Monitoring forest fires and their consequences using MODIS spectroradiometer data

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Abstract. Identification of fires by satellite methods and means is one of the main tasks of the modern forest fire monitoring system. The article presents a method for mapping forest fires based on the data of the MODIS Spectroradiometer, based on the analysis of the obtained images using the ScanMagic software package. In September 2009, a blocking anticyclone was established in Australia, contributing to an abnormal increase in temperatures, lack of precipitation, and as a result, the emergence of massive forest fires that led to smoke in the region. Studies have been conducted on the example of this phenomenon. As a result, the results of the study are considered, the analysis of changes in the number of fire centers and the assessment of smoke development is carried out. Currently, this method is well established and is used for detecting and analyzing fire situations, including in Australia with a wider range of functions presented in this paper.

1. Introduction

The problem of detection, registration and registration of forest fires is of global importance. Forest fires are one of the sources of greenhouse gases and aerosols in the atmosphere, contribute to the development of the greenhouse effect and have a destructive effect on phytoceneses. In recent years, a number of international projects have emerged aimed at creating and supporting remote methods and tools for global monitoring of forest fires. The most recent programs include the creation of regional networks for global monitoring of forest cover monitoring and their dynamics, within the framework of which regional networks for monitoring forest fires are being created [1].

In Russia, the monitoring, detection and control of forest fires is entrusted to the Federal Forestry Agency. The Russian system of remote monitoring of fires is used by forest protection units of the forest service to make operational decisions on the detection and suppression of forest fires. The currently ongoing development of existing systems for forest monitoring based on remote sensing data of the Earth [2].

The aim of the study is to study the information capabilities of the MODIS spectroradiometer and image analysis using the ScanMagic software package.
2. Methods and Materials
The MODIS spectroradiometer (Moderate Resolution Imaging Spectroradiometer) is one of the key instruments on board the American satellites of the EOS series (Terra (EOS AM-1) and Aqua (EOS PM-1)). The survey is carried out in a strip of 2330 kilometers simultaneously in 36 spectral zones of the visible, near, middle and thermal infrared ranges with a spatial resolution of 250, 500 and 1000 meters and a radiometric resolution of 12 bits per channel [3].

For the study, an area of Australia was selected in the district from Brisbane for the period September 27 and 29, 2009. It was during this period that severe fires were observed in the region, at which time a dust storm passed in the region.

Images were obtained from the EarthData website for the selected area on September 27 and 29, 2009 (figure 1).

Figure 1. Selection of the area of study of the MODIS spectroradiometer data of the Aqua satellite on the EarthData website.

Also, images of the hdf format were loaded, containing information about the satellite, date of recording, etc. in the image name (figure 2).

Figure 2. Download page of MODIS spectroradiometer data in hdf format on EarthData website.
The obtained remote sensing images were processed using ScanMagic software [4]. ScanMagic is an easy-to-use multi-functional software for viewing, analyzing and processing Earth remote sensing data. Supports a large number of formats. Due to its speed and versatility, ScanMagic is ideally suited for processing satellite data in near real-time mode. In the work, this software is used to improve the obtained images using the tool “Linear contrasting and equalization”, i.e. modifies the values of all pixels within the current radiometric range with the image contrasting

\[ s_k = T(r_k) = \sum_{j=0}^{k} \frac{n_j}{n}, k = 0,1,\ldots,L - 1 \]

It allows you to open one or more pictures, perform color synthesis of one channel or conduct arbitrary RGB synthesis [5]. Next, an analysis of the brightness samples of the image was carried out. The optical devices of remote sensing satellites are equipped with receivers with photosensitive detectors called CCDs (charge-coupled devices). The detector picks up radiation in a certain field of view, called instantaneous field of view (IFOV), and in a certain spectral range. The viewing angle of the detector will determine the minimum size of the object on the ground, which is reflected in one pixel. The spectral range forms a pixel luminance field with a certain value of the recorded radiation. The number of possible values of the recorded radiation, i.e. gradations of gray, each pixel is determined by the radiometric range of the detector. The concept of “luminance reference” of a pixel defines the value of the recorded radiation. In different spectral zones, the brightness samples of the same object on the ground will be different. It should be noted that the reflectivity of objects on the earth's surface is influenced by various factors, such as the state of the atmosphere as a whole and its surface layer, the height of the Sun, etc. For the correct analysis of different images and images obtained from different devices, there are algorithms for the absolute radiometric calibration of the original image, the essence of which is the translation of the brightness samples into certain physical quantities called the spectral density of energy brightness [6].

In our case, we used a method for measuring the brightness of the image in the form of constructing a profile for a cut of brightness samples. After building the profile, the screen displays information about the traced pixel value displayed above the graph (from left to right): the coordinates of the pixel in the image (Pixel:, Line:), the distance from the beginning of the profile line to the selected pixel (Distance:), the brightness report in the selected channel (Value:), statistics of the profile brightness count (Average:, Min:, Max:). On the vertical axis of the profile, the values of the samples of brightness of the pixels of the analyzed slice are plotted, on the horizontal axis, the length of the profile in pixels. In the Profile panel, you can select the values of the brightness of pixels involved in the construction of the profile: the option ISX. displays the source samples of the brightness of the raster, the EXIT option. displays screen brightness samples (after converting the image histogram). The values of the brightness samples of the original image are determined by the radiometric range of the raster [7].

3. Results and Discussion
On the image of Eastern Australia dated September 27, 2009, fires are clearly distinguished along the coast; a dust storm recorded during this period is recorded in the north of the study area (figure 3).
Figure 3. Remote sensing image from the MODIS spectrum radiometer for Eastern Australia on September 27, 2009.

Applying equalization to the image in the ScanMagic software package, we proceed to further analysis of the image brightness using the construction of the profile (figure 4). After applying equalization, all smokes are noticeable much better.

Figure 4. Remote sensing image from the MODIS spectrum radiometer for Eastern Australia on September 27, 2009 after applying equalization.

A histogram was constructed for the selected section. The section was made through smoke from a fire and a dust storm (figure 5).
Figure 5. Remote sensing image from the MODIS spectrum radiometer for Eastern Australia on September 27, 2009 with a cross-section brightness profile.

Smoke from fires spreads to the northeast. Most of the water surface in the satellite image is covered by a passing dust storm. According to the constructed profile, it can be seen that where there is a lot of smoke, the brightness values will be greater, and in place of clean water and the earth's surface, the brightness values are much lower. Using the constructed brightness profile, it is possible to determine the area of greatest smoke, as seen in our case, this occurs at pixel 36 and 324, the image indicates that a solid white color of smoke and dust storm is observed at this pixel length, and no water surface is visible here. Maximum smoke is observed almost at the fire site, it is worth noting that the intensity of smoke throughout the profile is high.

Note that on the profile, the brightness values of the dust storm are comparable with the values of smoke brightness, which can negatively affect the analysis of the direct consequences of fires.

Reviewed of this area was examined on September 29, 2009 in order to trace the dynamics of the fire (figure 6).

Figure 6. Remote sensing image from the MODIS spectrum radiometer for Eastern Australia on September 29, 2009.
The number of foci of forest fires decreased after 2 days, the dust storm captured in the images on September 27, 2009 is not observed in these images. For further analysis, equalization was applied to the satellite image and a histogram was constructed along the section from the fire source in the direction of smoke propagation (figure 7).

Figure 7. Remote sensing image from the MODIS spectrum radiometer for Eastern Australia on September 29, 2009 after applying equalization.

Smoke from the September 29 fire also spreads northeastward. After equalization, smoke is better visible above the surface of the earth and the water surface than in the original image. On the brightness profile (figure 8), it is noted that the greatest smoke is approximately 20 pixels long. On the profile, it is well noted that the brightness curve decreases with distance from the fire, which indicates that the maximum smoke is observed directly at the hearth and dissipates when moving away from it. It is worth noting that the analysis of forest fires according to remote sensing of the Earth can be based on machine learning algorithms or education recognition methods.[8]
Figure 8. Remote sensing image from the MODIS spectrum radiometer for Eastern Australia on September 29, 2009 with a cross-section brightness profile.

Compared to the brightness profile as of September 27, 2009, the brightness values are lower here, which is associated with a reduction in forest fires in this area and, consequently, with a decrease in smoke.

4. Conclusions

Based on the results of the study, it can be concluded that along with other approaches to managing geo-risks [9-11], the use of ScanMagic software is useful for analyzing any bad weather conditions or natural disasters.

When considering the situation with Australian fires in September 2009, which was caused by hot weather in this region, the considered algorithm for monitoring the fires and their consequences, in the form of smoke in the territory, showed rather good results and ease of use. Of the disadvantages, it is worth noting the similarity of the results obtained when observing several types of anomalies simultaneously.

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