POTENTIAL FIRE DETECTION BASED ON KALMAN-DRIVEN CHANGE DETECTION

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1. INTRODUCTION

Geostationary sensors, such as the SEVIRI instrument found on the Meteosat Second Generation (MSG) satellites, allow us to monitor earth surface properties at a high temporal resolution. Of particular interest to active fire detection is the Diurnal Temperature Cycle (DTC), which is a profile of the observed brightness temperature throughout the day at a given location. In this paper, a change detection algorithm is proposed which detects abnormal increases in temperature in the observed DTC; these increases are typically indicative of fire events. This approach considers an individual pixel without taking into account the condition of its neighbouring pixels, as opposed to the typical contextual fire detection algorithms.

Two different change detection algorithms are compared: one based on the standard Kalman filter, and one based on the extended Kalman filter. The Kalman filters are used to predict brightness temperatures one step ahead; the difference between the observed and predicted temperatures can then be used to flag potential fires.

2. BACKGROUND

The SEVIRI instrument has a 3.9μm channel, which is well suited to observing temperatures in the range of the earth's surface temperature, which implies that this channel can reveal regions with abnormally high temperatures. Several active fire detection methods have been applied to SEVIRI data, with contextual algorithms appearing to be quite popular despite SEVIRI's large pixel size. These contextual method often depend on fixed thresholds that may have to be adjusted either regionally, or seasonally, such as the approach used in the AFIS system [1]. Alternatively, conservative thresholds (different thresholds for nighttime and daytime) can be used, such as the approach used by the EUMETSAT FIR product [2], but this may not yield optimal detection rates for smaller fires. Another algorithm that relies on a combination of solar zenith angle heuristics and fixed thresholds was presented by Roberts *et al.* [3].

The requirements of active fire detection systems vary, with some systems placing an emphasis on early detection (*e.g.*, the AFIS system) at the risk of a possible increase in the false positive detection rate. Other systems may prefer to obtain more certainty, which may imply that active fires may only be detected after more observations have become available. In this paper the emphasis will be on early detection methods, often referred to as *potential fire detection* methods.

In a departure from the contextual approach, several change-detection based methods for SEVIRI have been proposed. A Kalman filter tracking approach was introduced by Van den Bergh and Frost [4]; this idea will be further developed in this paper. Another change-detection based method has been introduced by Calle *et al.* [5]; their method approximates the emissivity in the 3.9μm channel, which allows the solar contribution to be removed. After this preprocessing step, a potential fire can be detected by comparing the current brightness temperature with that of the previous day at the same time of day. Lastly, a method that directly tests the difference between successive brightness temperatures against fixed thresholds has been proposed by Laneve *et al.* [6].

3. METHODS AND DATA

Data collected using the Spinning Enhanced Visible and Infrared Imager (SEVIRI) instrument were used because of the sensor's high temporal resolution (15 minutes). MSG level 1.5 data were obtained from the EUMETSAT archive [1] over the region (20 S, 23 E) to (33 S, 38 E). The data correspond to a period spanning from 2007/07/31 to 2007/08/14. There were numerous fire events in this region during this time.

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3.1. Change Detection Algorithm

The method proposed by Van den Bergh and Frost [4] used an empirically derived DTC model to drive a simple Kalman filter, which was used to predict the expected brightness temperature at a given pixel, at a given time. Potential fires were detected by testing the difference between the observed temperature and the predicted temperature against a fixed threshold.

The method introduced in this paper extends that method by using a more sophisticated analytical DTC model, developed by Göttsche and Olesen [7], to serve as the underlying model for the Kalman filter. In addition, the simple Kalman filter has been replaced by the extended Kalman filter, which is expected to track the non-linear behaviour of the DTC profile with greater accuracy.

A residual temperature is computed at each time step by subtracting the one-timestep prediction of the extended Kalman filter from the observed temperature. Instead of using a fixed threshold to detect abnormally large residuals, an adaptive threshold is computed using a sliding window. The window includes residuals immediately preceding the current sample, as well as samples from a similar window at a 24-hour lag (*i.e.*, from the same time the previous day). This adaptive threshold is able to compensate for the diurnal changes in the variance of the residuals. The residuals (at each time step) were experimentally found to have a t-distribution, which is in agreement with previous experiments [4]. This distribution can be used to assign a confidence value to an observed residual, which can be used to derive an overall indication of the algorithm's confidence of detecting a potential fire.

4. RESULTS

As a first experiment, the potential fire detections reported by the two Kalman filter based algorithms have been compared to the fires reported by the MODIS MOD14 fire product. Only fires reported during the two observations closest in time to the MODIS overpass (one before, one after) were considered to make the comparison more meaningful. The result of this comparison is presented in Table 1. The *true positive* columns denotes fires that were detected in SEVIRI pixels that overlapped with corresponding MODIS detections in the MOD14 fire product. The *unconfirmed* columns denote potential fires that were reported by the Kalman filter based algorithms that did not correspond to active fires in the MOD14 product. These detections could be false positives, or they could be fires that were missed by MOD14 but picked up by SEVIRI in the next observation right after the MODIS overpass. Validation using burn scars is still underway, so these are merely counted as potential false positives for now.

Table 1. Results of change detection using Kalman filter (SKF) and the extended Kalman filter (EKF) at the time of the MODIS overpass, compared to the MODIS MOD14 fire product.

Date	MOD14 Fire products	SKF-Change detection		EKF-Change detection	
		True Positive	Unconfirmed	True Positive	Unconfirmed
2007 − 07 − 31	3044	1975 (65%)	21	2092 (69%)	13
2007 − 08 − 01	1983	1379 (70%)	18	1251 (63%)	17
2007 − 08 − 02	1178	711 (60%)	4	796 (68%)	4
2007 − 08 − 03	918	616 (67%)	9	658 (72%)	5
2007 − 08 − 04	2106	1216 (58%)	34	1532 (73%)	21

5. CONCLUSION

A new potential fire detection algorithm, based on an extended Kalman filter driven by an analytical DTC model, was introduced. This algorithm detects fires by comparing the expected temperature at a given time to the observed temperature. This version of the algorithm was experimentally compared to an older version based on the standard Kalman filter.

The extend Kalman filter algorithm was able to detect anomalies in the DTC profile, indicating potential fires, that could not be detected by the standard Kalman filter algorithm. Assuming that the *unconfirmed* detections are indeed false positive detections, then the extend Kalman filter based algorithm has further demonstrated a slight reduction in its false positive detection rate, compared to the standard Kalman filter algorithm. Despite the algorithms' lower detection rate, compared to MODIS, they have the advantage of a much more frequent updates.

6. REFERENCES

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