



HAL
open science

Change Detection in Satellite Images Applied to the Study of Sand Dunes

Amelia Carolina Sparavigna

► **To cite this version:**

Amelia Carolina Sparavigna. Change Detection in Satellite Images Applied to the Study of Sand Dunes. 2019. hal-02298624

HAL Id: hal-02298624

<https://hal.science/hal-02298624>

Preprint submitted on 27 Sep 2019

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Change Detection in Satellite Images Applied to the Study of Sand Dunes

Amelia Carolina Sparavigna¹

1 – Department of Applied Science and Technology, Politecnico di Torino, Torino, Italy.

Abstract: In recent years the research on Change Detection, applied to data and images obtained by remote sensing from satellites, has collected a huge number of publications, as we can easily see using Google Scholar or Semantic Scholar engines. For this reason, any review of this large research area must be necessarily fragmented according to specific applications. Here we consider the study of the motion of sand dunes.

Keywords: Image Processing, Change Detection, Satellite Imagery, Climate Change, Sand Dunes.

The sets of time series of satellite images and data maps, which are reporting information collected by means of remote sensing technologies, are today the main datasets used in the research field of Change Detection. 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. Besides monitoring the local environments, the trends extrapolated by the Change Detection can be used to forecast the evolution of the environmental conditions too. Not surprisingly therefore, we find, among the main subjects of the Change Detection, the analyses of deforestation, polar ice loss and all the global and local consequences of the Climate Change.

Several space agencies are contributing to provide time series of satellite images, useful for the previously mentioned problems. Images recorded on different dates can be statically compared or merged in a sequence, to obtain a multi-temporal image, by means of which we can easily observe the local changes. One of these agencies is ESA, the European Space Agency, which is running the Earth Watching Project. NASA, the National Aeronautics and Space Administration of the United States Federal Government, has service ARSET, Applied Remote Sensing Training, which offers a specific training to integrate the NASA Earth Science data into decision-making activities. Google, the American multinational technology company specialized in Internet-related products, has its service too. It is the Google Earth Timelapse, based on the time series of images in Google Earth.

The methods that we can use for a study of Change Detection can be roughly categorized into the two sets of supervised and unsupervised methods. The former set is based on supervised classification methods, which require additional information to obtain the desired features contained in the images or maps. The latter set performs change detection by means of a direct comparison of them, without incorporating any additional information [1]. As explained in [1], Change Detection by means of unsupervised methods uses the automatic analysis of change data, which are generally created as follow. First we have an image (or map) differencing. Then, this processing is followed by normalization and vector analyses [2]. Let us remember that image differencing-based algorithms accomplish the change detection by subtracting, on a pixel basis, the images acquired at two time instants to produce a new image called “difference image” [1]. The changes need to be identified in the difference image. Some methods to detect the changes in images, referenced in [1], are those given in [3-5]. Some recent works are given in [6-14].

In recent years, the research on the Change Detection collected a huge number of publications, as we can easily see using Google Scholar or Semantic Scholar engines. For this reason, any review of this large research area must be necessarily fragmented according to specific applications. Here we consider the study of the *motion of sand dunes*.

The sand dunes are a subject which has attracted many studies from the first pioneering works made by Ralph Alger Bagnold [15]. Today, instead of local explorations as those performed by Bagnold, we can easily study the dunes by means of the time series of satellite images. We can obtain the size distribution of the dunes, their motion, collision, and evolution (see for instance, [16-18]).

Actually, sand dunes can move and, during their motion, they can be a problems for human activities. Moreover, on the motion of sand dunes the climate change can strongly act, with disastrous consequences for local communities, as shown in [19-22].

The motion of the dunes has been studied by Change Detection in [23-26]; the method of analysis is based on the difference of images (in [26], the dunes of the Kharga Oasis have been analysed; these dunes are also representing a problem for the archaeological remains of the Oasis [27]).

The method is the following [25]. Two satellite images A and B of a dune field, recorded at different times and converted in grey tones, are merged in an image C. From image A, a new image A' is obtained by inverting the grey tones of it. Reducing its opacity to 50%, A' is copied as a layer on B. A' and B gives image C, an image like that shown in the Figure 1. In C, the dunes of image A appear as bright dunes, whereas the same dunes, recorded at a different time, and given by image B, appear in dark tones. We can join the two positions of the brink of each dune by a red line, to obtain the displacement of the dune. Since we have the dates when images have been recorded, we can easily obtain the speed of the dunes.

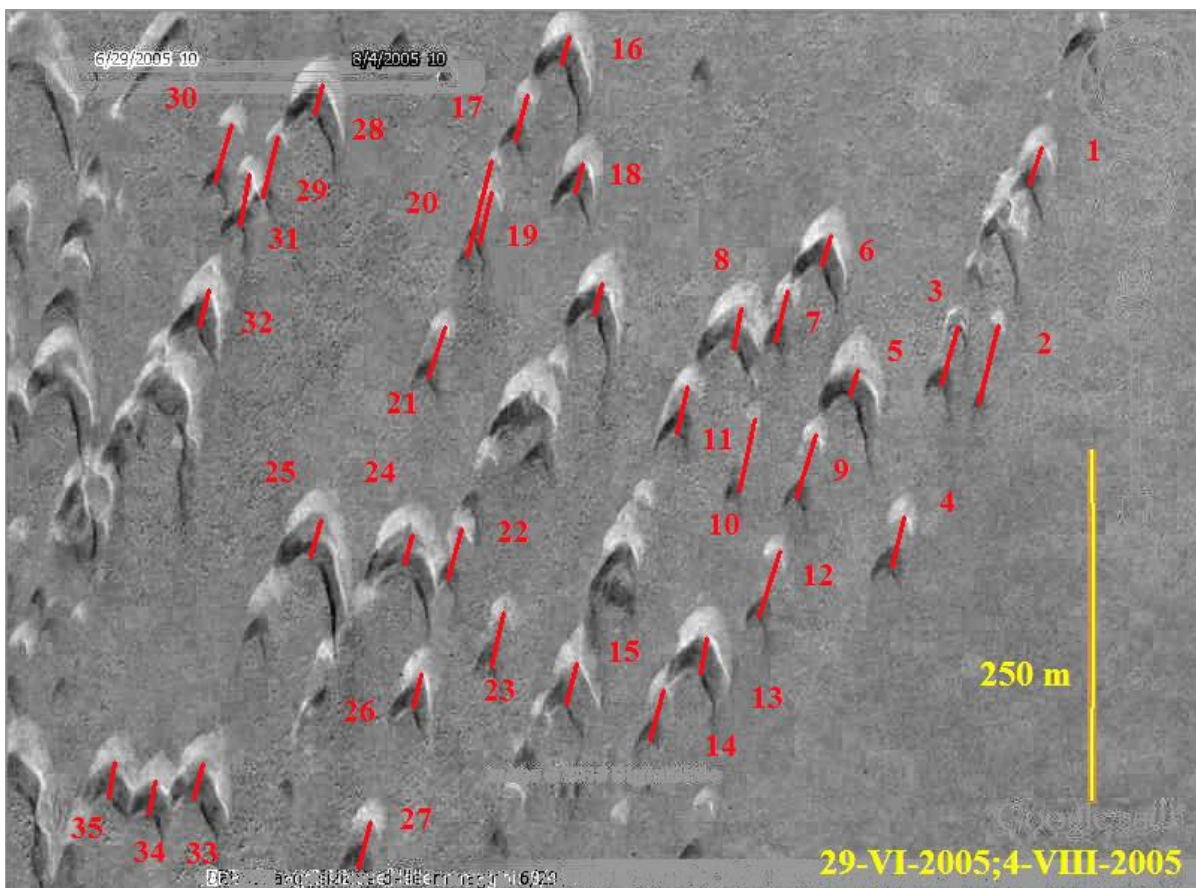


Figure 1: Dunes move, as we can see using the time series of Google Earth. See Ref.25 for more details.

Also the sedimentary patterns of the dunes can be easily studied, by means of satellites [28-30] (see for instance the Figure 2). Moreover, the satellite images also show that the dunes can change their shapes, as it is happening for the barchans of the Laayoune-Sakia El Hamra region and Khenifiss National Park [31,32] (see the Figure 3). Is this a consequence of the Climate Change?



Figure 2: Sedimentary patterns of a dune field in Orinoca Canton, Bolivia. Note the “footprints” of the dunes (see [28]).



Figure 3: Barchans move and can change their shapes (the red circle is the reference point). Note the faint “ghost” shapes (marked in red) of the previous position and shape of a dune (more details in [31,32]). The change in the shape was driven by a variation of the direction of prevailing winds. Is this variation induced by the Climate Change?

The Change Detection among images can be performed by many different approaches. In [33], the images are compared by means of a Radon Transform. Features based on the Radon spectrum are used to cluster dunes of various orientations. The dunes studied are those of the Gobi desert. A GIS-based method for extraction of sand sea encroachment was used for the dunes of the Rigboland Sand Sea, Central Iran [34]. According to the authors, their proposed analysis of the remote sensing images can be an effective tool for the monitoring and prognostication of sand dune movement and sand sea change.

Statistical parameters obtained by satellite images and wind data are used in [35], for the dunes of the Mesr Erg region. In [36], the Ubari Sand Sea (Libyan Fazzan) is studied, by means of image overlay and differencing; the Root Mean Squared Error (RMSE) was used to determine if the mapped dune patterns were significantly different.

Of course, Change Detection is not only applied to satellite images. In [37], a digital image analysis procedure was adapted to extract multispectral data from sequential colour air photos of a Lake Huron sand dune system. UAVs, Unmanned Aerial Vehicles, are also used [38-41]. In [42], by means of GIS techniques, it is the change of the elevation profile of coastal dunes, which is investigated. In fact, highly accurate and densely sampled coastal elevation data can be obtained by means of LIDAR topographic mapping (airborne Light Detection and Ranging). In [43], the coastal dunes of Cape Hatters have been investigated using this technology. In general, we can tell that the study of sand dunes and of other subjects of the Aeolian Science is today receiving a large benefit from the recent advances in Aerial and Information Technologies [44].

To conclude, let us also note that the study of the sand dunes is not limited to Earth. Dunes are also present on Mars and they move [45,46]. Then, the Change Detection can be applied also for these dunes too (Figure 4). Examples were proposed in [47,48].

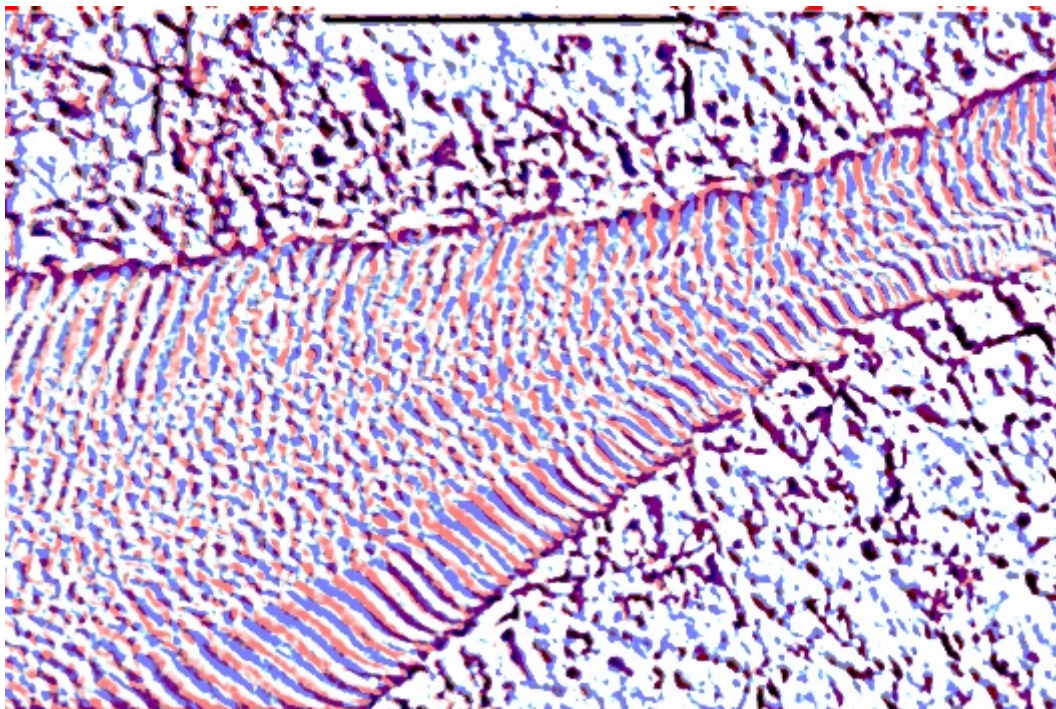


Figure 4: The red and blue pixels are showing the ripples on a dune in the Nili Patera Caldera on Mars, from two images recorded at different time by HiRISE, the High Resolution Imaging Science Experiment (Credit: NASA/JPL-Caltech/Univ. of Arizona/JHU-APL). See [25] for more details.

Mars is a sandy planet. The HiRISE camera on the Mars Reconnaissance Orbiter (MRO) is the powerful tool which is giving us detailed pictures of Martian dunes. On Mars, strong and sustained winds have been considered rare. However, in the case of the Nili Patera dune field, the dunes have unexpectedly high sand fluxes, similar to those we can find in Victoria Valley, Antarctica [49]. This fact induced the conclusion that rates of landscape modification on Mars can exist, similar to those observed on Earth.

References

- [1] Celik, T. (2009). Unsupervised change detection in satellite images using principal component analysis and k-means clustering. *IEEE Geoscience and Remote Sensing Letters*, 6(4), 772-776.
- [2] Pacifici, F., Del Frate, F., Solimini, C., & Emery, W. J. (2007). An innovative neural-net method to detect temporal changes in high-resolution optical satellite imagery. *IEEE Transactions on Geoscience and Remote Sensing*, 45(9), 2940-2952.
- [3] Bruzzone, L., & Prieto, D. F. (2000). Automatic analysis of the difference image for unsupervised change detection. *IEEE Transactions on Geoscience and Remote sensing*, 38(3), 1171-1182.
- [4] Boucher, A., Seto, K. C., & Journel, A. G. (2006). A novel method for mapping land cover changes: Incorporating time and space with geostatistics. *IEEE Transactions on Geoscience and Remote Sensing*, 44(11), 3427-3435.
- [5] Gamba, P., Dell'Acqua, F., & Lisini, G. (2006). Change detection of multitemporal SAR data in urban areas combining feature-based and pixel-based techniques. *IEEE Transactions on Geoscience and Remote Sensing*, 44(10), 2820-2827.
- [6] Leichtle, T., Geiß, C., Wurm, M., Lakes, T., & Taubenböck, H. (2017). Unsupervised change detection in VHR remote sensing imagery—an object-based clustering approach in a dynamic urban environment. *International Journal of Applied Earth Observation and Geoinformation*, 54, 15-27.
- [7] Cao, G., Li, X., & Zhou, L. (2016). Unsupervised change detection in high spatial resolution remote sensing images based on a conditional random field model. *European Journal of Remote Sensing*, 49(1), 225-237.
- [8] Wu, T., Luo, J., Fang, J., Ma, J., & Song, X. (2017). Unsupervised object-based change detection via a Weibull mixture model-based binarization for high-resolution remote sensing images. *IEEE Geoscience and Remote Sensing Letters*, 15(1), 63-67.
- [9] Lv, P., Zhong, Y., Zhao, J., & Zhang, L. (2018). Unsupervised change detection based on hybrid conditional random field model for high spatial resolution remote sensing imagery. *IEEE Transactions on Geoscience and Remote Sensing*, 56(7), 4002-4015.
- [10] Shao, P., Shi, W., He, P., Hao, M., & Zhang, X. (2016). Novel approach to unsupervised change detection based on a robust semi-supervised FCM clustering algorithm. *Remote Sensing*, 8(3), 264.
- [11] Moghimi, A., Mohammadzadeh, A., & Khazai, S. (2017). Integrating thresholding with level set method for unsupervised change detection in multitemporal SAR images. *Canadian Journal of Remote Sensing*, 43(5), 412-431.
- [12] Atasever, U. H., Kesikoglu, M. H., & Ozkan, C. (2016). A new artificial intelligence optimization method for PCA based unsupervised change detection of remote sensing image data. *Neural Network World*, 26(2), 141.
- [13] Touati, R., Mignotte, M., & Dahmane, M. (2019). Multimodal Change Detection in Remote Sensing Images Using an Unsupervised Pixel Pairwise Based Markov Random Field Model. *IEEE Transactions on Image Processing*.

- [14] Dharani, M., & Sreenivasulu, G. (2019). Land use and land cover change detection by using principal component analysis and morphological operations in remote sensing applications. *International Journal of Computers and Applications*, 1-10.
- [15] R. A. Bagnold, *The Physics of Blown Sand and Desert Dunes*, Chapman and Hall, London, 1941
- [16] Durán, O., Schwämmle, V., Lind, P. G., & Herrmann, H. J. (2009). The dune size distribution and scaling relations of barchan dune fields. *Granular Matter*, 11(1), 7-11.
- [17] Kumar, M., Goossens, E., & Goossens, R. (1993). Assessment of sand dune change detection in Rajasthan (Thar) Desert, India. *International Journal of Remote Sensing*, 14(9), 1689-1703.
- [18] Necsoiu, M., Leprince, S., Hooper, D. M., Dinwiddie, C. L., McGinnis, R. N., & Walter, G. R. (2009). Monitoring migration rates of an active subarctic dune field using optical imagery. *Remote Sensing of Environment*, 113(11), 2441-2447.
- [19] Thomas, D. S., Knight, M., & Wiggs, G. F. (2005). Remobilization of southern African desert dune systems by twenty-first century global warming. *Nature*, 435(7046), 1218.
- [20] Redsteer, M. H., Bogle, R. C., & Vogel, J. M. (2011). Monitoring and analysis of sand dune movement and growth on the Navajo Nation, southwestern United States. US Department of the Interior, US Geological Survey.
- [21] Boulghobra, N. (2015). Sand encroachment in the Saharan Algeria; the not declared disaster-Case study: In-Salah region in the Tidikelt. *Planet@ Risk*, 3(1). Available at <https://planet-risk.org/index.php/pr/article/view/172>
- [22] Boulghobra, N. (2016). Climatic data and satellite imagery for assessing the aeolian sand deposit and barchan migration, as a major risk sources in the region of In-Salah (Central Algerian Sahara). *Arabian Journal of Geosciences*, 9(6), 450.
- [23] Sparavigna, A. C. (2013). A Study of Moving Sand Dunes by Means of Satellite Images (August 2, 2013). *International Journal of Sciences*, Volume 2, Issue 8, pp.33-42. DOI: 10.18483/ijSci.229
- [24] Sparavigna, A. C. (2013). Moving dunes on the Google Earth. arXiv preprint arXiv:1301.1290.
- [25] Sparavigna, A. C. (2013). The GNU Image Manipulation Program Applied to Study the Sand Dunes. *International Journal of Sciences*, Volume 2, Issue 9, pp.1-8. DOI: 10.18483/ijSci.289
- [26] Sparavigna, A. C. (2013). A Case Study of Moving Sand Dunes: The Barchans of the Kharga Oasis, *International Journal of Sciences* Volume 2, Issue 8, pp. 95-97. DOI: 10.18483/ijSci.241
- [27] Sparavigna, A. C. (2017). Remote Roman Fortifications: The Forts of the Kharga Oasis (July 2, 2017). *PHILICA*, Article N. 1062, 2017. Available at SSRN: <https://ssrn.com/abstract=3082140>
- [28] Sparavigna, A. C. (2016). Sedimentary Patterns of Moving Sand Dunes in Orinoca District, Bolivia. *Philica*, Article number 614. Available <https://hal.archives-ouvertes.fr/hal-01329972>
- [29] Sparavigna, A. C. (2016). Analysis of the Motion of Some Brazilian Coastal Dunes, *International Journal of Sciences*, Volume 5, Issue 1, pp. 22-31. DOI: 10.18483/ijSci.905
- [30] Tsoar, H., Levin, N., Porat, N., Maia, L. P., Herrmann, H. J., Tatum, S. H., & Claudino-Sales, V. (2009). The effect of climate change on the mobility and stability of coastal sand dunes in Ceará State (NE Brazil). *Quaternary Research*, 71(2), 217-226.
- [31] Sparavigna, A. C. (2017). Dunes changing their shape: The case of the dunes of the Laayoune-Sakia El Hamra region. *PHILICA* Article number 941, 28 January 2017. Available <https://hal.archives-ouvertes.fr/hal-01448702>
- [32] Sparavigna, A. C. (2017). Sand Dunes of Khenifiss National Park of Morocco. *PHILICA* Article number 942, 30 January 2017. Available <https://hal.archives-ouvertes.fr/hal-01455721>
-

- [33] Varma, S., Shah, V., Banerjee, B., & Buddhiraju, K. M. (2014). Change detection of desert sand dunes: a remote sensing approach. *Advances in remote sensing*, 3, 10-22.
- [34] Ahmady-Birgani, H., McQueen, K. G., Moeinaddini, M., & Naseri, H. (2017). Sand dune encroachment and desertification processes of the Rigboland Sand Sea, Central Iran. *Scientific reports*, 7(1), 1523.
- [35] Maghsoudi, M., Navidfar, A., & Mohammadi, A. (2017). The sand dunes migration patterns in Mesr Erg region using satellite imagery analysis and wind data. *Natural Environment Change*, 3(1), 33-43.
- [36] Els, A., Merlo, S., & Knight, J. (2015). Comparison of two Satellite Imaging Platforms for evaluating sand dune migration in the Ubari Sand Sea (Libyan Fazzan). *The International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences*, 40(7), 1375.
- [37] Dech, J. P., Maun, M. A., & Pazner, M. I. (2005). Blowout dynamics on Lake Huron sand dunes: analysis of digital multispectral data from colour air photos. *Catena*, 60(2), 165-180.
- [38] Laporte-Fauret, Q., Marieu, V., Castelle, B., Michalet, R., Bujan, S., & Rosebery, D. (2019). Low-Cost UAV for high-resolution and large-scale coastal dune change monitoring using photogrammetry. *Journal of Marine Science and Engineering*, 7(3), 63.
- [39] Taddia, Y., Corbau, C., Zambello, E., & Pellegrinelli, A. (2019). UAVs for structure-from-motion coastal monitoring: a case study to assess the evolution of embryo dunes over a two-year time frame in the Po River Delta, Italy. *Sensors*, 19(7), 1717.
- [40] Pagán, J. I., Bañón, L., López, I., Bañón, C., & Aragonés, L. (2019). Monitoring the dune-beach system of Guardamar del Segura (Spain) using UAV, SfM and GIS techniques. *Science of The Total Environment*. In print.
- [41] Grottoli, E., Ciavola, P., Duo, E., & Ninfo, A. (2019). UAV application for monitoring the annual geomorphic evolution of a coastal dune in Punta Marina (Italy). *Earth observation advancements in a changing world*, Edited by Chirici G. and Gianinetta M., AIT Series Trends in earth observation. Volume 1. p.103.
- [42] Andrews, B., Gares, P. A., & Colby, J. D. (2002). Techniques for GIS modeling of coastal dunes. *Geomorphology*, 48(1-3), 289-308.
- [42] Woolard, J. W., & Colby, J. D. (2002). Spatial characterization, resolution, and volumetric change of coastal dunes using airborne LIDAR: Cape Hatteras, North Carolina. *Geomorphology*, 48(1-3), 269-287.
- [44] Scuderi, L. A., Weissmann, G. S., Hartley, A. J., Yang, X., & Lancaster, N. (2017). Application of database approaches to the study of Earth's aeolian environments: community needs and goals. *Aeolian research*, 27, 79-109.
- [45] Bourke, M. C., Edgett, K. S., & Cantor, B. A. (2008). Recent aeolian dune change on Mars. *Geomorphology*, 94(1-2), 247-255.
- [46] Cardinale, M., Silvestro, S., Vaz, D. A., Michaels, T., Bourke, M. C., Komatsu, G., & Marinangeli, L. (2016). Present-day aeolian activity in Herschel Crater, Mars. *Icarus*, 265, 139-148.
- [47] Sparavigna, A. C. (2013). Sand Dunes Moving in the Nili Patera Caldera on Mars (August 2, 2013). *International Journal of Sciences*, Volume 2, Issue 8, pp.105-108. Available at SSRN: <https://ssrn.com/abstract=2572765>
- [48] Sparavigna, A. C. (2013). Edge-Detection Applied to Moving Sand Dunes on Mars. *International Journal of Sciences*, Volume 2, Issue 8, pp. 102-104. - ISSN 2305-3925 [ijsciences](http://ijsciences.com)
- [49] Bridges, N. T., Ayoub, F., Avouac, J. P., Leprince, S., Lucas, A., & Mattson, S. (2012). Earth-like sand fluxes on Mars. *Nature*, 485(7398), 339.