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## **Satellite Images of Sand Dunes Filtered by Means of GIMP Retinex**

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**Abstract:** This is the second paper of a series which is discussing the several applications that Retinex filters can have for enhancing images. Applications are ranging from the images obtained by microscopes to the images coming from satellites. In the first paper, we considered the images from microscopes, here we will discuss how Retinex can help the investigation of the motion of sand dunes as detected by satellite imagery. The filter that we use is the GIMP Retinex, developed by Fabien Pelisson.

**Keywords:** Image Processing, Image Segmentation, Texture Analysis, Entropy, Satellite Imagery, Sand Dunes, Change Detection, Sand Migration, Retinex, GIMP Retinex.

Retinex methods of image processing can be used to solve some problems concerning the automatic vision, problems which are evidenced by experimental observations. Experiments show that it is easy to note discrepancies between an image that we have recorded by a camera and the real scene that we have observed. The reason is in the fact that humans are able to see details both in the shadows and in the nearby illuminated areas, whereas a photograph of the same scene is showing either the shadows as too dark or the bright areas as overexposed [1].

Some peculiar features of human vision concerning colours, brightness and contrast of an observed scene, are quite different from those of the recording devices [2,3]. Inspired by these features, several methods and algorithms of image processing had been developed, in order to mimic the capability of human vision to adapt itself to different conditions. Actually, these methods are known as the Retinex models. The first algorithm was conceived by Edwin H. Land, an American scientist and inventor, best known as co-founder of Polaroid Corporation [4-8]. As explained in Ref.1, through the years, Land evolved several models, until his last one proposed in 1986. The term “retinex” was coined by Land himself, combining the words “retina” and “cortex”, to indicate the results of his researches, that human colour perception is involving all levels of vision processes, from the retina to the cerebral cortex.

Several Retinex approaches exist [3,9]: the single-scale Retinex (SSR), the multiscale Retinex (MSR), and, for colour images, the MultiScale Retinex with Colour Restoration (MSRCR). GIMP Retinex is a freely available tool of this last family, developed by Fabien Pelisson [10]. The resulting image of this filter can be adjusted selecting different levels, scales and dynamics. In the GIMP tool, we have three “levels”. The uniform level tends to treat both low and high intensity areas fairly, the low level “flares up” the lower intensity areas of the image, and high level tends to “bury” the lower intensity areas in favour of a better rendering of the clearer areas of the image. A “scale” parameter determines the depth of the Retinex scale filtering, and a “scale division” determines the number of iterations used by the filter. A “dynamic” slider allows adjusting colour saturation contamination

around the new average colour. For what concerns the results of the GIMP Retinex filtering, we have shown, by means of a method based on the generation of a bulk set of images with selection and ranking, and using entropy too, that the information in the image is changed, in particular for dark and foggy images [11-14].

Applications of Retinex are many and are ranging from the images obtained by microscopes to the images coming from satellites. However, we can find also interesting uses for the increase of the visibility of objects in dark, foggy and underwater images, such as for increasing details in medical imaging and for fault- and face-detection. Besides these applications, others are possible such as the use of Retinex in the studies of painting masterpieces and in the digital restoration of cultural heritage. In a previous paper [15], we started the discussion of the several applications of Retinex filtering, with that concerning the enhancement of images coming from microscopes (for Retinex methods and applications, see [16-22]). Here we will discuss how Retinex can help the investigation of the motion of sand dunes in satellite imagery. The filter that we use is the GIMP Retinex, developed by Fabien Pelisson.

### **Retinex and the Change Detection to study the sand dunes**

In recent years the research about Change Detection, which is applied to data and images obtained by remote sensing from satellites, has collected a huge number of studies and publications. To detect changes, sets made by time series of satellite images and data maps are necessary. These sets of images and maps allow researchers to examine a given area over some specific periods of time, and determine the changes inside and investigate the related causes at the origin of variations.

In [23], we started a discussion of Change Detection, concerning the study of the motion of sand dunes. This is an important subject, because sand dunes can move and, during their motion, they can be a problems for human activities. For several reasons therefore, the sand dunes had been and are a subject attracting many studies. The first pioneering works were those made by Ralph Alger Bagnold [24]. Today, besides the local explorations as those performed by Bagnold, we can easily study the dunes by means of satellite images. Examples of how we can evaluate the speed of dunes in these images are given in [25-58].

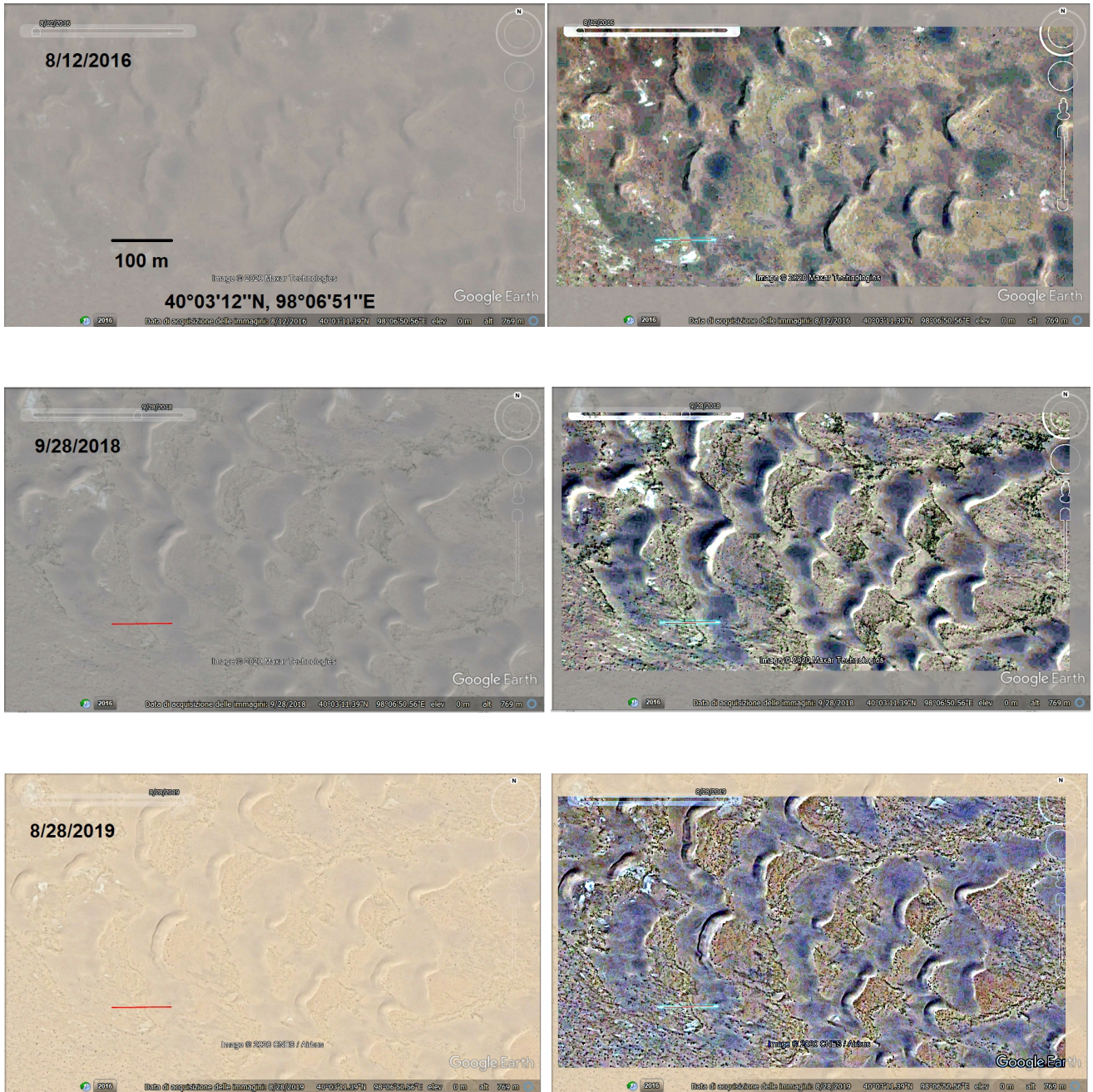
To evaluate how sand dunes are moving by means of remote sensing, we need a time-series of images. Many time-series are available from Google Earth, a precious instrument for researches concerning natural and urban environments. Of course, the study of the motion of sand dunes can be easily made by means of images, according to their quality, that is, according to their resolution, contrast and brightness. In the time-series, the visibility of dunes can be quite different from time to time. Therefore, adjustments are often required. Retinex filtering can be successfully used to enhance the visibility of the dunes. Here some case-studies and examples.

### **Barchans in the Central Hexi Corridor, China**

As told in [59], "Crescent-shaped barchan dunes often display an asymmetric shape, with one limb longer than the other. As shown in previous studies, asymmetric bimodal winds constitute one major cause of barchan asymmetry, but the heterogeneous conditions of sand availability or flux, as well as topographic influences, may be also important. Understanding the morphology and dynamics of asymmetric barchans may have an impact in a broad range of areas". In [59], migration rates and morphologic changes of asymmetric barchans have been investigated. The barchans are those of the Hexi Corridor, Northwest of China.

In the Figure 1, some images from a time-series of Google Earth are shown. The original images are on the left. On the right, we can see the results that we can obtain by applying to them the GIMP

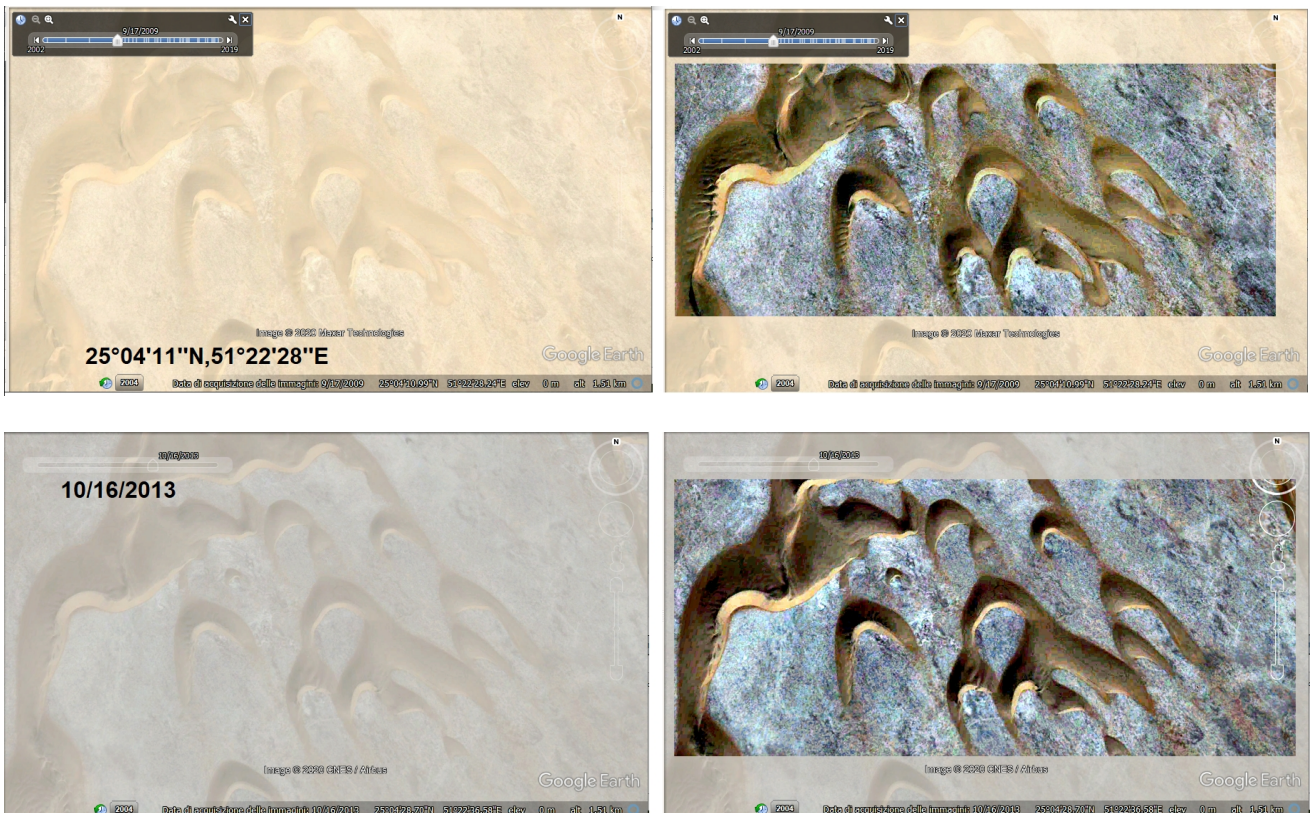
Retinex. This result is quite different from images that we have by adjusting contrast and brightness (Figure 2). Retinex is clearly showing the size of the dunes.



**Figure 1: China** - Examples of the use of GIMP Retinex to enhance the satellite images of the dune field discussed in [59] (original images on the left). Many thanks to Google Earth for the precious images, fundamental for research and study.



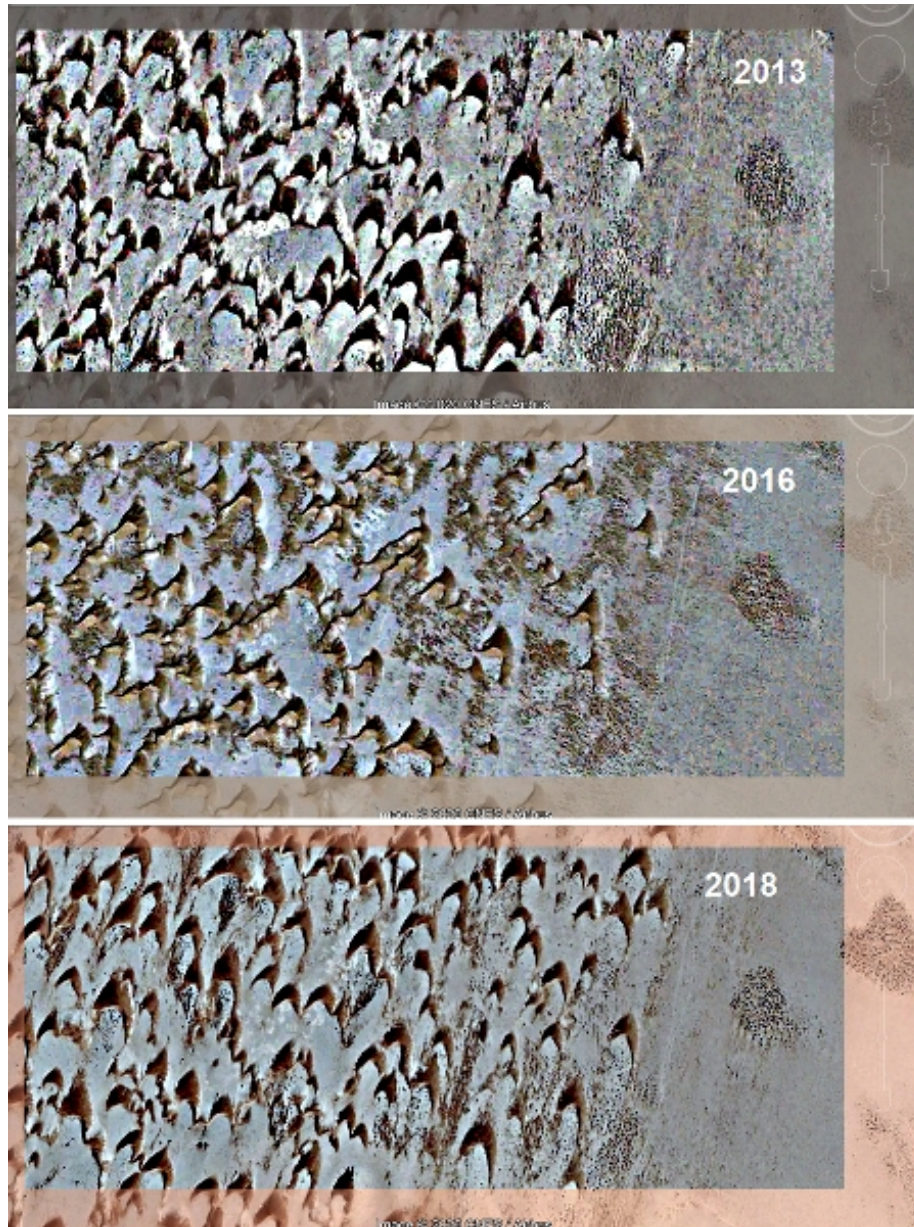
**Figure 2:** On the right, we can see the image on the left, after adjusting contrast and brightness. The result is quite different from that obtained by means of GIMP Retinex, as we can appreciate by a comparison with Figure 1.



**Figure 3: Qatar** - GIMP Retinex filter applied to dunes in Qatar. For the study of these dunes, see [60]. Many thanks to Google Earth for the precious images, fundamental for research and study.

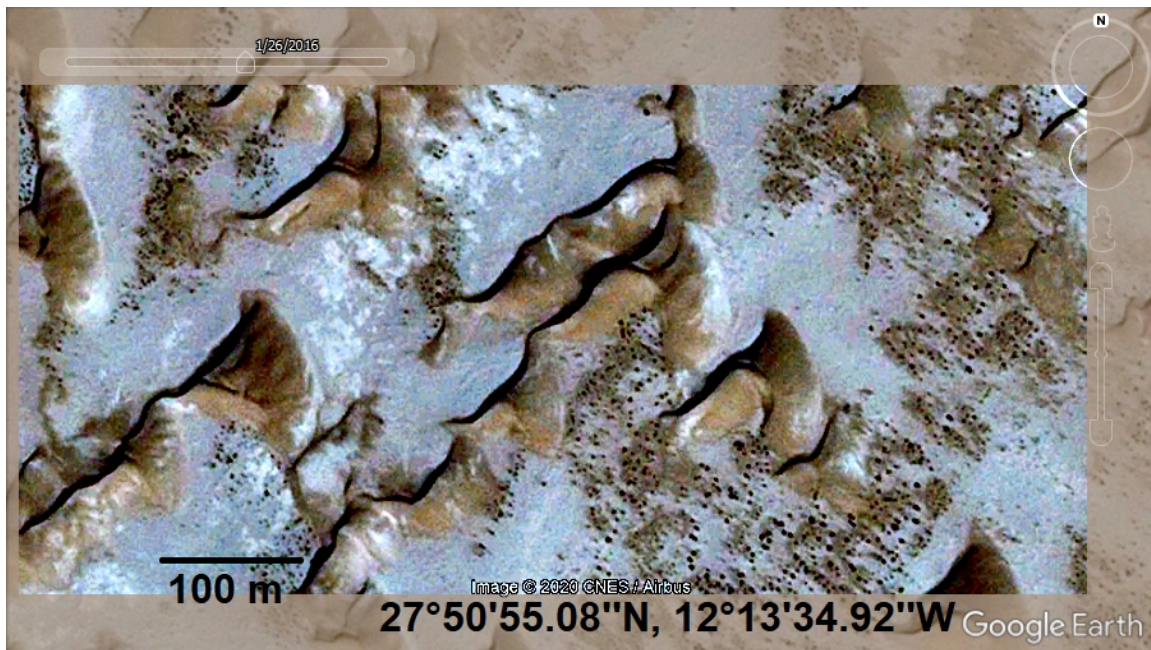
## Qatar

In the Figure 3, the GIMP Retinex filter has been applied to dunes in Qatar. This barchan dune field is discussed in [60]. In this article, it is told that the migration of barchan dunes is mainly controlled by "dune size, wind patterns, vegetation cover and human impact". The researchers had investigated the variability of dune migration in Qatar over a time period of 50 years using high-resolution satellite and aerial imagery.

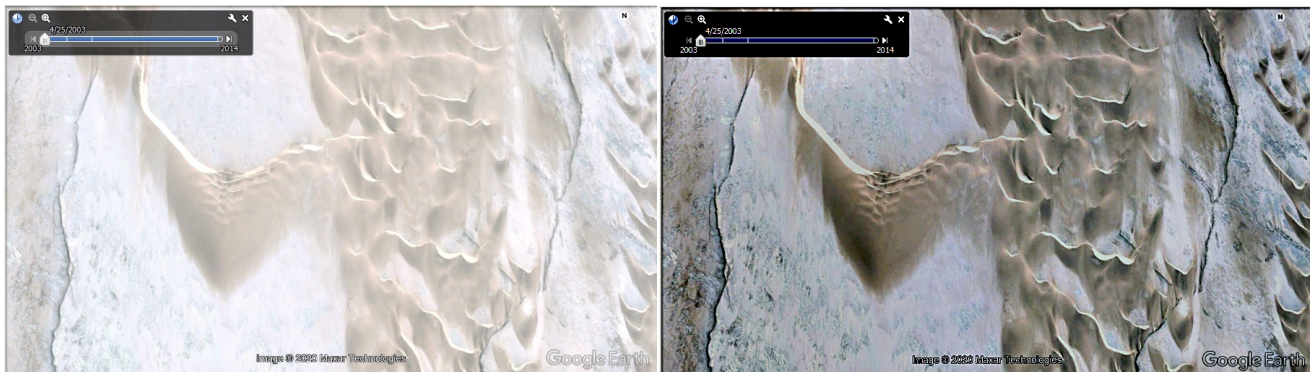


**Figure 4: Morocco** - GIMP Retinex filter applied to dunes in Morocco. Many thanks to Google Earth for the precious images, fundamental for research and study.

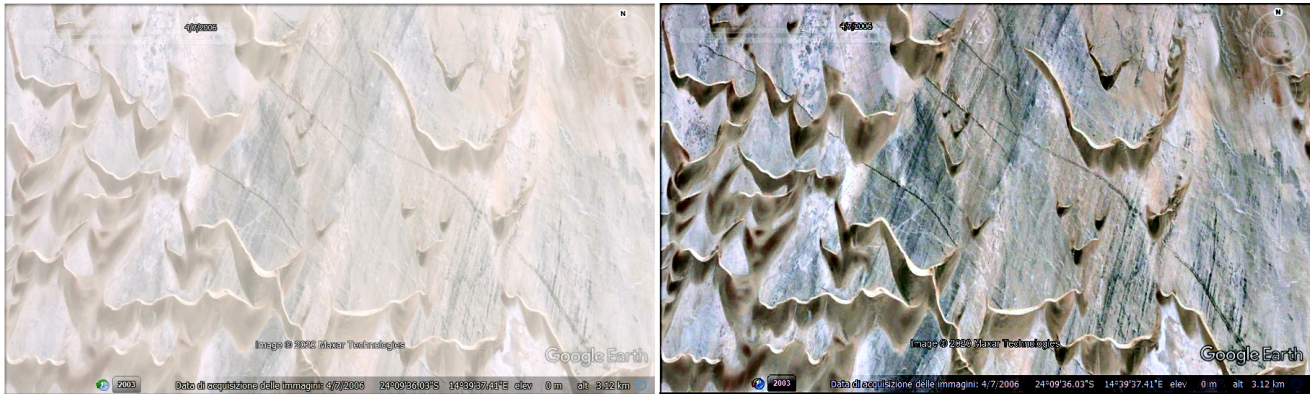
**Morocco** - In Morocco there is barchan dune field of which I discussed in [34,40,41]. In [40,41], we have shown how the barchans in this dune field changed their shape from 2013 to 2016 (in the Figure 4, the images are shown after GIMP Retinex filtering). This was depending on winds. As we can see from Fig.4, in 2018 the shape of the barchans returned to be the same as it was in 2013. It means that the migration of these dunes is a quite complex phenomenon, strongly depending on the change of the local prevailing winds, as shown by a modification of the dune shape accordingly. In the Figure 5, a detail of this dune field is given.



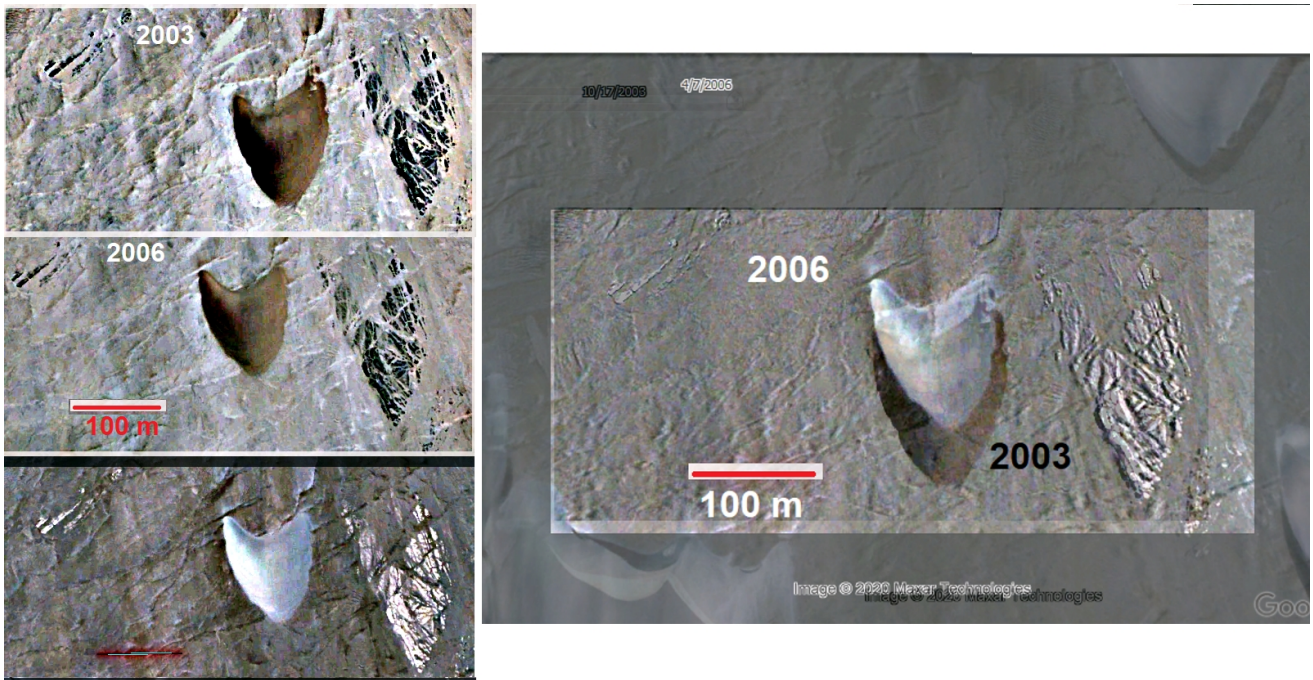
**Figure 5: Morocco** - GIMP Retinex filter applied to dunes in Morocco. Many thanks to Google Earth for the precious images.



**Figure 6: Namibia** - GIMP Retinex filter applied to dunes in Namibia. Many thanks to Google Earth, for the precious images.



**Figure 7:** GIMP Retinex filter applied to dunes in Namibia. Many thanks to Google Earth, for the precious images, available for research and study.



**Figure 8:** A barchan moving in Namibia. The satellite images from Google Earth had been enhanced using GIMP Retinex. On the left: upper panel, the dune in 2003; in the middle; the dune in 2006; lower panel, inverted colour image. On the right: we can easily measure the displacement of the dune as made in [34], by means of a comparison of the "black" dune (2003) and the "white" dune (2006).

## Namibia

Other examples of the use of GIMP Retinex are proposed in the Figures 6-8. The dunes, which have been considered for these figures, are in Namibia. In this case, we find in Google Earth very bright satellite images. Retinex can properly adjust the contrast. In the Figure 8 it is shown how to analyse the motion of a barchan dune. The approach has been described in detail in [34].

The examples given above have shown that GIMP Retinex is suitable for the study of the motion of sand dunes. In particular, this filter helps in enhancing the contrast of the satellite images, maintaining all the details recorded in them. For this reason, its use is better than the simple use of tools which are adjusting contrast and brightness.

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