

# CLASSIFICATION OF DUNE DYNAMICS FROM SAR IMAGES : CASE STUDY OF THE BARCHANS OF NORTH-EAST OF NOUADHIBOU, MAURITANIA (1995-2010)

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## ABSTRACT

The barchan dynamics threatens the existence of certain local infrastructures such as roads, airports and villages. The objective of this study is to produce a quantitative mobility analysis of a barchan field located northeast of the city of Nouadhibou (Mauritania). The diachronic analysis of SAR images acquired by the ERS-1/2 and ENVISAT satellites over a 15-year period (May 1995 to October 2010) led to identification of more than 900 barchans and allowed for studying the evolution of the morphology of the dune field. This approach was coupled with analysis of wind data from the ECMWF Interim Reanalysis data base for 1983-2012. The barchans are clearly identifiable. They appear as areas of low-grade rough patches with minimal backscatter against a rougher plane with high backscatter. The barchans are identified by image filtering and segmentation. Their 2D morphological is acquired by contouring. Finally, their morphometric characteristics are obtained by contour analysis. A series of indicators was derived: length, width, perimeter, surface, center of gravity, compactness index, displacement speed, etc. Various relationships already observed *in situ* were identified and confirmed: Length = f (Span) Width = f (length) Displacement speed = f (length) and so on. SSW displacement of barchan centers of gravity (mean = 190.4°) due to trade winds (mean = 189.5°) is clearly highlighted. The time necessary for a barchan to traverse its own length can be determined on the basis of distance covered and speed. This time can vary from 3 months to 18 years, depending on the size of dune. The modal value is six months. SAR imaging allows for detecting and pinpointing minor dune movement over short periods of time. Multi-temporal analysis obtained by amplitude images demonstrated the possibility of: (i) mapping the distribution of mobile sand dunes; (ii) determining speed and direction of sand remobilization; (iii) identifying areas facing the greatest threat of silting. Such analysis provides a useful method for addressing silting and sand

remobilization. It further allows for understanding the evolution of silting as well as the degree of environmental degradation over various periods.

## KEYWORDS

Barchan; dynamic; radar imagery; SAR; ERS-1/2; ENVISAT; Mauritania.

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## RÉSUMÉ

*Classification de la dynamique des dunes à partir de l'imagerie radar RSO : exemple des barkhanes du nord-est de Nouadhibou, Mauritanie (1995-2010).* La dynamique des dunes (barkhanes) en Mauritanie met en danger les infrastructures comme les villes et villages, les routes ou les aéroports. L'objectif de cette étude est de procéder à une analyse quantitative de la mobilité d'un champ de barkhanes situé au nord-est de la ville de Nouadhibou. L'analyse diachronique d'une série d'images radar RSO acquises par les satellites ERS-1 et ENVISAT entre mai 1995 et octobre 2010 a permis l'identification de plus de 900 barkhanes et le suivi de la mobilité du champ de dunes. Cette analyse a été couplée avec celle des champs de vents obtenus par la base de données ECMWF Interim Reanalysis de 1983 à 2012. Les barkhanes sont clairement identifiées sur l'imagerie; elles apparaissent comme des taches avec une rétrodiffusion minimale. L'identification est effectuée par filtrage d'image et segmentation ; les caractéristiques morphométriques sont obtenues par analyse de contour. Une série d'indicateurs a été dérivée : longueur, largeur, périmètre, surface, centre de gravité, indice de compacité, vitesse de déplacement, etc. Différentes relations déjà observées *in situ* ont été identifiées et confirmées: longueur = f (portée), largeur = f (longueur), vitesse de déplacement = f (longueur) et ainsi de suite. Le déplacement sud/sud-ouest des centres de gravité des barkhanes (moyenne = 190,4°) dû aux alizés (moyenne = 189,5°) est clairement mis en évidence.

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Le temps nécessaire à une barkhane pour parcourir sa propre longueur peut être déterminé en fonction de la distance parcourue et de la vitesse. Cette durée peut varier de 3 mois à 18 ans, selon la taille de la dune. La valeur modale est de six mois. L'imagerie RSO permet de détecter et de localiser les mouvements mineurs des dunes sur de courtes périodes. L'analyse diachronique des images d'amplitude a démontré la possibilité de : (i) cartographier la distribution des dunes de sable mobiles ; (ii) déterminer la vitesse et la direction de la remobilisation du sable ; (iii) identifier les zones les plus menacées d'ensablement. Une telle analyse permet en outre de comprendre l'évolution de l'ensablement ainsi que le degré de dégradation de l'environnement sur différentes périodes.

## MOTS-CLÉS

Barkhane ; dynamique ; imagerie radar ; ROS ; ERS-1/2 ; ENVISAT, Mauritanie.

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## 1. INTRODUCTION

The crescent-shaped barchan dunes lie in a windward direction and experience minimal sand arrival. They migrate on a hard substrate in the context unidirectional, or at least seasonally unidirectional, winds. The wind pushes the sand upslope to the top of the dune where it then rolls down onto the leeward side. This mechanism displaces the dune. Northeast of the city of Nouadhibou, straddling the border between Mauritania and Western Sahara, landscapes are characterized by the presence of vast areas of sandy sediment locally organized as barchan fields. Reactivated dunes threaten the existence of farmland, villages and roads. Quantifying the dynamics of barchan fields provides valuable information for management of local resources.

As opposed to platforms, which operate according to visibility, radar images SAR (Synthetic Aperture Radar) have the advantage of being available at all times and under all conditions, day or night and regardless of cloud cover. Amplitude images have been used in a variety of fields such as: mapping urban damage due to natural or industrial disasters; recording changes in coastal boundaries (Ba *et al.*, 2007); monitoring deforestation; monitoring ice melt; assuring lithology in a polar environment (Budkewitsch *et al.*, 1996a; 1996b; 1997); geological mapping (Singhroy and Saint-Jean, 1999); structural mapping (Wade *et al.*, 2001); crop

classification (Bruniquel and Lopes, 1994; Lopes and Nery, 1997); pattern recognition; spatial planning (Rudant *et al.*, 1996); detection and characterization of oil spills in marine settings (Mercier *et al.*, 2004); determination of soil surface moisture in arid and semi-arid areas (Troufléau *et al.*, 1994); detection of mesoscale phenomena in oceanography (Laborde and Deveaux, 1996); detection and analysis of landscape changes in the sub-Carpathian region of Buzau, Romania (Hachemi *et al.*, 2009; 2010); monitoring of hydrological events (floods, floods, etc.); mapping the degree of flood extension of the in the Piedmont region of Italy, November 1994 (Brivio *et al.*, 2002); identification of optimal features for monitoring urban flooding (McMillan *et al.*, 2006; 2008); study, monitoring and mapping of the dynamics of the Danube island system (Hachemi *et al.*, in press; Hachemi *et al.*, submitted). In the course of geological exploration in arid zones, Baghdadi *et al.* (2005) demonstrated that band "L" or "C" SAR imagery show greater potential for mapping than do ASTER optical images, especially for linear structures, such as dikes, and circular structures.

Desert and sub-arid environments represent a particularly favorable context for tracking linear studies of landscape radiometry and geometry modifications. SAR archive data based on the use of ERS-1, ERS-2 and ENVISAT satellites over the last three decades has been particularly useful and especially in the analysis of the mobility of the Barkhan field in this region from Mauritania (Hachemi and Thomas, 2013). The purpose of this study is: (i) to show that SAR imagery can detect and locate small movements of dunes over a short period of time; (iii) to classify the barchans in relation to their movement speeds; (iii) and also to emphasize the importance of SAR radar imagery as a methodology and processing for quantitative analysis in monitoring the dynamics of barchans and dunes in general.

## 2. STUDY AREA

### 2.1. Barchans

A barchan is the crescent-shaped dunes lie in a windward direction and emerge in a context of minimal sand arrival. The dunes migrate most often on a "hard" substrate in a context of unidirectional, or at least seasonally unidirectional, winds. The wind rolls the sand upslope to the top of the dune where it rolls downwards onto the leeward side. This phenomenon produces migration of the dune. **Figure 1** indicates the morphology and movement of a barchan.