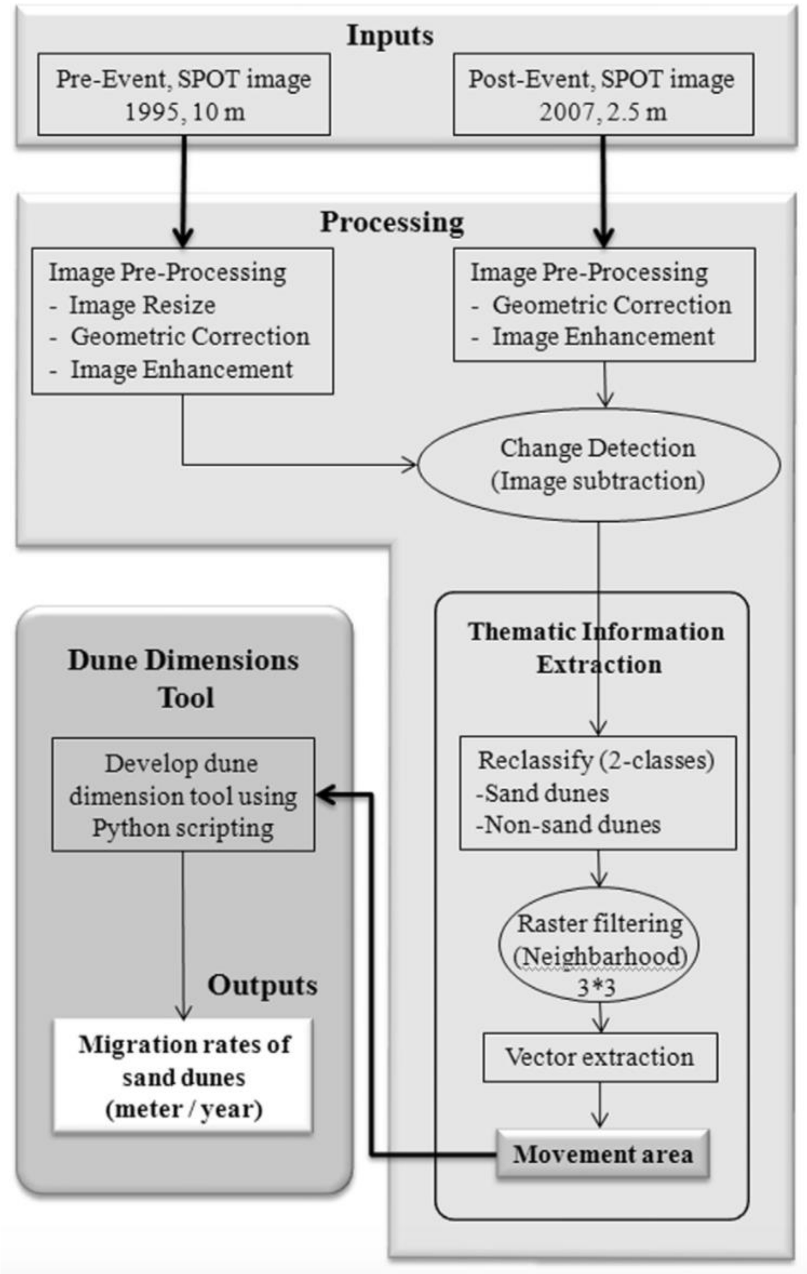
Technologies and Methods Used for Dune Detection from Remote Sensing Data

1. "A new GIS-based model for automated extraction of Sand Dune encroachment case study: Dakhla Oases, western desert of Egypt ", M. Ghadiry, A. Shalaby, B. Koch.

Area of study: Dakhla Oases, located in the western desert of Egypt, between latitudes 25° 31^{0} and 25° 41^{0} 30^{00} N, and 28° 46^{0} 30^{00} and 29° 2^{0} E. The study region covers an area of approximately 500 km^2.

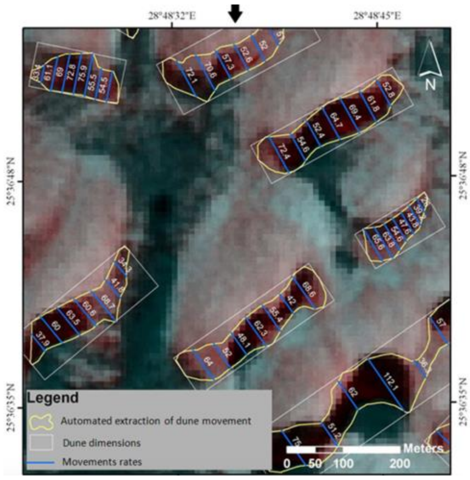
Image source: SPOT images (commercial high-resolution optical imaging), 1995 and 2007 (1995, 10 m & 2007, 2.5 m).



Methodology:

Geometric correction: Accurate per-pixel registration of multi-temporal remote sensing data is essential for change detection (image subtraction) since the potential exists for registration errors to be interpreted as land-cover and land-use change, leading to an overestimation of actual change. In this study, 25 ground control points obtained from a digital topographic map at a scale of 1:10,000 were used.

Pixel resizing: The pixel size of SPOT-5 image of 2007 has a pixel size of 2.5 m while the pixel size of 1995 SPOT-3 image is 10 m. Therefore, neighbourhood statistic function was used to resize the pixel size of 1995 SPOT image from 10 to 2.5m.



Creation of Dune Dimension Tool (DLL) using Python: Vector data that represent the sand dune movement were processed in Arc GIS 9.3 and exported as an ASCII raster grid as an input to Python. Using Python script a minimum boundary rectangle around each sand dune movement polygon was created. A number of transect lines were created inside the rectangle, to measure the minimum and maximum movements of each dune.

ModelBuilder tool development: The ModelBuilder was created in ArcToolbox to enable the developer to adapt the existing tools according to the demand and situation. The geo-processing tasks were carried out in a step-wise and integrated manner using a customised tool under ModelBuilder. The Model- Builder uses each function to create designated output. The output of each function is the input for another function.

2. “Retrieving sand dune movements using sub-pixel correlation of multi-temporal optical remote sensing imagery, northwest Sinai Peninsula, Egypt”, ElSayed Hermas, Sebastien Leprince, Islam Abou El-Magd.

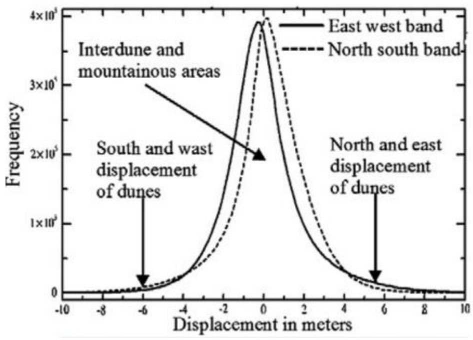
Area of study: northwestern corner of the Sinai Peninsula, Egypt.

Image source: two SPOT 4 L1A Panchromatic images at 10 m ground resolution. The master image was acquired in May 2007, and the slave image in January 2008.

Methodology:

Preprocessing: ortho-rectification (The tie points were selected at the intersection between road and stream networks available in the study).

COSI-Corr Fourier correlation engine: Coregistration of Optically Sensed Images and Correlation, It is a software package developed in IDL (Interactive Data Language), and integrated under the user friendly interface ENVI (Environment for Visualizing Images), by ITT. COSI-Corr is provided free of charges for academic and research purposes. The SW was used to correlate the first image (May 2007) with the second image (January 2008). The statistics of the filtered correlation image indicated a Gaussian distribution:



3. “Comparison of Two Satellite Imaging Platforms for Evaluating Sand Dune Migration in the Ubari Sand Sea (Libyan Fazzan)”, A. Els, S. Merlo, J. Knight.

Area of study: Ubari Sand Sea located within the Libyan Fazzan in the Central Sahara, and covers an area of approximately 61,000 km^2.

Image source: two Landsat tiles and three Worldview 2 strips (Acquisition date for both: September, 2014).

Methodology:

The following ENVI v5.1 tools were used:

- FLAASH Atmospheric Correction Model for atmospherically correction
- "Seamless Mosaic"
- The Worldview 2 strips' DN values were converted to reflectance with the use of the "Radiometric Calibration".

A range of classification modules was explored:

- A K-Means unsupervised classification was performed, on both Landsat and Worldview; in order to determine if the different dune features (including crest, slopes and inter-dune area) can be identified based on spectral information only. The classification was run using 11 classes to cater for the other features (lakes, settlements and vegetation) present in the classification, and to exclude these from the dune features.
- maximum likelihood and minimum distance were also performed on both images. The training samples were developed based on the higher spatial resolution Worldview imagery overlain over Distance SRTM (in order to ease the identification of the crest of the dune). A total of 11 classes were identified.

Similar methodology was used in "Remote sensing and GIS for mapping and monitoring land coverage land-use changes in the Northwestern coastal zone of Egypt" Adel Shalaby, Ryutaro Tateishi.

4. "A GIS add-in for automated measurement of sand dune migration using LiDAR-derived multi-temporal and high-resolution digital elevation models", Jisheng Xia and Pinliang Dong

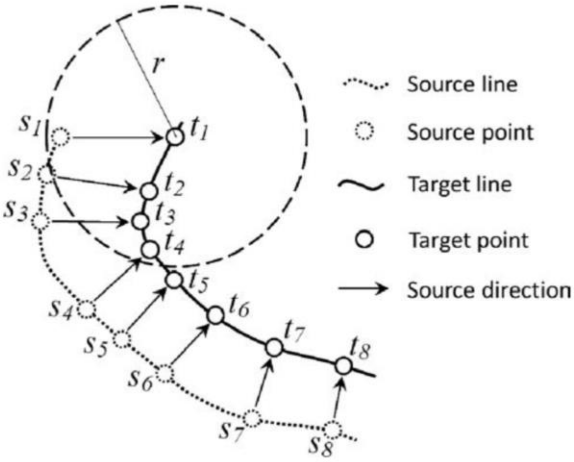
Area of study: a 2.4 km by 9 km study area in the White Sands dune field in New Mexico (USA).

Image source: 1-m-resolution DEMs derived from LiDAR data acquired on 24 January 2009 and 6 June 2010.

Methodology:

An ArcGIS add-in was implemented using Python.

Sand avalanching and slumping events caused by gravity occur in the inclination direction of the dune slip face. This observation is used as the theoretical foundation of the PSTP method. Although it is difficult or impossible to monitor every step of dune movement, multi-temporal data sets such as high-resolution DEMs derived from LiDAR data can be used as snapshots for studying sand dune migration. In the PSTP method, the angle of repose (AOR) is used as a sensitive indicator of dune migration.



Faces are extracted from DEMs based on AOR values, and the centrelines of slip faces are obtained by vectorization. For any random target point t_n on a target line, a search radius r is used to search for the nearest source point s_n on the source line. If no source point is found, the target point is deleted; if a source point is found, the direction of the source point relative to the target point is called source direction, which is statistically related to the prevailing wind direction.

The source direction is further compared with the orientation of the line segment on the source line to validate the target point. If the source direction is not perpendicular to the line segment that contains the source point, the target point is deleted. For example, the source direction from s_1 to t_1 in Figure 1 is not perpendicular to the line segment that contains s_1, and so t_1 is deleted.

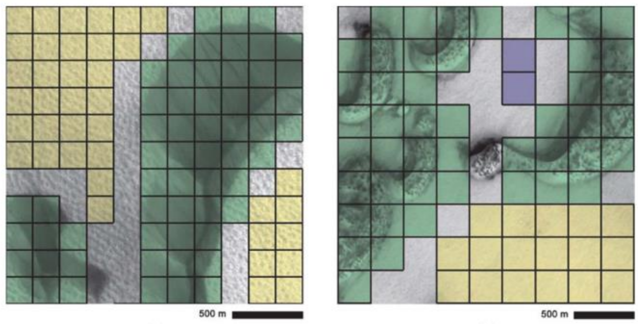
5. “Automated Detection of Martian Dune Fields”, Lourenço Bandeira, Jorge S. Marques, José Saraiva, and Pedro Pina.

Area of study: a 2.4 km by 9 km study area in the White Sands dune field in New Mexico (USA).

Image source: A set of 78 remotely sensed images of the surface of Mars captured by the Mars Orbiter Camera (MOC) (at a narrow-angle mode) of the Mars Global Surveyor probe. Those images are from different locations on the planet, cover a total area of about 5032 km2, and are representative of the diversity of barchan and barchanoid dunes on Mars. They are single-band images with 256 gray levels and have a spatial resolution between 1.61 and 6.80 m/pixel. For each image, aground truth information was constructed by manually delineating the “dune”, “not-dune” areas.

Methodology: In order to perform classification gradient-based features were selected, which the authors consider to be among the most appropriate to detect the patterns exhibited by sand dunes.

Boosting and SVM classifiers were used to detect dune areas, both resulting in high performance.



(a) (b)

Fig. 4. Details of correct detection in images differently zoomed (each cell is 40 pixels wide). (a) E03-02056. (b) R18-01147 (TP in green, TN in yellow, and FP in blue; image credits: MSSS/NASA/JPL).

6. “Classification of Land Use on Sand-Dune Topography by Object-Based Analysis, Digital Photogrammetry, and GIS Analysis in the Horqin Sandy Land, China.” Takafumi Miyasaka, Toshiya Okuro, Xueyong Zhao and Kazuhiko Takeuchi.

Area of study: central part of Naiman County, Inner Mongolia of China.

Image source: remote-sensing images from two sensors installed on ALOS: PRISM, with 2.5 m spatial resolution, and AVNIR-2, with 10 m spatial resolution.

Methodology:

eCognition 4.0 and ArcGIS 9.1.

1. Object-Based Classification of Preliminary Land-Use Types
Object-based classification is characterized by an image segmentation process. This process creates image objects by merging pixels, and those objects are used as classification units instead of single pixels. Not only spectral, but also texture, shape, and topological information can be calculated for each object and utilized for classification.
2. Generation of Digital Surface Model (DSM)

3. GIS-Based Classification of Sand-Dune Topography
Classification of the topography with the DSM by GIS analysis into lowlands, flat sandy lands, and sand dunes. A slope image was then generated from the DSM and was divided into flat and slope areas using an empirically determined threshold of slope angle (2 degrees). Dune crests, however, needed to be grouped in sand dunes from the perspective of their topographic characteristics.

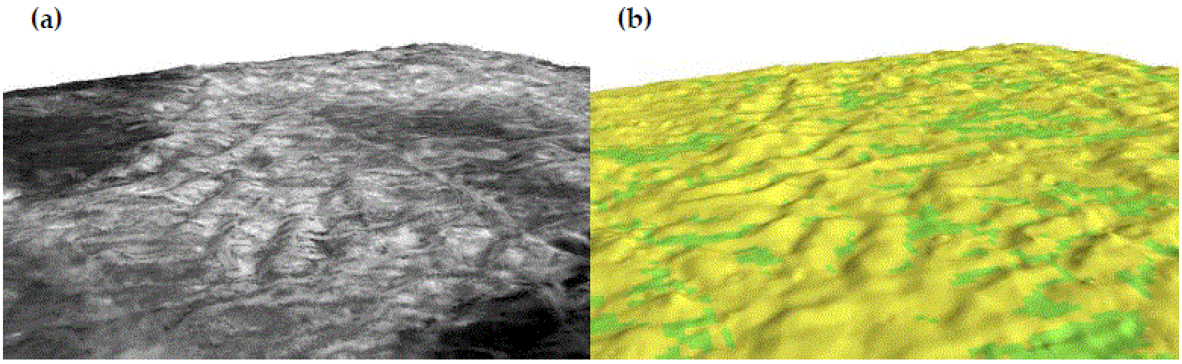


Fig. 2 Subset bird's-eye view images of the generated digital surface model (DSM) with (**a**) the summer PRISM data and (**b**) topography classification map (green is flat sandy lands; yellow is sand dunes). The height in images is exaggerated threefold to facilitate visualization.

7. "Analysis of Desert Sand Dune Migration Patterns from Landsat Image Time Series for The Southern California Desert" Weigand J., Potter C.

Area of study: the Palen Dune complex located east of Joshua Tree National Park in the western Sonoran Desert of southern California

Image source: Landsat Hematic Mapper (TM) 5 and 8 image.

Methodology:

1. Image data calibration and atmosphere correction (ENVI 5.0)
2. Bi-temporal layer stacking and RGB-Clustering
The approach of a Bi-Temporal Layer Stacking (BTLS) has its origin from Write Function Memory Insertion (WFMI) methods first presented by Jensen. WFMI is a visual change detection technique, where single bands from multi-temporal satellite images are displayed in specific colours (typically red, green and blue-RGB. WFMI is applied to multi-temporal Landsat images to detect the dynamics of sand dune movement.

By adjusting the RGB classes during clustering, the pixels representing sand movement were matched to Landsat BTLS maps. The new raster layer from RGB-clustering was used to estimate the migration rates of dunes.

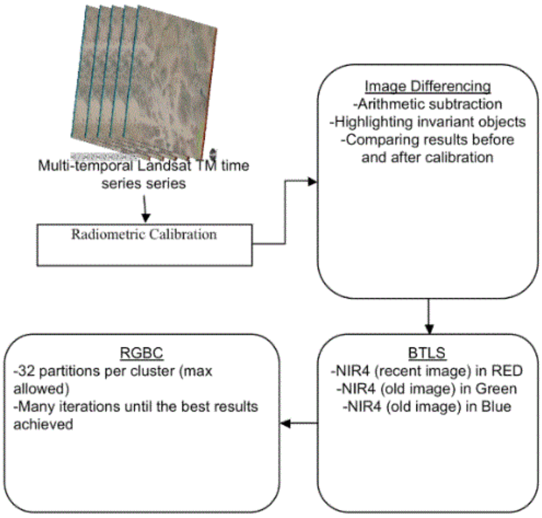


Figure 4: Processing scheme for sand dune movement mapping with Landsat images.

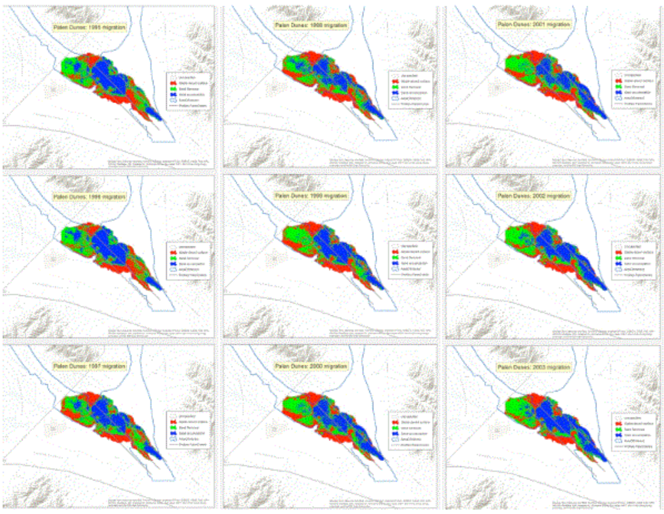


Figure 11a: Time-series maps of Palen sand dune migration, generated from Landsat RGB clustering results.