DATA PROCESSING OF RUSSIAN FOREST FIRE REMOTE MONITORING SYSTEMS

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ABSTRACT

Sustainable forestry and forest fire management are not possible in Russia without using remote monitoring data, because the territory under forest fire risk is huge. There are three main remote monitoring systems in Russia. The aim of the study is to consider data of two systems and to suggest some methods for comparison. Different SQL and geospatial queries were used for the systems to be compared. The results obtained demonstrate that there are some considerable contradictions between these systems. To overcome these problems advanced processing remote monitoring datasets were used and some kinds of advanced processing methods are suggested. A fuzzy logic was applied to match the fires reported by different systems. The fuzzy logic model is considered in detail in this paper. The result of this data processing can be the basis to develop future fire forecasting systems and decision support systems. The proposed methods of comparative analysis and additional processing of the data provided by the monitoring systems meant to improve input data quality in various modelling and forecasting applications.

INTRODUCTION

The number of wildfires in Russia is from 10 to 90 thousand per year (1). Only in the Siberian Region they threaten more than 4000 settlements with a population over 2 million people. Because wildfires are a dangerous and dynamic process, tending to appear randomly in time and space, it is difficult to control and model them. Practically the entire territory of Russia is covered by wildfire risks, excluding the polar desert area. The area at risk of forest fires is more than 15 million square kilometres. Wildfires covering the Russian territory from 1996 to 2011 are shown in Figure 1. The only way to control the wildfire situation is to use remote monitoring. There are three main remote monitoring systems used in Russia.

- Informational system of forest fire remote monitoring (ISDM-Roslekhoz), Russian State Forestry Agency (1)
- Remote monitoring system “Kaskad” from Russian Emergency Ministry
- Public geospatial service ScanEx Fire Monitoring Service (SFMS) (2).

It should be mentioned that the first and the second systems were founded and are now supported by the government and the third one has been supported by commercial organizations. But only SFMS data are available with open access. Unfortunately, SFMS has two disadvantages: the data is unofficial, and there is no mechanism to obtain raw data. Therefore SFMS data were not considered in this study. System “Kaskad” has intranet access only, so there is no reference of this system.

When comparing the results one can see significant differences, which are virtually due to algorithmic reasons only. The input data are similar in all systems. The systems have been using data from the following satellites: NOAA, Terra, Aqua, Spot, Landsat, RapidEye, and Meteor-M. Different algorithms lead to a variety of results. A graphical example of the systems’ differences is shown in Figure 2: the same area in Far East of Russia, near Taezhniy, Amurskaya oblast, and the same data obtained on 31 May 2012. There are two fires identified in ISDM-Roslekhoz, four fires in SFMS and eight fires in Kasksad. Coordinates and areas of fires are also different. This situation creates confusion and leads to various manipulations with the wildfire statistics.

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The main purpose of this study was to compare the results of the remote monitoring systems and to develop a technique for identical fire detection in various systems. With this objective the data of two systems were compared: ISDM-Roslekhoz and Kaskad.

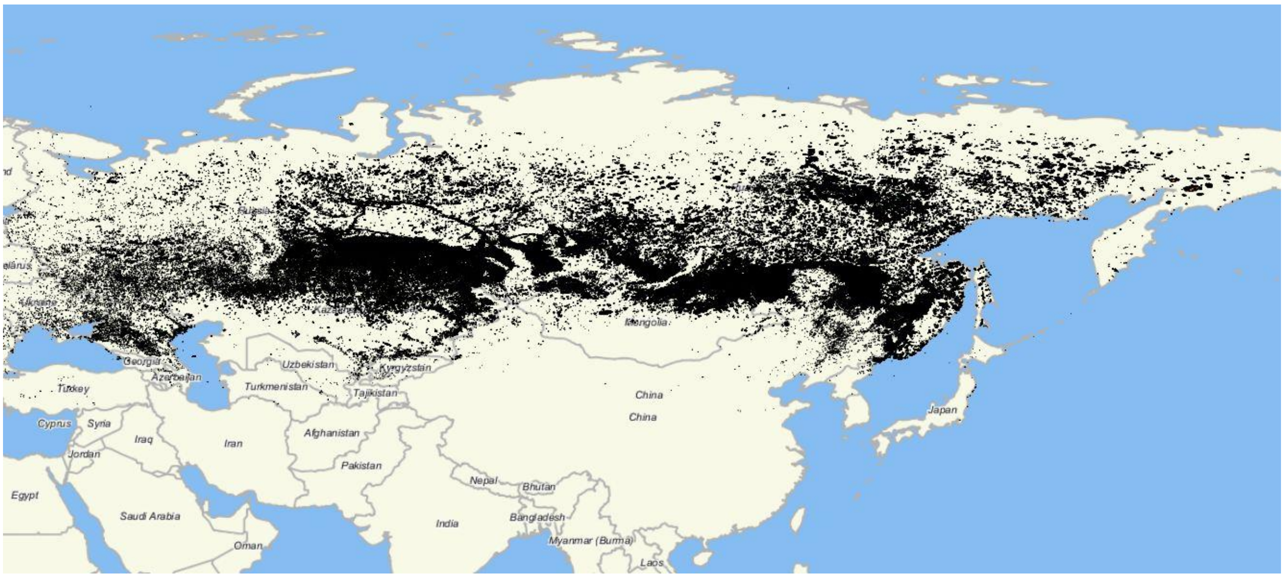

Figure 1: Distribution of wildfires in Russia and contiguous countries from 1996 to 2011.

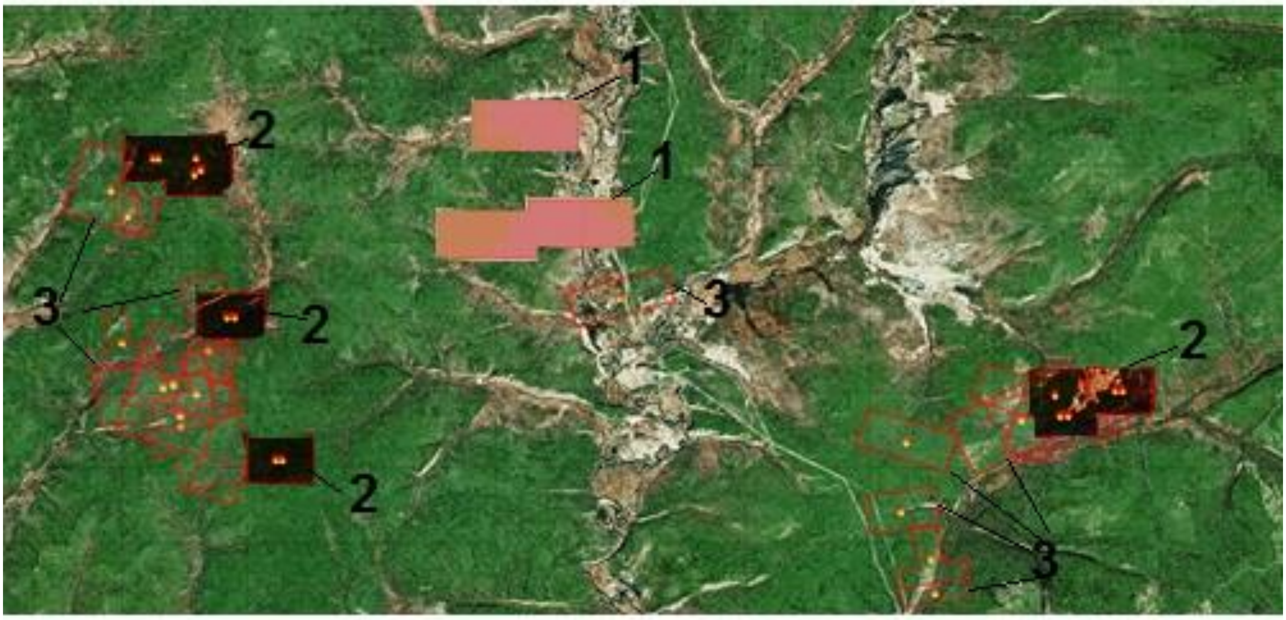

Figure 2: An example of the differences observed between the systems: Fires from: 1 – ISDM-Roslekhoz, 2 – SFMS, 3 – Kaskad.

METHODS

There are no convenient mechanisms to obtain raw data from all systems. For example, to download ISDM-Roslekhoz data one has to choose year and region, and to download data as Microsoft Excel file.

In Figure 3 an algorithm proposed by the author is represented. In a first step, data are obtained in one or another way. Pre-processing consists in translating data to the same format, in this case Microsoft Excel is used. Then, data are uploaded to a database and an SQL query is performed to get similar fires according to some criteria.

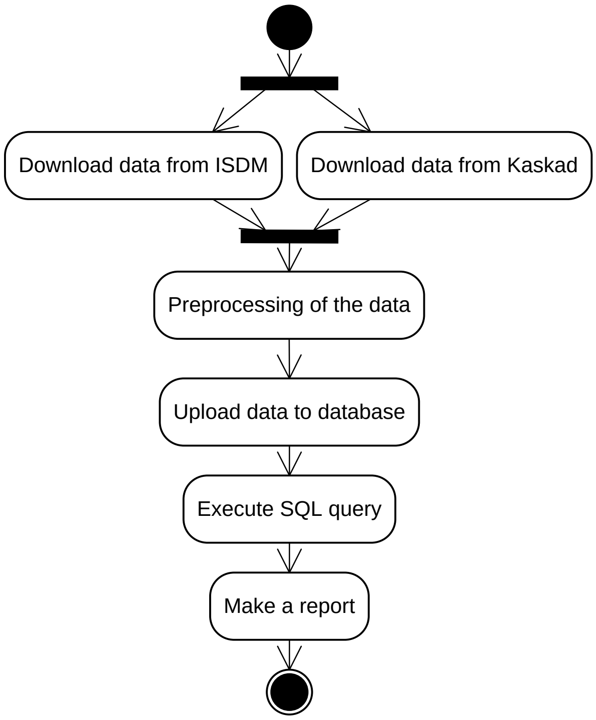

Figure 3: A comparison algorithm.

To compare the results of two systems we have to define general identity criteria of two fires. Let D be a distance between two fires in metres. Let t_1 be a detection time of one fire, hours, t_2 be a detection time of another fire. Then, $\Delta t = t_1 - t_2$ be a detection time difference. We have defined the general identity criterion as follows:

$$\begin{cases} D \le 1000 \text{ m} \\ \Delta t \le 24 \text{ hours} \end{cases}$$

This criterion is discussable and additional investigations are needed. We have taken into account the following reasons to define the criterion.

1. Resolution of satellite fire detection is about 250 m
2. Frequency of remote sensing is 3 or 4 times a day
3. Both tested systems have attributive data tables, where coordinates and detection time are represented.

So we can calculate criterion 1 for each pair of fires. The most convenient method is to use an SQL query. The general structure of an SQL query has been defined as follows:

SELECT DISTINCT system1.fireID, system2.fireID, system1.latitude, system1.longitude, system2.latitude, system2.longitude

FROM system1, system2

WHERE (system1.detection_time – system2.detection_time ≤ 24) AND (SQRT((system1.latitude – system2.latitude)2 + (system1.longitude – system2.longitude)2) ≤ 1000);

To use the query structure shown above, one should change “system1, system2” to the existing table names, and, of course, use the appropriate field names. This query returns the table containing identification numbers and coordinates of wildfires in each system. The comparison of the results of the two systems is discussed below.

The described method is suitable to compare system results *a posteriori.* For an operational comparison of fires, another method is needed. We developed a method based on a fuzzy logical approach. The same criteria were used: distances and time difference. But each criterion has been represented as a linguistic variable with three terms. Each term is characterised by its membership function. For example, if the distance is 1000 m, then the membership function value for term “Close” will be ~0.2 and for term “Middle” will be ~ 0.99. So one can conclude that a distance of 1 km is rather “Middle” than “Close”.

Then we developed a rule base. There are only nine rules, which describe the model behaviour:

1. If (Distance is Close) and (Time is little) then (output1 is Yes) (1)
2. If (Distance is Middle) and (Time is little) then (output1 is Yes) (0.5)
3. If (Distance is Far) and (Time is little) then (output1 is No) (1)
4. If (Distance is Close) and (Time is middle) then (output1 is Yes) (0.7)
5. If (Distance is Middle) and (Time is middle) then (output1 is No) (0.5)
6. If (Distance is Far) and (Time is middle) then (output1 is No) (1)
7. If (Distance is Close) and (Time is long) then (output1 is No) (0.3)
8. If (Distance is Middle) and (Time is long) then (output1 is No) (0.6)
9. If (Distance is Far) and (Time is long) then (output1 is No) (1)

The structure of the rules is a classical implication. After each rule the weight is shown. To fill the rule base an expert approach is used. The principal scheme of the fuzzy logical system and the membership function plots are represented in Figure 4.

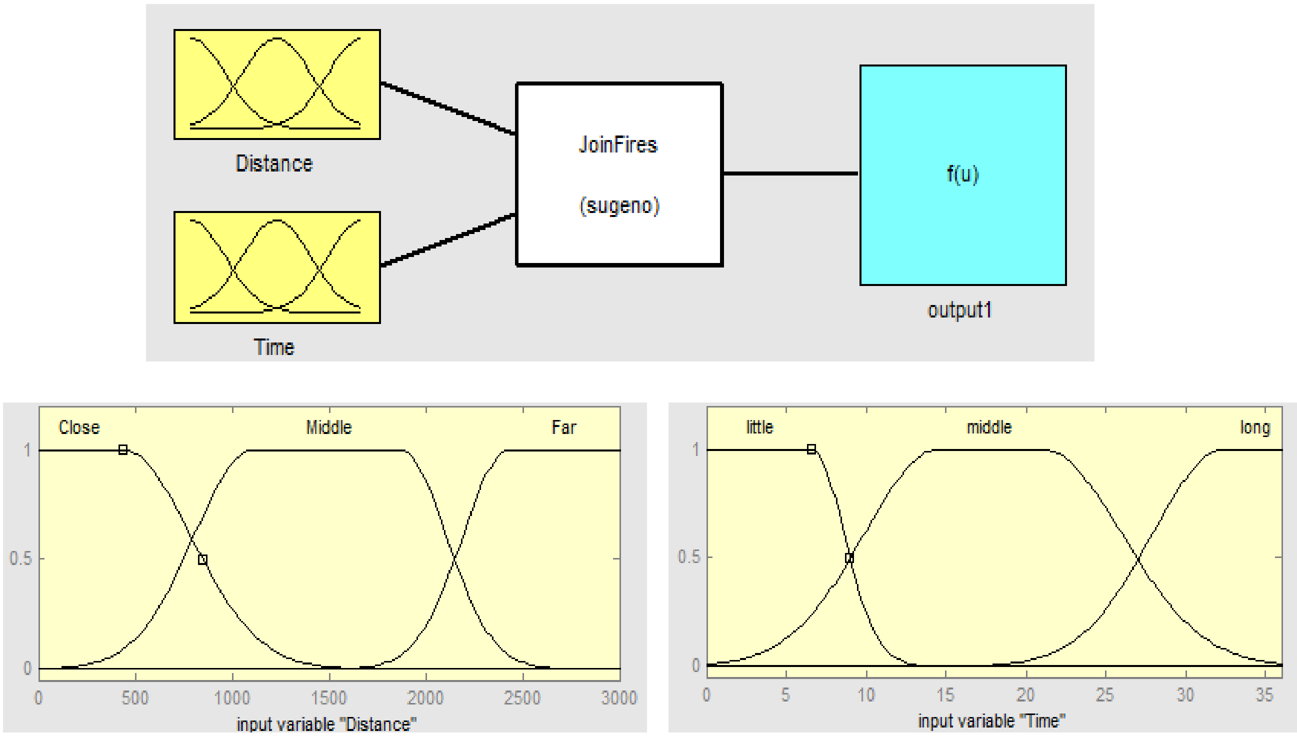

Figure 4: Fuzzy logical scheme and membership functions.

We have been using the well-known Sugeno algorithm (3). The output variable represents a value of the membership function. This function can take values [0;1]. The value demonstrates a membership degree. The higher the degree, the greater the confidence that fires are the same. So one can use this method as a decision making technique. Actually, the system has to answer the questions: “Are two fires the same ones?” and “What is the confidence in the answer?”. The method is further explained in Figure 5. The distance is 980 metres, time difference is 5.2 hours. The best coincidence demonstrates the second rule, because the membership function values for Distance:{middle} and Time:{little} are maximal. Therefore the answer must be “Yes” (fires are the same), with the membership value obtained as a result of the Sugeno algorithm. It should be mentioned, that the method is not transitive: if there are fires A, B, C, and if, according to the method, fire A is the same as fire B, it does not mean that fire A is the same as fire C.

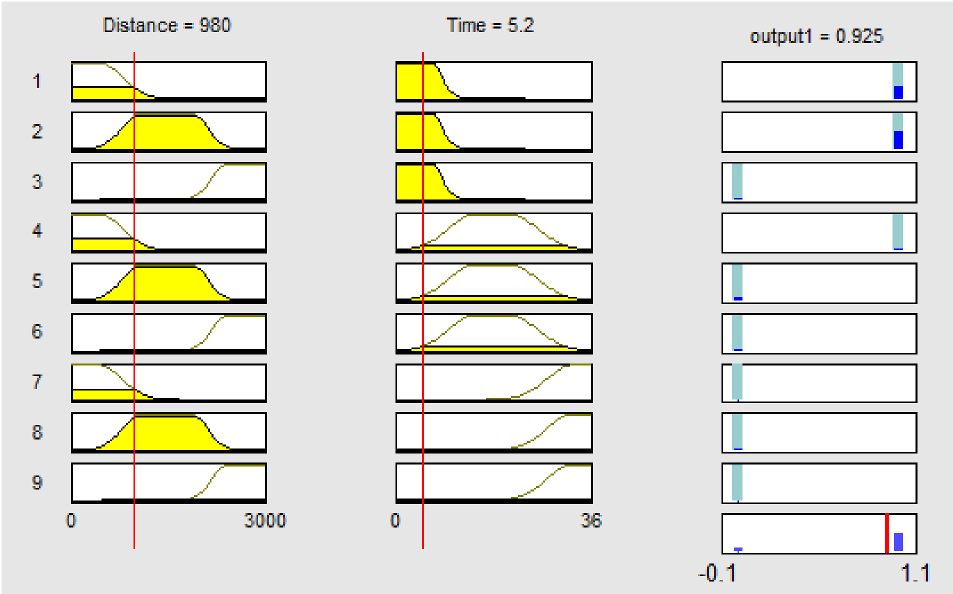

Figure 5: Decision-making example.

RESULTS

Every year, 13,421 to 89,634 fires occur according to ISDM-Roslekhoz. From year 2000 to 2011, 556,560 fires occurred. Kaskad has demonstrated other results: 290,842 fires. The discrepancy between these systems in the number of fires is from 23% to 77% or 48% on an average. As to the same fire search according to criterion 1, see Table 1 for the result. As can be seen, the match is from 0.7 to 39.3%.

Table 1: Results of comparison.

Year	ISDM-Rosleskhoz, fires	Kaskad, fires	Coincidence, fires	Coincidence, %
2000	18720	10200	131	0.7
2001	13421	6210	161	1.2
2002	35218	14496	352	1.0
2003	89634	24503	3854	4.3
2004	45249	10313	2986	6.6
2005	51097	27178	3781	7.4
2006	60384	28984	7306	12.1
2007	47183	28258	8493	18.0
2008	65537	37324	15663	23.9
2009	54643	24612	16065	29.4
2010	41400	31853	14366	34.7
2011	34074	46911	13391	39.3

If a decision has to be made based on the monitoring system data, what system has to be chosen? Currently, the choice is defined as follows: Persons working for the Russian Forestry Agency have to use ISDM-Roslekhoz, persons working for the Russian Emergency Ministry have to use Kaskad, and other persons have to use the systems accessible to them. This situation produces confusions in fire statistics. Each organization which possesses its own system makes its own statistics. This problem not only concerns the number of fires, but also the fire areas. The problem of accuracy in wildfire remote monitoring systems has been acknowledged a long time ago, but the problem of disagreements between various systems has not been stated before. Fortunately, the fire detection algorithms have become better from year to year, so that disagreements between systems have been slightly reduced.

Coincidence increased during all periods and the discrepancy in the number of fires tends to decrease. The diagram shown in Figure 6 might be explained by improved monitoring algorithms. But the problem as a whole has not been solved yet.

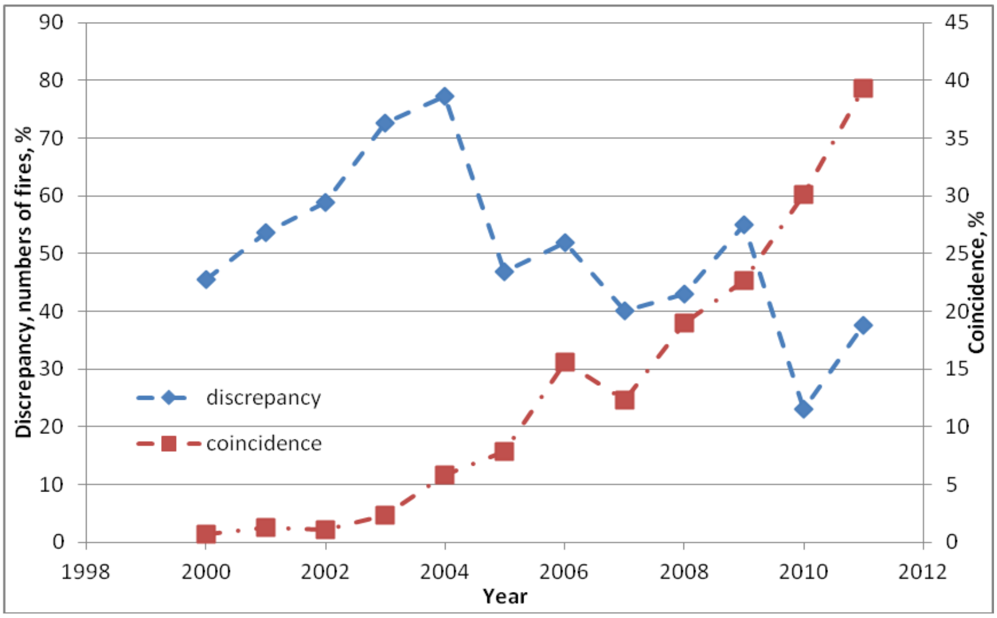

Figure 6: Comparison result diagram.

The result of the second method is presented in Figure 7. There are two fires: k-1000 in ISDM-Rosleskhoz and 8658 in Kaskad (2011, Krasnoyarsk region). The distance between the fires is about 980 metres. The last detection time is 21:44 and 16:23, respectively.

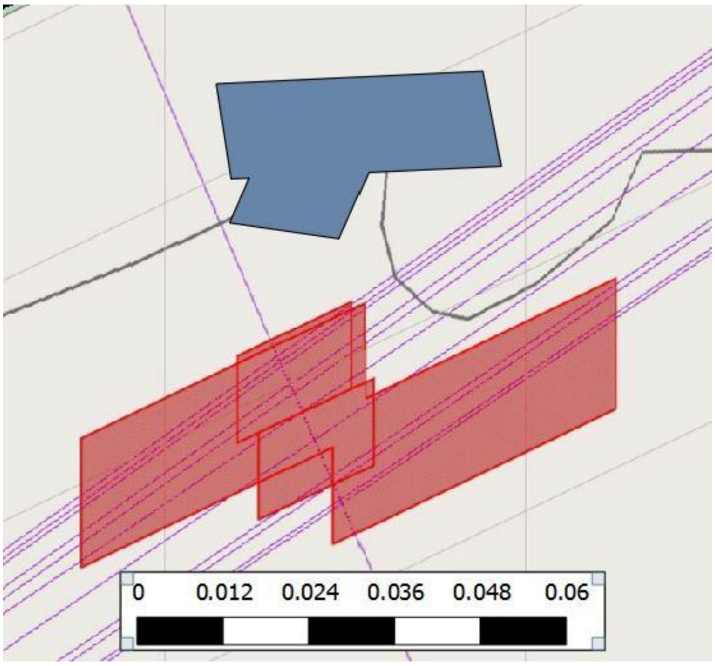

Figure 7: The same fires observed in different systems. Scale numbers are relative degrees latitude.

According to our system these fires are the same ones with a membership value of 0.93. The technique described is suitable for comparison of a pair of fires in any practical applications. For example, in the decision support system for firefighters, which has been developed by our research group (4), we have envisaged the possibility of using this technique. We believe that this measure could improve the effectiveness of the system.

CONCLUSIONS

Remote sensing and monitoring wildfires are very important parts of fire management, especially in the huge Russian Federation territory. There are three main remote monitoring systems used in Russia. We propose two methods of remote monitoring system data processing. The first method allows us to compare some period results as a set. The second method is intended for operational use. Both methods have been tested on the two systems data. The study showed that there are considerable contradictions between the two systems. The main results of our investigation are:

1. Compliance between systems has been increasing, but not enough yet.
2. For practical applications it is better to load data from various systems and check all fires to be taken into account.

The next task to be investigated in detail is a comparison criterion. It is planned to obtain data from SFMS and to carry out a comparison of three systems or, maybe, include data from FIRMS.

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