provide an indication for dune motion

The first step of this work was to develop a methodology to precisely register all the SAR images. Our algorithm co-registered the images to a registration of better than 0.1 parts of a pixel. The second step was the coherence map creation. The coherence image of interferometric pair is shown in Figure 3 and figure 4. Clearly, the absolute coherence values are ranged between greater than 0.0 and less than 1.0, where values near 0.0 present totally decorrelated areas while the absolute coherence value near 1.0 represents a perfect coherence and the interpretation is stable area.

Results: LThe interferogram was converted into a color code map and the coherence converted into a three layer color map where one layer shows coherence of one day, the second of 10 months, and the third of almost two years. Decorrelation appears as salt and pepper pixels detached from the fringe pattern. The dune areas of the Northern Negev show high correlation over time caused by the fact that there is a biogenic crust on most of this area and little, if any, grazing. The area to the west demonstrates decorrelation starting within one day for small areas on the crest of the dunes. Within ten months the entire area of the Sinai side is decorrelated whilst the Negev (the Israeli side of the border) still maintains at high correlation

Conclusions: Radar remote sensing is a very useful toll in geomorphic studies and mapping. The additive value regarding the structure and geometry of dunes can and needs to be exploited. Moreover, beyond the amplitude imagery the phase information provide a unique capability of generating interferograms. Alongside the interferograms, temporal coherence maps are generated classically a measure of noise. These temporal coherence maps provide original and unique information compared with traditional optical and radar imagery. Dune motion is of interest in geomorphology studies especially of arid regions. Using the coherence maps, one can actually extract information regarding the dune motion. It is, thus, a useful tool for the mapping of dune activity.

This paper demonstrated an area with two very different land use policies yet identical climate showing dune changes on one side of the international boundary over short time periods and stable dunes on the other, over a long time periods.



The above figure shows the coherence map of the interferometric pair of images acquired between 1995-07-14 and 1996-05-24. In this set the Egyptian side, Sinai is to the west, is decorrelated and has shown motion of the dunes.