

# APPLICATION OF MOMS-02 DATA FOR ANALYSIS OF SAND DUNE FORMS AND THEIR DEVELOPMENT

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## ABSTRACT

The main objective of the reported investigations was to evaluate the MOMS-02 data for the geomorphological studies of the sand desert areas and to indicate the advantages of these data in comparison with other remotely sensed data. In introduction Author gives general information regarding sand desert areas with particular attention paid to the Libyan Sahara. Libyan Sahara represents a large variety of dune forms and patterns, which appear in the huge Libyan sand seas. The performed analysis was based on the MOMS-02 images registered from orbits 75 and 91 over the northern Libyan sand seas: i.e. the middle part of the Great Sand Sea and over the northern part of Ramlat Zaltan called Ramlat Zaqqut. The results on performed analysis indicated large advantages of the high resolution MOMS-02 data registered in channel 5. These data allowed to detect and to analyse the small dune forms such as crescentic dunes, crescentic chains, barchans and star dunes as well as the giant ripples called zibars. The performed analysis enabled to define the relationship between the particular dune forms and other climatic, topographic and geologic factors controlling their development.

## 1. INTRODUCTION

The continental deserts, which cover one-fifth of land area of the Earth, belong to the most unknown part of our globe. Sahara is one of the largest climatic desert of the world which fills almost the east-west oriented northern part of Africa. The Libyan Sahara which constitute the eastern part of Sahara, belongs to the super arid desert and occupies more than 90 percent of Libyan territory. The Libyan sand seas, which cover more than 300 000 sq km., belong to the most unknown part of Sahara and represent a large variety of conspicuous dune forms and patterns.

The remote sensing technologies provide a very useful tool for the complex investigations of sand desert areas. The medium resolution satellite data are very helpful in the macro-scale studies of sand seas, while for the meso- and micro-scale studies the high resolution remote sensing data are required. In geomorphological studies, the highest importance is given to small dune forms such as barchans, linear dunes, crescentic chains and zibars, which express the contemporary trends in dune formation and development. In this context, the MOMS-02 data constitute the most useful material.

## 2. MOMS-02 DATA OVER LIBYAN SAHARA

MOMS-02 constitutes the second generation of MOMS system, which was successfully flown on the board of the second German Spacelab Mission D2 from 26 April 1993 to 6 May 1993. MOMS-02 combines a high resolution three-channel stereo-module with a four-channel multispectral unit. MOMS-02 provides along-track stereo capability, to be operated in panchromatic mode, alone or in various combinations with spectral channels. The system was designed both for the thematic mapping on the basis of multispectral data (channels 1, 2, 3 and 4) and for photogrammetric mapping on the basis of the stereo images registered by this system (channels 5, 6 and 7).

MOMS-02 multispectral system consists of four sensors working in the following spectral bands: channel 1: 449-511

nm, channel 2: 532-576 nm, channel 3: 645-677 nm and channel 4: 772-815 nm. The ground resolution of the multispectral data acquired from the altitude of 300 km is ca 13.5 m and the ground swath of imagery is ca 78 km.

The stereo-system works along the orbit track. In the stereo-mode, one image (channel 5) is recorded at nadir orientation, with the ground resolution of 4.5 m, while two others (channels 6 and 7) are taken at an angle of  $\pm 21.4^\circ$  with a resolution of 13.5 m. The swath width of high resolution imagery is 37 km. The stereo-channels cover the panchromatic region between 512 and 765 nm.

During the MOMS-02 mission images were acquired only over the northern part of Libya. The images were recorded from orbits 13, 60, 75 and 91. There are four images, recorded from orbit 13, in multispectral mode 2, which cover the middle part of the Great Sand Sea but unfortunately these images are partially cloud covered. Twelve scenes from orbit 75 were recorded in stereo mode 1, from which scenes 14 and 15 were registered over the Great Sand Sea. The images taken from orbit 60 and 75 were acquired in mode 1/30°. The images from these orbits have been taken over the northern part of Ramlat Zaltan and the middle part of the Great Sand Sea.

For the evaluation of MOMS-02 data for sand desert investigations the images recorded from orbits 75 and 91 were selected. Scene 14, acquired from orbit 75 in mode 1, covers the central part of the Great Sand Sea, whereas scenes 22 and 23 recorded from orbit 91 in mode 1/30° were acquired over the northern part of Ramlat Zaltan. All the scenes were registered from the Space shuttle orbit altitude of 303 km. For scene 14, the sun elevation was 32° and sun azimuth 89°, and for scenes 22 and 23, 28° and 88° respectively.

## 3. GOAL AND SCOPE OF INVESTIGATIONS

The main goal of the performed investigations was to evaluate the MOMS-02 data recorded in different modes in relation to the specific requirements of sand desert morphology. The investigations were focused on:

- determination of the relationships between the geometric resolution of MOMS-02 data and the dimensions of dune forms,
- evaluation of the stereoscopic capability of MOMS-02 stereo-images in the studies of dune morphometry,
- determination of the relationship between the dune forms and factors controlling their formation and development.

#### 4. APPLICATION OF MOMS-02 DATA FOR ANALYSIS OF SAND DESERT MORPHOLOGY

The selected scenes have been digitally processed on the Intergraph MicroStation and the processed images were analysed on the monitor screen. In the case of scene 14, recorded in mode 1, over the Great Sand Sea, the main objective was to evaluate and to compare the data recorded in the high resolution channel 5 (4.5 m) with the images taken in channels 6 and 7 which have a resolution of 13.5 m. The images from high resolution channel 5 and one of the off-nadir channels 6 or 7, were simultaneously projected on the monitor screen at the same scale. The results of the processing and enhancement indicated that the maximum scale on the monitor, with good visibility and interpretability of sand desert forms is ca 1:8,000 for the images recorded in channel 5 and 1:16,000 for the images acquired in channels 6 and 7. The images presented on the screen at the smaller scale permit to analyse the general dune forms and trends, as in the case of the Landsat data. On the images monitored at larger scales, small dune forms as well as zibars can be detected in interdune areas. Owing to the high resolution, the possibility of detection of the small simple or composite dune forms exists. In this respect the MOMS-02 data are more advantageous than other sources of satellite remote sensing data.

The analysed scene 14 overlays a terrain swath ca 37 km wide (NS) and ca 110 km long (WE). The images recorded in channels 6 and 7 cover the same terrain. The images registered in channel 5 consist of 3 sub-scenes, described as a, b and c. After geometric matching, these three sub-scenes correspond with the same part of terrain surface as the images from channels 6 and 7. The longer axis of image strip extends almost W-E direction, from the boundary between As Sarir and the Great Sand Sea up to the eastern boundary of sand sea. The different sand dune forms appearing in this part of sand sea are easily discerned in this scene. On the western border, linear dunes and their components represented by very open crescentic dunes are clearly visible. That part of image which covers the central part of the sand sea, where two trends of dunes can be distinguished, is very instructive. On the image, presented on the monitor screen at smaller scale, only the larger dune forms representing subdued sandridges, are visible, but after enlargement, the contemporary dune trends, represented by linear dunes, can also be detected. These linear dunes are developed in the bi-directional wind regime which governs this part of sand sea. This is very spectacular part of the Great Sand Sea, in which the transition process, from one dune form to another, can be observed. Zibars covering the interdune areas can also be detected, thus indicating the strongest winds.

In the northern part of Ramlat Zaltan and particularly in Ramlat Zaqqut, the MOMS-02 images recorded on scenes 22 and 23 were investigated. These focused on the evaluation of the interpretability of the different dune forms which appear in this area (mainly star dunes, crescentic chains and linear dunes), in comparison with the Metric Camera photographs

and on the evaluation of the stereoscopic capability of the stereo mode of MOMS-02 system.

The MOMS-02 data were transformed onto the Metric Camera space photograph No.158 from 1983, which was converted to the digital form on the photogrammetric scanner PhotoScan PS-1. The data registered in the high resolution channel 5 led to determine the small linear dunes and crescentic chains as well as very well displayed zibars. The analysis of these data led to the establishment of the relationship between dune forms and zibars and their relationship to the wind regime in this region. The application of stereo-images led to the establishment of the relationship of the linear dunes to terrain topography and their preferential development along small terrain depressions. The trend of linear dunes thus recognized is evidently determined by terrain topography; dune trends are obviously tailored and adjusted to terrain topography. Such trends can also be related to the secondary surface winds affected by terrain topography. Composite linear dunes, formed by connected, very open, crescentic dunes were also detected from these high resolution data.

The most spectacular dune forms which are present in the region of Ramlat Zaqqut are so called star dunes. Owing to the high resolution and stereoscopic capability of the MOMS-02 images, it was possible to study different types of star dunes: single star dunes, twin-star dunes and chains of star dunes, their connection with other forms and their relationship to the terrain topography.

#### 5. COMPARATIVE ANALYSIS OF DUNE FORMS REGISTERED BY METRIC CAMERA IN 1983 AND MOMS-02 DATA FROM 1993

The space photograph No 158, taken by Metric Camera on 2 December 1983 and the scene 23 acquired by MOM-02 system from the orbit 91 in mode 1/30 in May 1993, were used for detection of time changes in the dune morphology in Ramlat Zaqqut. The Metric Camera photograph was converted into digital form, and then both sets of data were processed on an Intergraph MicroStation.

The detailed comparative analysis indicated several changes in dune forms. The new trend of linear dunes, which were not depicted on Metric Camera photograph can be easily detected on MOMS-02 scene. This new trend is presumably related to the changes in the wind regime in this region. Significant changes were also detected in the forms of star dunes surrounding the horseshoe-shaped depression in Ramlat Zaqqut. The changes in star dune arms are quite obvious. The performed analysis indicated significant dynamics of dune forms and confirmed the contemporary processes of dune development in this part of Libyan Sahara.

#### 6. CONCLUSIONS

The main conclusions, derived from the performed investigations are as follows:

- The MOMS-02 images fill the gap between the small scale aerial photographs and the medium resolution satellite data;
- MOMS-02 data due to the high geometric resolution allow to detect and analyse all types of dune and their relationships;
- The repetitive MOMS-02/P data can be used for monitoring of sand desert dynamics and for prediction of future development of desert areas and their influence on desertification processes.