COMPARISON OF FIRES DETECTED BY SATELLITE AND IN-SITU DATA IN SCANDINAVIA

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Abstract

We compared fires detected by different satellite systems with in-situ data mainly for Finland from year 2002 to year 2005. We had access to fires detected by the Finnish detection system for AVHRR images developed by VTT (Technical Research Centre of Finland), the MODIS based system developed by NASA and the University of Maryland, and the (A)ATSR based system developed by ESA. For in-situ data, we have at our disposal the database of reported Finnish fires and information about fires detected by the VTT system. We found that very few fires detected by satellite can be matched with fires from in-situ data or fires from other satellite systems. Furthermore, most of the hot spots are from controlled burning and are not reported in the Finnish fire database.

INTRODUCTION

Satellite based fire and thermal anomaly detection systems are indispensable for both research and operational use. Satellite instruments that have a channel around 3.9 microns can be used (e.g. Dozier 1981, Matson and Dozier 1981). Most operational systems use NOAA/AVHRR data that has been readily available for years. Lately systems based on MODIS and SEVIRI data have been proposed and implemented. However, all satellite based fire detection systems have their shortcomings. There are lower limits for fire sizes that instruments can detect. Fires cannot be detected through clouds. A polar orbiting satellite cannot see brief fires that take place between the satellite overpasses. Geostationary satellites have better temporal resolution, but worse spatial resolution and have problems when scanning at high viewing angles.

The main purpose of this study was to assess the in-situ information of forest fires as the ground truth for satellite based fire detection systems. Because we concentrated on Nordic countries, mainly on Finland, we studied only polar orbiting systems.

SATELLITE BASED FIRE DETECTION SYSTEMS

We had the access to fires detected by three detections systems: (1) the system based on AVHRR, developed by VTT (Technical Research Centre of Finland) (Rauste 1997), (2) the system based on MODIS, developed by NASA and the University of Maryland (Giglio et al., 2003), (3) the system based on ATSR and AATSR, developed by ESA. The results of NASA/MODIS and ESA/AASTR systems are freely available and can be downloaded from the Internet. Results of the VTT/AVHRR systems have not been published, but were made available as unpublished reports (Rauste 2001, Rauste 2002, Rauste 2003, Rauste 2004, Rauste 2005). For VTT/AVHRR and ESA/AASTR the results consisted of the coordinates and the time of detected hot spots. For NASA/MODIS we used the level 3 8-day daily composite product that meant we also had the information of cloud cover and the quality of detection. By using the level 3 product, we lost the exact time of the fire detection as the fires are only reported in the one day intervals, but we didn't consider this to be a major flaw. We did not use the quality

information in level 3 files, but used all fire pixels available. For the ESA/AASTR system, results of two algorithms were available, in this study we used the results of the algorithm 2. The original idea was to compare fires from all satellite systems for all years when MODIS data was available, but because of the problems of the in-situ data (see below), only years from 2002 to 2005 were used for the comparison.

In Figure 1, hot spots from the ESA/AASTR system for years 2000-2005 are shown. The number of fires is quite limited compared to other systems, maybe because of the very simple algorithm. Hot spots over the sea are from the oil platforms.

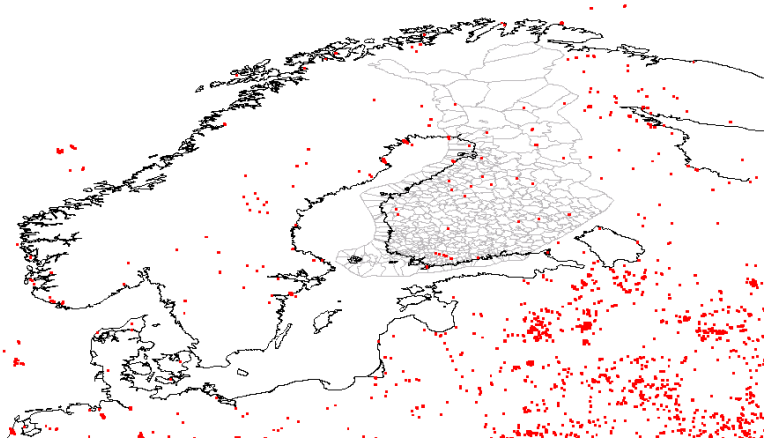

Figure 1: **Hot spots from the ESA/AATSR systems, years 2000-2005**

In Figure 2, hot spots from the VTT/AVHRR system for years 2000-2005 are shown. Only hot spots in Finland, Sweden, Norway, Estonia, and to some extend Russian Karelia are available, others have been discarded. Oil platform fires are also filtered out. Compared to Figure 1, the VTT/AVHRR system see much more fires.

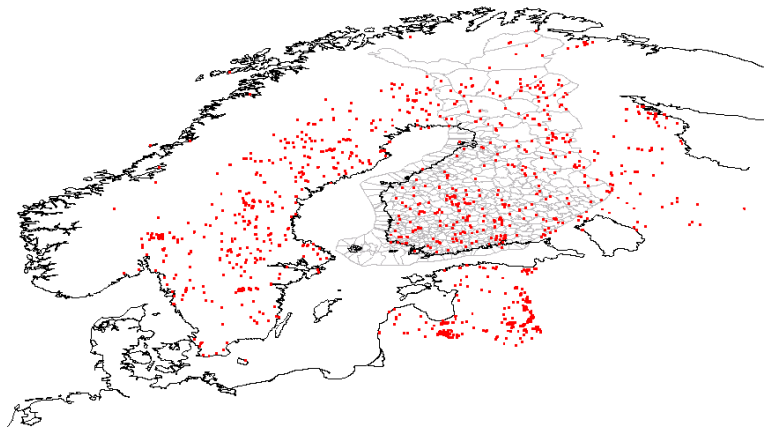

Figure 2: **The hot spots from VTT/AVHRR, years 2000-2005.**

In Figure 3, hot spots from the NASA/MODIS system for years 2002-2005 are shown. As is expected, because the MODIS instrument is the most sensitive to fires of three instruments in this study, the number of fires is greater than in the two previous Figures. Apparently, the fires over the sea have been filtered out.

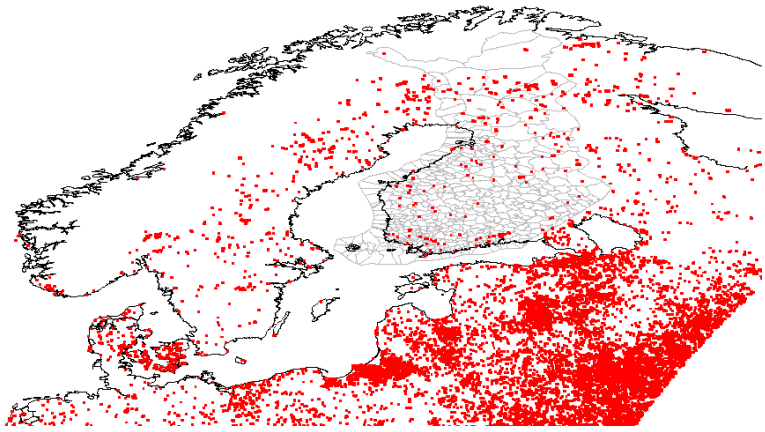

Figure 3: **The hot spots from NASA/MODIS, years 2002-2005. Please note that not as many years are included than in Figures 1 and 2.**

As the number of hot spots was much greater in NASA/MODIS products, it was necessary to join individual hot spots to aggregated fires to be able to do the meaningful intercomparison. Our algorithm for this was quite simple. Fires were connected to each other, if fires occurred the same day and the distance of hot spots was less than 0.015 degrees, which is about 5 kilometers in Finland. This is quite a relaxed condition and could be improved. However, we thought it is enough for the present study. In Table 1 the number of fires after the aggregation are shown. As expected, the aggregation process had the greatest effect on NASA/MODIS hot spots.

	Hot spots	**fires**
ESA/AATSR	51	47
VTT/AVHRR	274	237
NASA/MODIS	1034	378

Table 1: **Number of hot spots from satellites and aggregated fires from 2002 to 2005 in Finland.**

Factories and other known sources of thermal anomalies are filtered out from the VTT/AVHRR hot spots by VTT. There are not filtered out from ESA/AASTR or NASA/MODIS hot spots, but it was estimated their impact to our results is negligible.

IN-SITU DATA

For in-situ data, we have at our disposal the database of reported Finnish fires. The database covers years from 1985 onwards. Fire types include forest fires, peat fires, house fires etc. We decided not to use house fires in this study, as there are too many house fires and most of them are too small to be seen by the satellite instruments. The location information in the database can be coarse for our purposes: for most fires, older than a couple of years, only the municipality is known. However, most of the fires from years from 2002 to 2005 had high resolution location data and, as the result, the study was confined to this time period.

Another source of in-situ data is from VTT system: Authorities in Scandinavian and Baltic countries are notified of fires detected by the satellite with the request to report on the reality of fires.

COMPARISONS FROM IN-SITU DATA TO FINNISH FIRE DATABASE

For years from 2002 to 2005, there are almost 5000 fires in the Finnish fire database. Most of them are quite small, and unlikely to be detected by satellite instruments. So, when we try to match fires from to the database to fires detected from satellites, it is prudent to have some threshold for the smallest fire we hope to be able to match. In Table 1 the results of the attempt to match fires from the database to fires from satellites are presented.

the threshold for smallest fire	n	VTT/AVHRR matched	NASA/MODIS matched	ESA/ATSR matched
0.1 ha	**1490**	15	12	0
0.5 ha	**767**	14	7	0
1.0 ha	**428**	12	7	0
5.0 ha	**65**	10	5	0
10 ha	**25**	7	5	0

Table 2: **Comparison between the Finnish fire database and satellite systems.**

It is clear that not many pairs were found. Even if we limit our study to major fires, greater than 10 ha, less than one third VTT/AVHRR fires, only one fifth of NASA/MODIS fires can be matched, and no fires can be matched with ESA/AASTR fires. Two possible reasons come to mind: (1) Fires are very short-lived and occur between satellite overpasses. (2) Fires are obscured by clouds. The first hypothesis is appealing, but unfortunately it is hard to prove directly with our present data as the fire duration information is lacking in the database. For the second hypothesis data is available. In Figure 4 the cloud fraction for approximately the fire season 2005 is shown. The cloud fraction is calculated from the MODIS instrument on-board the TERRA satellite and was download using the Giovanni MOVAS service.

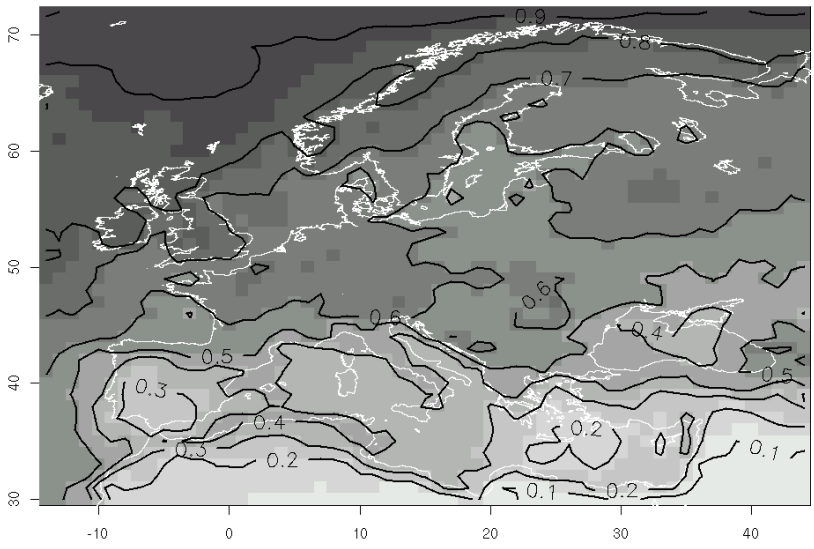

Figure 4: **The cloud fraction of MODIS/TERRA images from Giovanni MOVAS. Day time only algorithm is used for the period from 1st April to 30th September 2005.**

The cloud fraction in Finland is more than 0.6; if the clouds and fires are uncorrelated, this could cause problems for the satellite based fire detection as the odds of seeing cloud free surface would be less than one in two. However, there might be some correlation. To test this, for every fire in the Finnish fire database (years 2002-2005) we calculated the cloud fraction using the cloud mask information in the

level 3 fire products from NASA/MODIS (Figure 5). The cloud fraction was calculated for pixels inside the area of the municipality where the fire was reported.

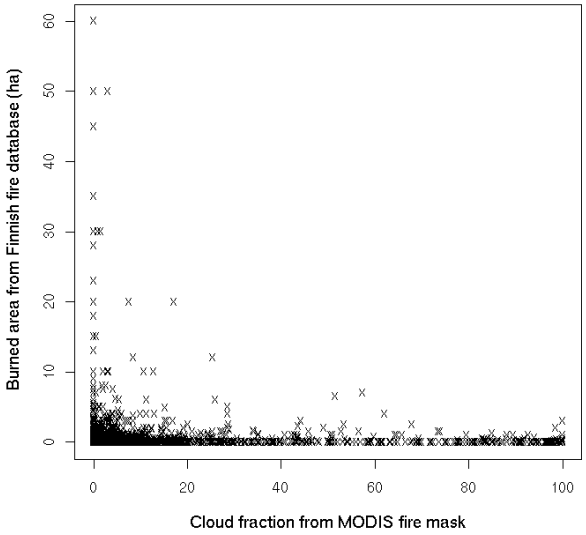

Figure 5: **The relation of the burned area of Finnish fires and the cloud fraction. Burned area from the Finnish fire database and the cloud fraction from MODIS fire product cloud information.**

It is quite likely, that the cloud mask from the fire product is not directly comparable to the general cloud mask, but it is reasonable to conclude that most large fires occur when there are very few clouds. Clouds should not be the biggest barrier for fire detection.

COMPARISONS FROM IN-SITU DATA TO VTT REPORTS

In Figure 6 fires from the VTT/AVHRR system are plotted colour coded with the reported fire type.

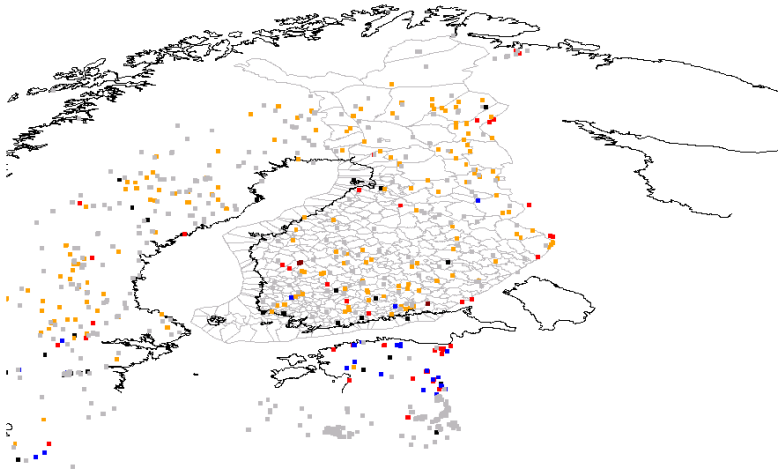

Figure 6: **Reported fire types for VTT/AVHRR fires (years 2002-2005). Red - forest fire, orange - prescribed fire, dark red - peat fire, blue -other, black - not real i.e. false alarm, grey - unknown i.e. not reported.**

Qualitatively, most of the known fires are prescribed. Forest fires and peat fires are only a small minority. In Figure 7, this is shown in more quantitative fashion.

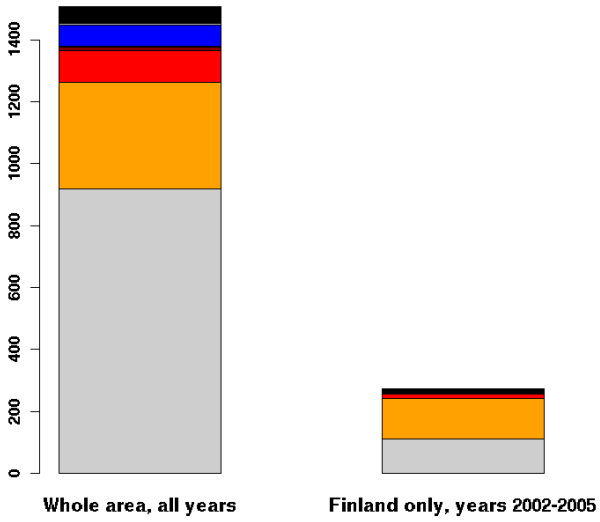

Figure 7: **Reported fire types for VTT/AVHRR fires (years 2002-2005). Red - forest fire, orange - prescribed fire, dark red - peat fire, blue -other, black - not real i.e. false alarm, grey - unknown i.e. not reported.**

Outside Finland, most of the fires remain unreported. Inside Finland prescribed fires are the clear majority, but these fires will not be in the Finnish fire database. So the idea to use the Finnish fire database as a ground truth for satellite based systems is flawed. Note that the amount of false alarms is quite small, which is encouraging.

COMPARISONS BETWEEN SATELLITE DATA

By matching the fires from different satellite systems we can see if the satellites see the same fires at all. In Table 3, 4 and 5 the comparisons between the NASA/MODIS and VTT/AVHRR systems, between the NASA/MODIS and ESA/AATSR systems, and between the ESA/AATSR and VTT/AVHRR systems are presented.

	NASA/MODIS		
VTT/AVHRR		yes	no
	yes	95	142
	no	283	

Table 3: **The contingency table for NASA/MODIS and VTT/AVHRR fires.**

	NASA/MODIS		
ESA/AATSR		yes	no
	yes	17	30
	no	361	

Table 4: **The contingency table for NASA/MODIS and VTT/AVHRR fires.**

	VTT/AVHRR		
ESA/AATSR		yes	no
	yes	6	41
	no	231	

Table 5: **The contingency table for NASA/MODIS and VTT/AVHRR fires.**

From the comparison it can be seen that the fires seen by different satellites vary a lot. This gives some credence to the hypothesis that the short life time of the fires is the main reason for the mismatch between the satellite based fires and the in-situ fires.

CONCLUSIONS

We found that it is tricky to match in-situ fires to satellite fires and it is also tricky to match fires from different systems based on different satellites. One reason for this are clouds, even if the major fires probably occur when there are very little clouds. The other reason is that fires are relatively short lived, so satellites with different orbit see different portion of fires. However, there is very little information on the duration of fires, so this is speculative. One of the aims of this study was to assess the suitability of Finnish fire database as a ground truth for satellite based detection systems. Unfortunately, the most of the potential hot spots will not be in the fire database, as most of the hot spots in Finland are caused by the controlled burning.

There are still areas for refinement and further study. For example, for ESA/AATSR and NASA/MODIS, we did not filter out hot spots caused by industrial areas etc. And in the matching between in-situ and satellite fires, our matching methods were relatively crude, if sufficient. We should include house fires in the matching of in-situ data and satellite data. These refinements should not alter our conclusions, though.

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