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AEROGEODESIS MONITORING OF POTENTIAL AREAS OF SPONTANEOUS COMBUSTION OF THE FOREST

The **subject matter** of the article is method for detecting potential zones of forest tracts spontaneous combustion using remote sensing data of the Earth. **Aim** of the article is to show how to increase the speed of decision-making to prevent negative consequences caused by spontaneous combustion of forest areas without a source of fire brought in from outside. The **object** of the research is a comprehensive analysis of the aerogeodesic monitoring data and contact measurements to identify and localize on the satellite images areas with high fire potential in the presence of a fire source directly in the territory of a possible fire. The **methods** used are the positions of general physics and higher geodesy, the basics of digital image processing and thematic interpretation. **Results of research.** The main factors affecting the process of autoignition of forest tracts are analyzed. A method of aerogeodetic monitoring, which is based on a map of thunderstorm activity, is presented. Method is based on remote observations of thunderstorms. At the same time, the map reflects the position of active thunderstorm cells in space and the projection of their coordinates on the geodetic map of the forest and is also a route for the purposeful search and elimination of local sources of fire. In order to be able to make quick decisions related to the prevention of negative consequences, an approach is used in which thunder cells are diagnosed for the purpose of assessing fire hazard by their ability to activate the process of origin of local sources of fire. In this case, we consider such controlled parameters as - the intensity of the electric field of the thunderstorm cell and the coordinates of its spatial position with respect to the forest area. **Conclusion:** to identify the origination of local sources of fire in the localization of possible autoignition zones, a relationship of thunderstorm clouds with the formation of the CCD was established. Aerogeodesic monitoring of the CCD is the basis for the operative estimates obtaining of the current object state of observation and prediction of the fire hazard level. The negative impact of forest fires on climate change, both local and global, is quite significant. Insufficient knowledge of this aspect requires further collection of material and its analysis, together with little-known "indirect" factors that cause spontaneous combustion of forest tracts and their individual sites.

Keywords: geodetic map; polarization; spark; organic compounds; the storm cell.

Introduction

It is well known that forest fires covering large areas of the earth's surface cause significant damage not only to the economies of various countries, but also to the environment in General. This problem is dealt with by various organizations associated with the study of the nature of forest fires and improvement of measures to deal with the problem, is a subject of many scientific works, however, the task of rapid detection of potential zones of spontaneous combustion of the forest are still relevant. Opportunities for timely decisions to prevent negative consequences caused by forest fires, the proposed method of aerospace monitoring detecting and locating potential zones of spontaneous combustion of the forest, based on the main provisions of the General physics and elements of higher geodesy. It is considered that a forest fire occurs only in the presence of the fire source, combustible materials and conditions conducive to their ignition. In this case, one of the most critical factors influencing the fire hazard is weather. Namely, high temperature, often accompanied by low relative humidity cause rapid drying of combustible materials and ignite them from the fire source. In terms of the spread of fires also directly affected by wind and cloud. Rain occurrence plays a very important role as well. The combination of all these factors allow the departments of the hydrometeorological service to compile an information card with applying them to the different classes of fire danger.

It is assumed that since the sources of fire in f – they are always given a priority [1].

In the classical approach, all indicators of fire hazard are reviewed and evaluated only from the point of view of the ignitions degree and speed of burning of forest materials. It is obvious that even with a higher emergency class, burning, no fire is possible without a spark or some kind of fire initiation. However, despite this, all prescribed fire activities will be conducted. This patrol flights over several days, and a number of other, less costly events. The advantages of these known methods include a large enough list of options to perform assessment of the possible combustion of solid combustible materials. The only drawback of known methods is the lack of real information about the source of fire and its potential presence on site, although this factor is dominant in the prediction of fire danger of forests. On this basis, the main emphasis in identifying areas with high fire hazard potential should be given to the definition of the conditions constituting the source of the fire directly on the territory of a potential fire, assessing their possible effects on climate change, both locally and in General.

1. Statement of the problem and the content of the paper

It is known that for a number of fires the fire source, usually recorded on the territory of the forest from the outside (the human factor or natural phenomenon such as lightning). The process of occurrence of such fires are well known and researched. With the proper approach, the cause of the fire and the fire source accurately set. Therefore, we will not discuss the issue in the article. The emphasis here is given to the

investigation of fires on the territory of which the sources of heat and combustible materials generated solely by the forces of nature.

1.1. Analysis of local sources of fire

All that is known about fires caused by local heat sources is that they often occur when changing weather conditions. Spontaneous combustion usually occurs spontaneously, is hidden from human eyes, and takes a long time, and stitches smoldering heat can be distributed over long distances. And only in the presence of wind, flames of fire suddenly cover a large part of the territory of the forest. The thermal energy sources are negligible, respectively, and the ignition energy of combustible materials must be of the same order. This gives grounds to believe that such a source can be a spark, provoked by the electric field of the clouds. Thus, in the area of powerful clouds, the electric field can reach 10^4 V/m or more. Plants appeared in the field of such clouds are polarized and acquire an electric moment. If, when the polarization was a leak of charges of the same sign, then the excess charge after the disappearance of the external field determines a loaded condition of such plants (the conductivity is provided by the plant tissue, which transport water with mineral salts from the roots to the leaves).

In these conditions, the vegetation of the forest, having a pointed form (stems, leaves, and needles of pine trees, grass, etc.) is characterized by a well-known phenomenon of "expiration of electricity with "needles by" (pretreatments). In this case, if the local field near the tip reaches a value of $3\cdot10^6$ V/m is required for electrical breakdown of air, it actually happens. Thus, when the field strength E_0 acting between the cloud base and the plant, the size of the power plants and the maximum field intensity at its tip are respectively equal to [2]:

$$Q_{\max} = \pi \frac{\varepsilon_0 E_0 b^2}{\lg(2b/a) - 1} \quad \text{and} \quad E_{\max} = \pi \frac{(b/a)^2 E_0}{\lg(2b/a) - 1},$$

where b is the length of the edge, and a its width (b > a), ε_0 – electric constant, F/m,

The electric field at the tip can reach breakdown values when E_0 very far from this value. Under these conditions, it can be observed pre-treatments associated with the illumination of the "punch" of air near the tip. Then, the ionized air increased the electrical conductivity is preserved for a relatively long time, in spite of the recombination of electrons and positive ions, due to the slowness of recombination of the ions opposite to each other. Ionized air can be considered as a gaseous conductor, which is a continuation of the conductive body of the plant and performing the role of "nozzle" on the edge.

Due to the smaller curvature of the "nozzle", the field intensity at the surface is less than the breakdown value and pre-treatments outside stops. However, if E_0 increases, the area of the corona somewhat expanded, i.e., expanded and extended the "cover" formed by a broken air.

When the elongation of this "case" comes to oppositely charged plants occurs the electric discharge. Allocated to spark energy

$$W = Q_{\max}^2 / 2C,$$

where $C = (b^2 - a^2)^{1/2} / arc\,h(b/a)$ – the electrical capacity of the plant, F [3].

For example, when $E_0=10^4$ V/m, $b=5\cdot10^{-1}$ m and $a=5\cdot10^{-3}$ m maximum field strength at the tip of the plant $E_{max}=10^7$ V/m, the induced charge on the plant $Q_{max}=7\cdot10^{-8}$ KL, spark energy $W=2{,}5\cdot10^2$ J.

Thus, the plant with the apex of a tip can be a source of spark discharge when you step on it the electric field of a thundercloud.

1.2. Analysis of combustible materials

Determined in accordance with the formulae that has been mentioned above, the amount of energy a local source is clearly insufficient for the ignition of traditional solid fuels. But it fully covers all four categories, classifying combustible gas mixture according to their Flammability energy from electrical discharges ($0{,}3 - 0{,}06\cdot10^{-3}$ J) [4]. In this regard one of the natural phenomena should be noted, typical for a large part of the vegetation of the forest. It is producing them in the environment organic compounds, which are a perfect combustible mixture, as contain carbon, hydrogen, oxygen, etc [5]. It should be noted that a feature of conifers is the production of large quantities of terpene hydrocarbons, which accounted for over 80% of the number of emitted compounds. On the contrary, for deciduous trees there is high content of isoprene. Such trees producing a large number of isoprene include various species of willow, poplar, aspen and oak.

Thus, a feature of the distribution of organic compounds is that they are composed of cuticular wax, a protective layer covering the leaves and stems of plants. Spraying cuticular wax is most active in the coniferous forests. For example, the static charge creates a strong electric field around the tip of the needles, causes dispersion of the wax with the formation of aerosol particles of submicron size. The scale of the territory of emission of hydrocarbon compounds in vegetation of forests is huge. For example, for day 1 ha coniferous forest in the South of Crimea allocates an average of 4 kg of organic substances, and 1 ha of deciduous forest about 2 kg. It is obvious that under favorable weather conditions, especially during the growing season, the forest may have areas rich flammable mixture of hydrocarbon compounds.

1.3. A potential area of spontaneous combustion of the forest (CCD)

It is considered that the CCD is forest areas where ignition sources are created exclusively by forces of nature. In contrast to the case where spontaneous combustion comes from lightning, which is stored on the territory of the future of the fire from the outside, the local source of fire arises directly on it. Location lightning well visually monitored in contrast to the cases where the ignition of combustible materials arises from the flames of the hidden nature of the development process, which is virtually impossible to control. Therefore, their monitoring should be based on the presence of a combination of natural factors that generate these sources.

The first factor – producing vegetation, woods gaseous combustible mixture of hydrocarbon compounds. This factor is continuous and present throughout the vegetation period, which is characterized by the highest intensity fires. The second factor is directly linked to the passage of storm clouds that generate abnormally high tension of the electric field at the tip tops of the plants, leading to spark discharge. Basically, CCD is a forest "lighter", in which a gaseous combustible mixture of organic compounds being produced by forest vegetation. The source of the fire is a spark from the tip of the tops of the plants, provoking a storm cloud. Thus, local places of accumulation of the gaseous combustible mixture plus the passage over them of the cumulonimbus clouds are the two most important factors that form the CCD with the fire source, is sufficient to cause reaction of hydrocarbon compounds with subsequent ignition of the solid (traditional) combustible materials.

2. Method of aerogeodesis monitoring potential areas of spontaneous combustion of the forest

For operational decision-making related to the prevention of negative consequences caused by fires, the proposed method aerogeodesis monitoring, which primarily analyzes the "potentially dangerous" areas, selected on the basis of the dynamics of changes of meteorological parameters. This approach differs from the known fact: assess fire danger diagnose of the storm cell by their ability to activate the process of emergence of local sources of fire. Focuses on such control parameters as the electric field intensity of the storm cell and the coordinates of its spatial position with respect to the territory of the forest. The ability to activate the process is determined by the critical value of the electric field at the earth's surface according to the condition

$$E_{CR} = \frac{E_{BR} R h}{4\pi (h^2 + l^2)^{3/2}} \geq E,$$

where E_{BR} the electric field intensity of the storm cell, and $E \geq 10^4$ V/m (selectable calculation or empirically), h is the cell height relative to the surface of the Earth; R is the radius of the storm cell, l is the shortest distance of the cell to the perimeter of the controlled area of the forest.

It should be noted that the method is based on the map of storm activity, constructed according to remote sensing observations of thunderstorms. The map reflects the position of the active storm cells in space and the projection of their coordinates on the geodetic survey map of the forest.

For example, when $E_{BR}=2\cdot10^5$ V/m, $R=2\cdot10^3$ m, $h=1{,}5\cdot 10^3$ m, $l=10^3$ m, the critical field strength at the earth's surface $E_{CR}=3\cdot10^4$ V/m. This cell is able to activate the process of emergence ($E_{CR}>E$) of local sources of fire. Therefore, the projection of its coordinates is plotted on a geodetic map of the forest as a CCD. Basically, this map is a route targeted search and eliminate local sources of fire. Currently, the storm cell is controlled by known electronic systems. It should be noted that many countries, e.g., Australia, England, Japan, Argentina, India, Pakistan, Russia, USA, France, etc. have a permanent system of observation of thunderstorms. Their number in each country is determined by the size of the areas occupied by these services and the tasks that are set before them. Typically, the system consists of 4-5 paragraphs of observations. When placing them at the vertices of the angles of equilateral polygons at distances of about 1000 km, the radius of such a system reaches 2500-3000 km, and the area of its overview, respectively 20-28 million sq. km [6].

3. The Negative impact of forest fires on climate change

As a result of burning forests in the atmosphere produces a significant amount of heat and combustion products. Allocated quantity of energy in a forest fire can be estimated by the thermal power of W [7]:

$$W = qm/t,$$

where q is the average heat of combustion, MJ/kg; m – mass of burnt substance, kg; t – time of burning.

For example, as a result of forest and peat fires in the exclusion zone of the Chernobyl nuclear power plant on an area of 130 hectares (summer 2015) stood out the thermal energy equivalent of 60,000 MW [7].

There are more than a thousand forest fires [8] in Ukraine annually, the energy from which briefly heats the atmosphere and causes local climate change. Thus, in the process of forest fire stands out greenhouse gases (carbon dioxide, nitrogen oxides) that cause climate change. According to [9], the combustion of 1 ha of forest is allocated to the atmosphere 1,875 tons of carbon dioxide (CO_2). According to the MOE of Ukraine [8] in 2014, a 15.4 sq.km of burned forest, resulting in the atmosphere stood at about 28.9 million tons of CO_2. This amount of carbon dioxide from fires corresponds to emissions from all road transport for the year [10].

It should be noted that the analytical review of the scientific literature showed that the assessment of the impact of forest fires on climate change are still poorly understood and requires further research.

Conclusion

In conclusion, I would like to mention that the installed logical connection of the clouds with the formation processes of the CCD allows to effectively control the fact of generating local sources of heat and, consequently, to promptly forestall or eliminate them.

Aerogeodesis presents a method of monitoring the CCD may be of interest to organizations concerned with fire danger forecast and liquidation of forest fires, for example, state emergency services and forest protection services.

The negative impact of forest fires on climate change, both local and global, is quite significant since it is comparable to the carbon dioxide emissions from road transport near the highways. Insufficient knowledge of this aspect requires further gathering of material and its analysis together with the poorly known "indirect" factors causing spontaneous combustion of plots of woodland and their individual sections.

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Аерогеодезичний моніторинг потенційних районів спонтанного загоряння лісу

О. С. Бутенко, С. І. Горелик, Д. С. Гусаков, Є. А. Буравченко

Предметом досліджень в даній статті є методи виявлення потенційних зон самозаймання ділянок лісових масивів з використанням даних дистанційного зондування Землі. **Об'єкт досліджень** – комплексний аналіз даних аерогеодезичного моніторингу та контактних вимірювань для виявлення і локалізації на космічних знімках ділянок місцевості з високим пожежонебезпечним потенціалом в умовах наявності джерела вогню безпосередньо на території ймовірного пожежі. **Мета досліджень** полягає в підвищенні оперативності прийняття рішень, пов'язаних із запобіганням негативних наслідків, що викликані самозайманням лісових площ без наявності зовнішнього джерела вогню. Використовуваними **методами** є такі: положення загальної фізики і вищої геодезії, основи цифрової обробки зображень і тематичного дешифрування. **Отримані такі результати:** проаналізовані основні фактори, що впливають на процес самозаймання ділянок лісових масивів. Представлений метод аерогеодезичного моніторингу, який базується на мапі грозової діяльності, що будується за даними дистанційних спостережень гроз. При цьому карта відображає стан активних грозових осередків в просторі і проекції їх координат на геодезичної карті лісу, а також є маршрутом цілеспрямованого пошуку та ліквідації локальних джерел вогню. Для можливості оперативного прийняття рішень, які пов'язані з попередженням негативних наслідків, був використаний підхід, в якому з метою оцінки пожежної небезпеки діагностують грозові осередки по їх здатності активувати процес зародження локальних джерел вогню (ЗЛДВ). **Висновки:** для виявлення ділянок зародження локальних джерел вогню при локалізації зон можливого самозаймання було встановлено взаємозв'язок грозових хмар з процесами формування ЗЛДВ. Аерогеодезичний моніторинг ЗЛДВ є основою для оперативного отримання оцінок поточного стану об'єкта спостереження та прогнозування рівня пожежної небезпеки. Негативний вплив як локальних, так і глобальних лісових пожеж на зміну клімату, є досить істотним. Недостатня вивченість даного аспекту вимагає подальшого збору матеріалу і його аналізу спільно з маловивченими «непрямими» чинниками, що викликають самозаймання ділянок лісових масивів і їх окремих ділянок.

Ключові слова: система; геодезична карта; поляризація; іскри; органічні сполуки; грозовий осередок.

Аэрогеодезический мониторинг потенциальных районов спонтанного возгорания леса

О. С. Бутенко, С. И. Горелик, Д. С. Гусаков, Е. А. Буравченко

Предметом исследований в данной статье являются методы обнаружения потенциальных зон самовозгорания участков лесных массивов с использованием данных дистанционного зондирования Земли. **Объект исследований** — комплексный анализ данных аэрогеодезического мониторинга и контактных измерений для выявления и локализации на космических снимках участков местности с высоким пожароопасным потенциалом в условиях наличия источника огня непосредственно на территории вероятного пожара. **Цель исследований** заключается в повышении оперативности принятия решений, связанных с предотвращением негативных последствий, вызванных самовозгоранием лесных площадей без наличия внешнего источника огня. **Используемыми методами исследований** являются положения общей физики и высшей геодезии, основы цифровой обработки изображений и тематического дешифрирования. **Получены следующие результаты:** проанализированы основные факторы, влияющие на процесс самовоспламенения участков лесных массивов. Представлен метод аэрогеодезического мониторинга, который базируется на карте грозовой деятельности, строящейся по данным дистанционных наблюдений гроз. При этом карта отражает положение активных грозовых ячеек в пространстве и проекции их координат на геодезической карте леса, а также является маршрутом целенаправленного поиска и ликвидации локальных источников огня. Для возможности оперативного принятия решений, связанных с предупреждением негативных последствий, использован подход, в котором с целью оценки пожарной опасности диагностируют грозовые ячейки по их способности активировать процесс зарождения локальных источников огня (ЗЛИО). **Выводы:** для выявления участков зарождения локальных источников огня при локализации зон возможного самовоспламенения установлена взаимосвязь грозовых облаков с процессами формирования ЗЛИО. Аэрогеодезический мониторинг ЗЛИО является основой для оперативного получения оценок текущего состояния объекта наблюдения и прогнозирования уровня пожарной опасности. Негативное влияние лесных пожаров на изменение климата, как локальные, так и глобальные, является довольно существенным. Недостаточная изученность данного аспекта требует дальнейшего сбора материала и его анализа совместно с малоизученными «косвенными» факторами, вызывающими самовозгорание участков лесных массивов и их отдельных участков.

Ключевые слова: система; геодезическая карта; поляризация; искра; органические соединения; грозовая ячейка.