A new approach to fire detection by geostationary sensors based on temporal background

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Abstract

Fires are an important and highly variable source of air pollution in many regions of the world, significantly controlling the inter-annual variability of the atmospheric composition. Remote sensing constitutes the most effective way of operationally monitoring active fires over continental areas. Traditional procedures are based on heritage from contextual algorithms designed for polar, sun-synchronous instruments, namely NOAA/AVHRR and MODIS/TERRA-AQUA. These algorithms are based on radiative signatures in the MIR and TIR channels. A potential fire pixel is compared with the neighboring ones and the decision is made based on relative thresholds of brightness temperature.

This traditional approach is on the basis of the Fire Detection and Monitoring (FD&M) and the Fire Radiative Power (FRP) products that are currently being generated on an operational basis by the Satellite Application Facility on Land Surface Analysis (LSA-SAF). This type of approach, however, does not take advantage of the high temporal resolution (15 min.) that is available for the SEVIRI instrument. On the other hand, because of the coarser spatial resolution (3km at sub-satellite point) of SEVIRI when compared with polar orbiters (e.g. 1km for MODIS), the buffer area that is used for defining the background is several times larger and usually encompasses different types of land cover.

We propose an algorithm that makes use, for each pixel, of temporal information of brightness temperatures in SEVIRI channels IR3.9 and IR10.8. A temporal background is then defined based on the statistical behavior of daily values as observed in the preceding 10 days at the considered time. Such an approach has the advantage of making use of SEVIRI high sampling frequency and of taking into consideration changes in the radiometric signal associated to the daily cycle of brightness temperatures that are particularly large for several land cover types.

A feasibility study is presented together with a performance assessment taking the MODIS Thermal Anomalies & Fire product for reference. Results obtained are also compared against the ones from the FRP product.

Introduction

Most fires burn at temperatures between 500 and 1200 K leading, in accordance with Wien's displacement law of blackbody radiation, to a very strong emission in the middle-infrared (MIR) at wavelengths of 3-5 µm, as opposed to the background where the peaks of emission are located in the thermal infrared (TIR) at wavelengths on the order of 10 µm.

Recent remote fire detection methods rely on contextual algorithms where values of thresholds of the MIR and TIR channels are dynamically derived using appropriate statistics obtained from neighbouring pixels; if the contrast between a given pixel and its surroundings is high enough, then the pixel is flagged as containing an active fire. These algorithms undergo 2 main steps: first, a pixel is flagged as a potential fire by simply applying appropriate thresholds to MIR and TIR channels; a potential fire pixel is then confirmed as a pixel containing an active fire by comparing its spectral signature against the radiative properties of the respective background.

Data

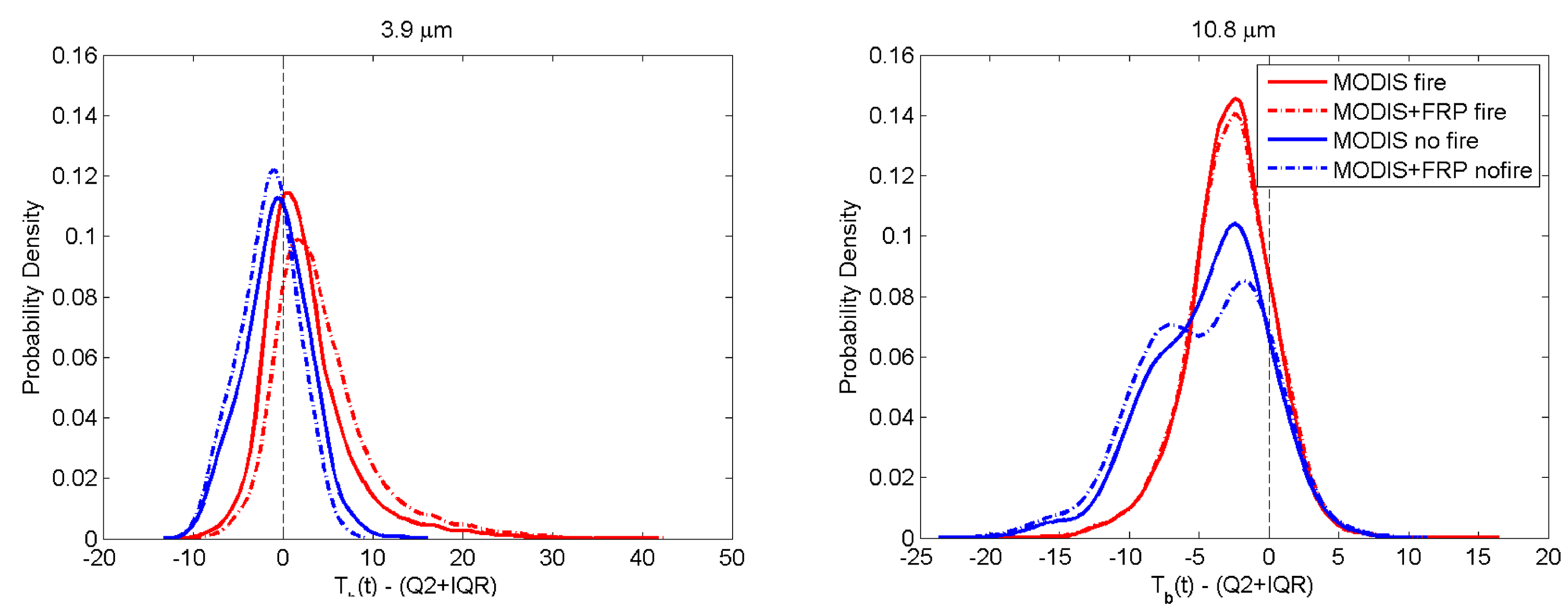
The present study is based on SEVIRI imagery from a fixed spatial window defined in the Meteosat disk that encompasses Northern Africa (NAfr). Remote-sensed data covers the period of January 2013, corresponding to the period of highest fire activity. The observed TOA infrared radiances from channels IR3.9 and IR10.8 were converted into brightness temperatures (Tb).

Two different fire detection products are used as baselines for comparison: 1) NASA's MODIS Thermal Anomalies & FIRE from both AQUA and TERRA satellites (MOD/MYD14) and 2) LSA-SAF's Fire Radiative Power (FRP) that uses observations from SEVIRI. Two learning databases were constructed based no MODIS product: one containing MODIS detected fires, referred hereafter as "MODIS fire", and the other containing clear MODIS pixels, referred as "MODIS no fire". In both cases, each MODIS L2 swath pixel is re-project to the closest SEVIRI pixel. A given MODIS pixel is considered as "MODIS fire" if: MODIS view zenith angle (VZA) is lower than 40º and the observation is performed within ±5 minutes of SEVIRI observation. A MODIS pixel is considered a "MODIS no fire" if: MODIS VZA is lower than 20º, the pixel and all surrounding SEVIRI pixels are clear of MODIS fires and the observation is performed within ±5 minutes of SEVIRI observation.

Results

The proposed method makes use of a temporal background for the fire confirmation, instead of the traditionally used spatial background. The background is set by computing the median (Q2) and interquartile range (IQR) for observations in the 10 days preceding the instant under analysis t, at the same time of day. The statistics are only applied to pixels classified as cloudless, not affected by sunglint or high reflectivity and considered as containing no potential fires. A given pixel is considered to contain a potential fire using a procedure similar to the one being operationally used by FRP, based on brightness temperature thresholds that depend on sun zenith angle and applying a high pass spatial filter. A potential fire pixel is then confirmed as an active fire if the MIR (TIR) brightness temperature is higher (lower) than Q2+IQR of the preceding 10 days.

Figure 1 shows the distribution of the difference between the brightness temperatures of the MIR and TIR channels and the respective Q2+IQR for the "MODIS fire" and "MODIS no fire" datasets. Results are only shown for potential fire pixels and it is worth noting that pixels were also checked for FRP fires.



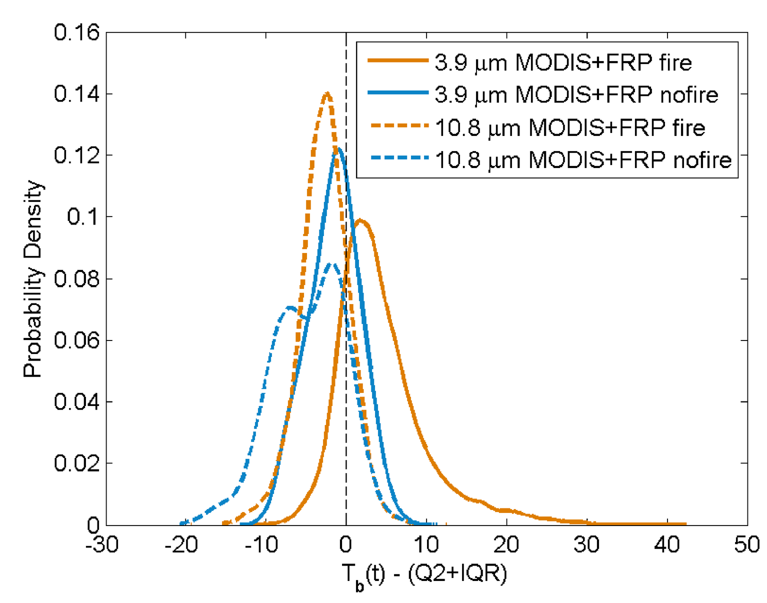


Figure 1 - Probability density of pixels of the diference between brightness temperatures of the MIR (3.9 µm) and TIR (10.8 µm) channels and the respective median plus interquartile range (IQR) of the preceding 10 days.

For "MODIS fire", there is a shift of the distribution towards positive values for the MIR channel (top left panel) but there is no change in the case of the TIR (top right panel), as expected. This shift is particularly significant if we consider only the pixels where MODIS and FRP are in agreement (bottom panel), increasing the confidence of the detections.

Table 1 shows counts of pixels from both datasets that are confirmed as fires by the proposed algorithm. The respective Probability of Detection (POD) and False Alarm Ratio (FAR) are defined as:

$$POD = \frac{\text{SEVIRI fires that are also MODIS fire}}{\text{Total MODIS fires}} \qquad FAR = \frac{\text{SEVIRI fires that are not MODIS fire}}{\text{Total SEVIRI fires}}$$

Table 1 - Counts of "MODIS fire" pixels (top row) and "MODIS no fire" pixels (bottom row) that are a SEVIRI potential fire and confirmed fire, and respective POD and FAR. Values for the FRP product are shown in brackets.

			SEVIRI			
			Potential Fire	Fire		
MODIS	Fire	59710	12373	6316 (7025)	10.6 % (11.8 %)	POD
	No fire	97691	509	155 (151)	2.4 % (2.1 %)	FAR

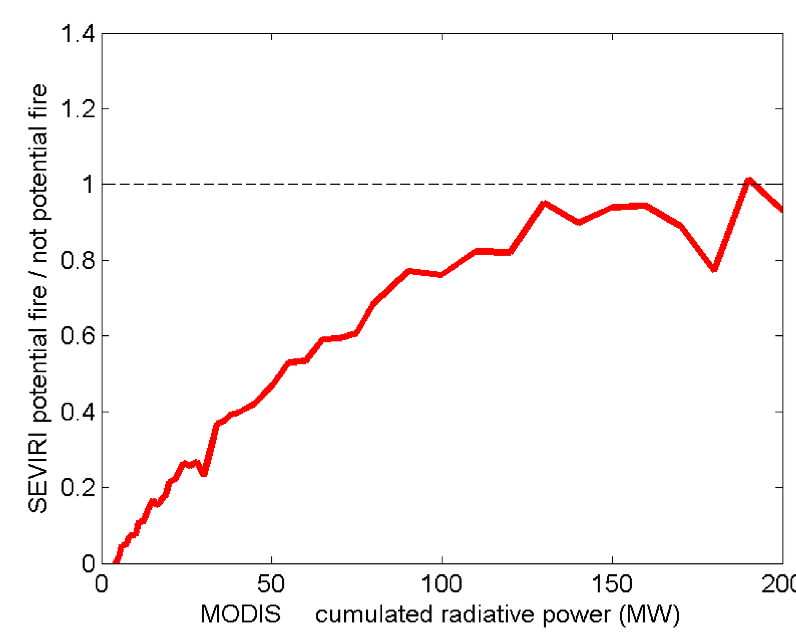


Figure 2 - Ratio of the number of SEVIRI potential fire to the number of not potential fire pixels as a function of MODIS accumulated fire radiative power (in MW) within the SEVIRI pixel (only shown up to 200 MW).

For comparison, the results for FRP are also shown (in brackets). Values of POD and FAR are very similar to the ones obtained with FRP. The low POD value may be attributed to the fact that only 20% of MODIS fire pixels are identified as potential fires by SEVIRI. This is to be expected given the coarser resolution of SEVIRI that makes difficult the identification of small fires. This effect is clear in Figure 2, where the ratio of the number of potential fire pixels to the number that are not potential fires is shown as a function of the cumulated radiative power of MODIS fires. It may be noted that very small fires are very seldom detected and that the ratio of the number of potential to not potential fire pixels is only close to 1 for power values from ~130 MW onwards.

Concluding remarks

Geostationary satellites have a coarser resolution than polar orbiters but present the advantage of having a much higher resolution in time, a feature that is particularly adequate for wildfire monitoring.

The higher temporal resolution of the SEVIRI instrument (one image every 15 min) is on the basis of the algorithm for fire detection here presented. The aim was to develop an alternative procedure to the one currently used by operational algorithms that are based on contextual tests performed in a buffer centered on a pixel that is considered as containing a potential fire. The proposed temporal algorithm avoids the difficulties related to the coarse resolution of SEVIRI (3 km at the sub-satellite point) where there is an increased likelihood of having distinct types of land cover and land characteristics in the defined buffer around a potential fire pixel.

When compared with results from the MODIS sensor, those obtained with the proposed algorithm present a level of performance that is similar to the one of the currently operational Fire Radiative Power product of the LSA SAF.

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