

# STUDY OF NATURAL AND ECONOMICAL OBJECTS DYNAMICS BY COLOR COMPOSITION OF MULTITEMPORAL IMAGES

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## ABSTRACT

The most common way of satellite images use for dynamics investigation relies on separate interpretation or computer classification of multitemporal images with subsequent matrix comparison of classification results for changes discovering. These procedures are rather complicated and time-consuming. As a method convenient for everyday efficient image analysis we suggest method of changes determination based on composition of color multitemporal image and its interpretation. Methods of visual interpretation and simplified computer processing of multitemporal composites have been created. The "interpretation key" was formulated for ERS/Envisat SAR images of Kalmykian coastal zone of the Caspian Sea, where coastal zone dynamics under sea level fluctuations was studied. Applications of suggested method is demonstrated by several examples from different branches of geographical investigations: coastal relief dynamics (Sulak river delta), seasonal vegetation changes in Volga River delta; changes in forests distribution in Central European Russia (Kostroma) area; growth of agricultural fields in Al Kufrah oasis, Libya; changes of land use at the Murgab-Tedjen oases region in Turkmenistan.

## 1. INTRODUCTION

Regular space survey gives plentiful materials for investigation of natural and economical objects changes. There were a lot of methods elaborated for change detection with remote sensing images (Singh, 1989, Kniznikov, Kravtsova, 1991, Serpico S., Bruzzone L. 1999, and many other). The most common way of satellite images use for dynamics investigation relies on separate interpretation of multirate images or computer classification of them with subsequent matrix relation of classification results for changes discovering (Proceedings..., 2002). These procedures are rather complicated and time-consuming. In search of the most effective, simple and convenient methods for changes detection through satellite images, we produce a simplified technique for revealing of earth objects changes. It bases upon color composition of images obtained at different dates and further analysis of colored multitemporal image. Methods of visual interpretation and simplified computer processing of multitemporal composites have been created.

## 2. METHODS ELABORATION

### 2.1 Color compositing of multirate images

The methods which are suggested base upon the widely used procedure of image processing - Color Composition, i.e. combining three images: one of them is displayed in shades of red, others in shades of green and in shades of blue, that results. After combining three images of different dates we obtain one color composite multitemporal image suit for further analysis of colored objects. Color composition of multitemporal images is used relatively widely, especially on the analysis of radar-images, as it is a unique way to receive the color image from radar-images which by the nature only black-and-white (Nezry E. et al, 1995, Stussi N, Liew Ch., et al., 1996).

Succeed in applying this technique depends on how sharply changing objects on study stand out against a background of an image in their brightness. So it is expedient to use images with a simplified brightness structure. For example, images of near infrared band are the most suitable for studying changes at coastal zone, since they are characterized with the most evident contrast between water and land or vegetation. Images taken in winter are the most proper on research of forests distribution changes, because dark forest-covered areas stand out against a background of snow covered woodless zone. Green growing vegetation of oases (dark tone at an image) contrasting with sand of desert (bright tone) gives a similar effect at the image in a visible range.

Sometimes, it is advisable to simplify image structure executing quantification to 2-3 levels intensity of grey, as this procedure allows obtaining composite multitemporal image with clear color separation of different changes. It is evident also that images acquired at different dates should be geometrically identical: georeference or mutual transforming and resampling should be done beforehand.

At color compositing, generally speaking, it is possible to use any order of multirate images coloring by filters R, G, B, providing the best color division of investigated objects. But use of a uniform rule for applying Red - Green - Blue colors in order from earlier survey date to later one provides also uniform approaches to interpretation such color composite multitemporal images, to decoding changes of brightness, "temporal signature an image". Consequently, one can define the character of replacement of objects basing on their color at a color composite multitemporal image.

For the revealing of a character of changes (replacement) of objects basing on their color at a color composite multitemporal image an "interpretation key" was formulated. The key was

developed in a case study of changes in Kalmykian coastal zone of Caspian Sea in connection with fluctuations of a sea level.

## 2.2. Materials and peculiarities of a study area

SAR and ASAR images of the Kalmykian coastal zone from satellites ERS-1,2 and Envisat received at 1995, 1999, 2004 were used for the method elaboration (Figure 1). They all cover post-transgressive period, when after intensive Caspian Sea level rising during 1978-1995 by 2,4 m, the level stabilized and decreased a little (nearby 0,4 m).

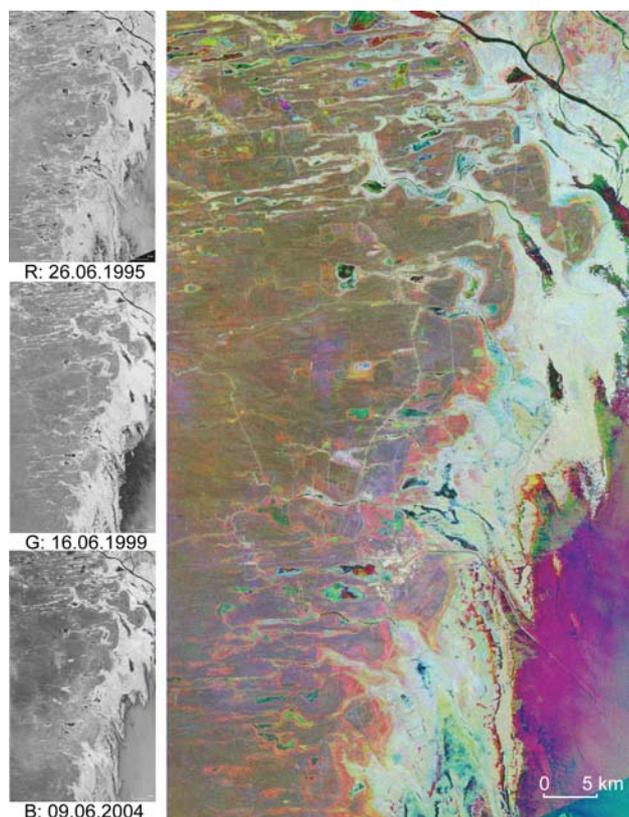


Fig.1. Multitemporal color composition image for the Kalmykian coastal zone of the Caspian Sea, composed of multi-date SAR images

Main objects of the Kalmykian coastal zone are clearly defined at SAR images: water surfaces without waves and ripples are seen as dark, almost black areas, reed zone has high radar brightness and it is represented by light gray, nearly white tone, and inland dry steppe plains have gray tone at the images.

Principal changes occurring at a coastal zone under sea level fluctuation, become apparent in different environments. Firstly some changes happen at the boundary between reed belt and open water. A flood of reed belt on a sea level rise or moving of reed area towards the sea occurs on sea level falling. Secondly a formation of lagoons, underflooding of soils and increase of reed belt occur at areas between reed belt and inland territories during sea level rise. Also increase of inland aridity and decrease of reed belt become perceptible on sea falling. These types of changes were revealed by separate analysis of multitemporal images in visible range.

## 2.3. Interpretation key

Figure 1 is a color composition multitemporal image synthesized of images acquired at different dates using the rule formulated above. Analysis of this image shows that poorly changed objects have achromatic colors (reed belt has white color, and land is grey-brown), and all areas of changes are marked with bright colors. Each color of changed area corresponds to the certain combination of brightness at the multitemporal images, that summarized in Table 1, which represents the suggested "interpretation key". It shows what combinations of brightness of the multitemporal images correspond to all colors of an iridescent spectrum. This table was resulted from proceeding sets of radar images (correctness of objects identification on radar-images was checked up using images of visible band) and it completely corresponds to the theory of colors addition. The key gives us an answer what changes took place at coastal zone for each color of multitemporal color composite.

Color at a multi-temporal color composite	Intensity or grey tone at black-and-white images, which are colored by			Temporal signature of the object
	Red	Green	Blue	
Red				w g b 95 99 04
Orange				w g b 95 99 04
Yellow				w g b 95 99 04
Yellow - Green				w g b 95 99 04
Green				w g b 95 99 04
Green - Light Blue				w g b 95 99 04
Light Blue				w g b 95 99 04
Blue				w g b 95 99 04
Blue - Light Violet				w g b 95 99 04
Violet				w g b 95 99 04
Purple				w g b 95 99 04

Table 1. Colors at the color composite multitemporal image resulting from different tone at initial images (letters at graphs of temporal signatures mean: w – white tones, red; g – gray tones, dry land; b – black tones, water)

## 2.4. Environmental results of interpretation key application for Kalmykian coast

Regularities of the coastal zone reaction to fluctuations of the sea level (i.e. some falling after intensive rise) can be revealed at use the interpretation key. It has appeared, that changes at sea border of a reed belt were minimal during that period, but in a rear part of it, where reed borders on dry land, general retreating of reed has occurred to marine side and disappearance of reed in depressions between Baer mounds. The areas of such retreating are seen as yellow and pink strips at the multitemporal color composite. These facts give an example of decrease of ground waters level. Also overgrowing by reed and disappearance of a part of lakes can be seen at the multitemporal image, though changes of water objects have no such a unidirectional character and they can have different colors due to water-management activities.

The method of multitemporal images interpretation developed for a case study of the Kalmykia coast and the interpretation key approach, certainly, have more general meaning and can be applied at visual work with images of different type and on studying of various objects.

### 3. APPLICATION OF MULTITEMPORAL COLOR COMPOSITE IMAGES IN DIFFERENT BRANCHES OF GEOGRAPHIC RESEARCH

The efficiency of considered techniques can be illustrated by some examples from various areas of geographic researches.

#### 3.1. Studying of changes of forests distribution

For studying of forests distribution changes (cutting off or renewal of wood vegetation) it is recommended in our researches to use winter images where dark plots of forests contrast sharply with bright bare snow-covered areas. Attraction of such materials creates favorable conditions for use of color composition of multitemporal images. This method allows directly fix changes of forests distribution, as both disappearance of forests and their appearance are represented at such images by different colors, whereas territories without changes have black or white color. Figure 4 illustrates this example showing a small site in timber industry area at the Kostroma region in Central European Russia.

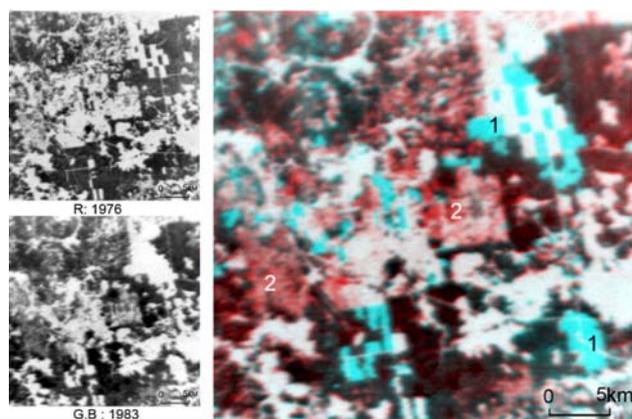


Figure 2. Color composition of winter images by MSS/Landsat of 1976 and MSS "Fragment"/Meteor-30 of 1983 (numbers are explained in text)

Winter images of 1976 and 1983, were synthesized to color two-temporal image, where plots of the cut down forests (1) and restored forest (2) plots are clearly divided by colors. This color multitemporal image shows, that for the 7 years interval cutting out of forests here was carried out systematically by quarters. Renewal of forests occurred by spontaneous growth of small-leaved forests.

#### 3.2. Studying of seasonal changes of vegetation

Fixing and studying of seasonal development of vegetation is a necessary stage of long-term changes revealing. It is especially important for coastal areas, where vegetation state is characterized by evident seasonal cycle or areas of seasonal flooding by a high water in valleys of snow feed rivers. For example, vast territory where this question is of important value

is the Volga delta. The color image (Figure 3) was composed of radar images ERS-2 of May, June and September of 1999.

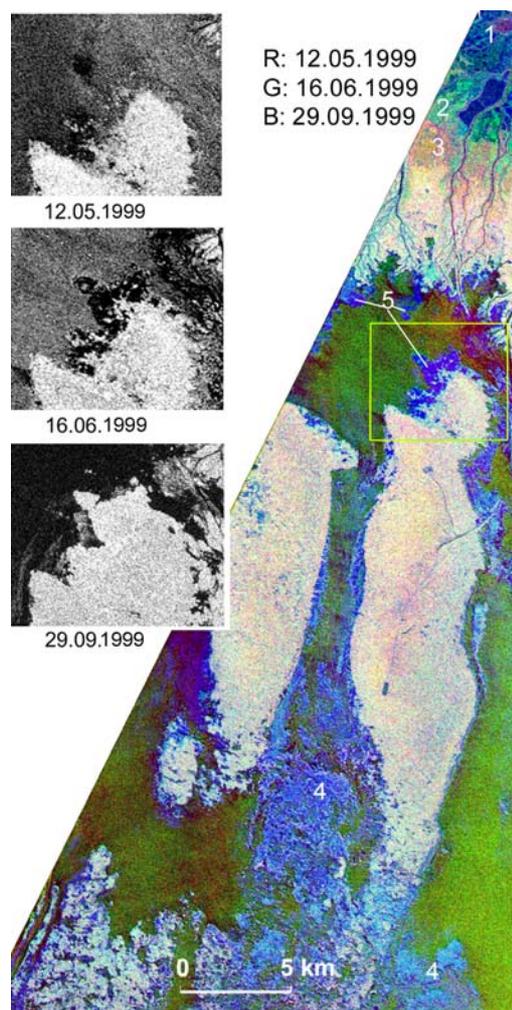


Figure 3. Seasonal changes of water vegetation at the Volga delta at multitemporal color composite SAR images (numbers are explained in text)

Intensive dark blue color of some land plots in a coastal part of surface delta (1) indicates in accordance with Table 1 that in the spring and in the beginning of summer these plots had low radar brightness (they were flooded by water), and by September they had high radar brightness (i.e. they were covered by meadow vegetation). Number 2 marks the areas which have greenish-blue color, that means that these plots have low brightness at image of May (i.e. flooded, or covered by water), but in June and September they were characterized by high radar brightness at the image (i.e. they were covered by dense vegetation). Red-orange plots at the multitemporal image, labeled by 3, represent areas with thick green reed meadows (high level of brightness at the image), which have not been covered by water in May, but by June or September were mowed or withered (middle level of brightness at the image).

This multitemporal image also clearly reflects seasonal development of water vegetation. Water vegetation appears in delta at different time that is well displayed by colors at the image. At southern edges of flat islands where waters get warm earlier, water plants appear in June, so such areas have light blue colors (4). Late growing plants and vegetation developing

in areas washed by cold freshet waters, which can be seen at an image only by the middle of summer, have intensive dark blue color at the multitemporal image (5).

### 3.3. Research of coastal relief forms dynamics

Color composition allows showing at one image positions of dynamical spatially changing forms of a coastal relief, doing it similarly the fallen asleep animation or film-gram. Figure 4 shows delta of the Sulak river at the western coast of the Caspian Sea.

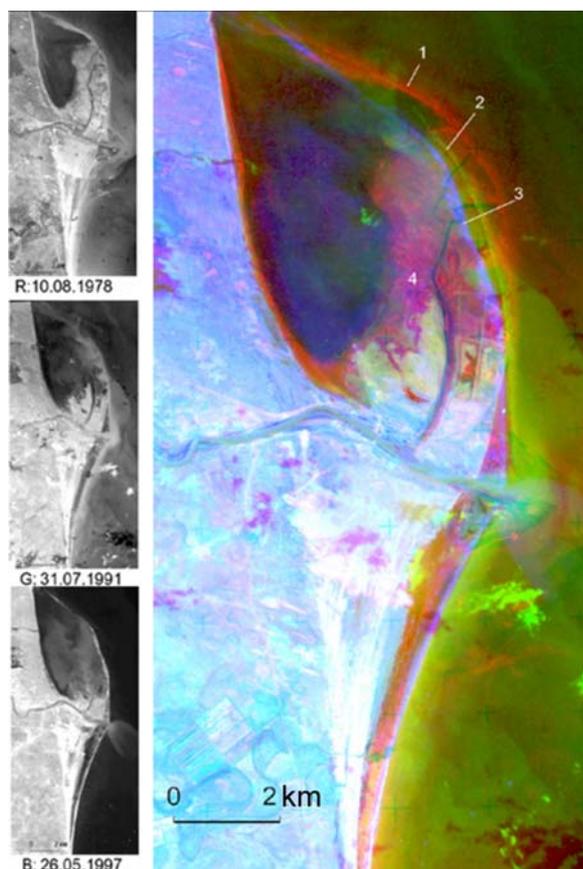


Figure 4. Sulak spit and Sulak river delta at multitemporal color composition (numbers are explained in text)

Processes of washing away of the eastern delta edge stipulated the growth of a narrow spit about 5 km long. That spit changed its position during the sea level rise. At studying of these processes using separate multitemporal images (high-altitude aerial photograph of 1978, space image by KFA-1000-/Resourse-F of 1991, and image by MSU-E scanner /Resourse-O of 1997 it is complicated enough to notice changes in spit position.

At Figure 4 all three accumulative forms are clearly visible at the color composition of all multitemporal images: sandy spit (light tone) against a background of water (dark tone) is seen well enough, and its color indicates the time of this spit formation. Thus (at composition images by a rule of use of filters R, G, B from old to new dates), spit represented by red color (1), existed in 1978, yellow-green (2) has the bar formed to 1991, and dark blue (3) - spit, formed again to 1997. Sites of the delta ledge which existed in 1978 and has been washed away to 1991 were represented by the red color (4), washed

away after 1991 – greenish-yellow, and the part of the delta which kept unchanged to 1997 – light blue.

### 3.4. Monitoring of deserted lands development and growth of agricultural fields and their influence to surroundings

Pivot irrigated fields have a specific form of a circle, they are well perceived at space images due to specific round form and dark tone of agricultural vegetation, that sharply contrasts with a light background of surrounding deserts. Blocks of round fields of Al Kufrah oasis in a southeast of Libya drew attention of cosmonauts already in the first space flights. One of the first images of Al Kufrah oasis made a crew of spacecraft “Souz-12” in September 1973. In succeeding years this territory was photographed many times that helped to reveal the expansion of the oasis (Figure 5).

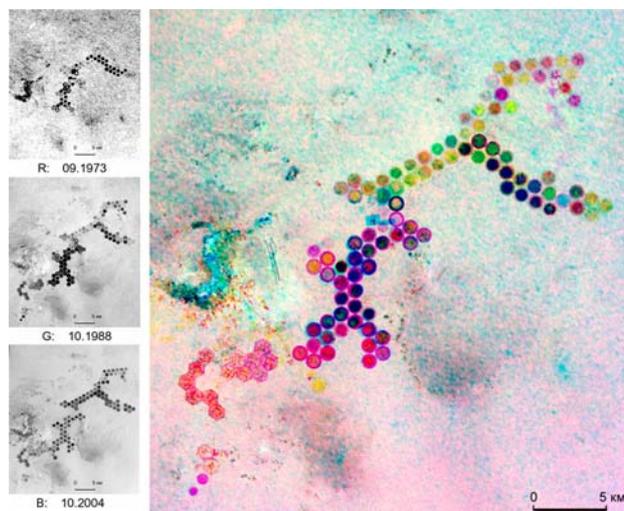


Figure 5. Al Kufrah oasis growth. Color composition of the images of 1973, (“Souz-12”), 1988 (STS026) and 2004 (ISS-010: image ISS010-E-5266)

Figure 5 displays a picture of the oasis growth, developing of new fields for concerned time intervals. At use for color composition R, G, B colors order from early image to later ones, according to a key given in Table 1, the fields existed in all 3 dates, are represented by black color, the fields which appeared to 1988 have the red color, and fields appeared later (by 2004) have yellow color. The picture allows noting distinctions in use of irrigated fields in different years: thus, reduction of irrigated fields area from 1988 by 2004 within the limits of separate fields is shown in a picture as blue circles framing these fields. Thus, in this case color composition can be the elementary method for display of growth rates of an oasis and change in intensity of irrigated fields use.

Other example is an illustration of the expansion of irrigated lands at the Kara Kum desert with Murgab and Tedjen oases in Turkmenistan. At the color composite (Figure 6) olive-brown color indicates the fields borrowed by a cotton crops in all dates of survey (1), red color corresponds to fields which have appeared by 1985 (2), and yellow color have the blocks of irrigated grounds developed and used in 2001 (3). The picture shows, that agricultural development of new lands coincides with ecologically adverse plots of secondary soil salinization at periphery of subaerial deltas. The plot of dark blue color (4) on periphery of the Murgab oasis testifies, that in 2001 these fields

were not cultivated or neglected. The string between oases is the Big Kara Kum canal, along which bogging of lands due to infiltration waters from not concreted canal sides is observed. Visible on picture red and yellow strips along the canal show that infiltration processes and expansion of a swamping strip proceeded through these years.

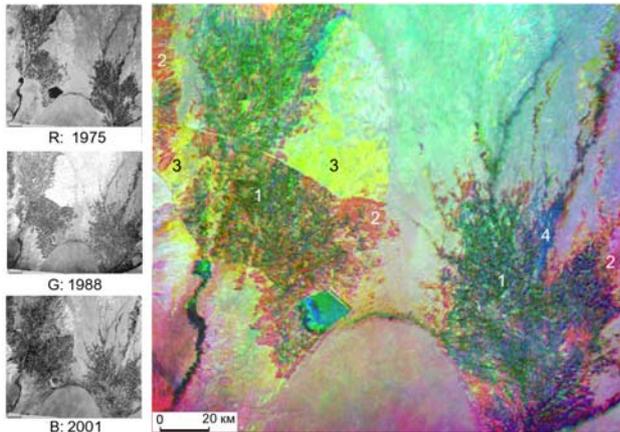


Figure.6 Color composition of images of 1975 (Space station "Saljut"-4), 1985 (Space Shuttle STS51F) and 2001 (ISS-002: image ISS002-E-7685) (numbers are explained in text)

## CONCLUSIONS

Although the color composition of multitemporal images is used rather wide in remote sensing images interpretation, we suggest the new approach for multitemporal images analysis. It supposes to set a correspondence between color of a plot at an image and trend in its changes – the so-called "interpretation key", that can be used as a decision rule for multitemporal images analysis and interpretation. The method of multitemporal images interpretation developed for a case study of the Kalmykian coast have more general sense and can be applied at analysis of different type images and on studying of various objects.

Applications of this method for multitemporal image analysis in different branches of geographical investigations proved the effectiveness of the method.

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