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ENHANCED ESTIMATION OF BACKGROUND TEMPERATURE FOR FIRE DETECTION USING NEW GEOSTATIONARY SENSORS

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ABSTRACT

ENHANCED ESTIMATION OF BACKGROUND TEMPERATURE FOR FIRE DETECTION USING NEW GEOSTATIONARY SENSORS

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Recent increases in the frequency and intensity of active fire has heightened the importance of remote sensing as a source of early warning information for fire incidents. The launches of new geostationary sensors, such as Himawari-8 over the Asia-Pacific, have vastly increased the information available with which to detect and attribute these incidents, with observations every 10 minutes possible over key parts of the electromagnetic spectrum (3.8 -- 4µm). Remotely sensed fire products such as Sentinel Hotspots and the MODIS active fire product have focussed upon use of contextually derived background temperatures for isolating hotspots, dictated by the low temporal frequency of available images. This research proposes a new paradigm in fire detection, which utilises the increased temporal resolutions of geostationary sensor imagery to provide a baseline dataset for land surface temperature estimation based upon location and time of day. To achieve this, a multi-temporal diurnal characterisation of temperature is calculated for each pixel based upon a large area latitudinal transect. Hot spot anomalies are then identified based upon the deviation of the location's temperature from the expected diurnal cycle. Validation of the fire detection algorithm has focussed upon case study fires from the 2016/17 fire season, by way of inter-comparison with commonly used MODIS and VIIRS active fire products, and a burned area product. Results show increased capability for early fire detection using the new algorithm in comparison to traditional single image contextual algorithms employed for polar orbiting systems. Other advantages include notable resilience to sources of occlusion such as cloud and smoke. Further research will focus on the wider application of this method across the Australian continent and methods for countering more challenging detection conditions.

1. INTRODUCTION

The use of remote sensing for fire detection is an increasingly important tool for emergency services and land management agencies, to ensure adequate warning is given to the public, and to plan fire mitigation and asset protection strategies. The introduction of new geostationary satellites such as the Advanced Himawari Imager (AHI) onboard Himawari-8 provides a dramatic improvement of fire detection capability over previous geostationary sensors, with increases in temporal resolution and reductions in the spatial footprint over previous geostationary sensors (Xu 2017 and Hally 2016). This increased capability, along with a far larger pool of information about the characteristics of the land surface during the diurnal cycle, allows us to attempt innovative methods for early fire detection.

This paper presents a case study of fire detection over a portion of northern Western Australia during August 2016. The study uses the method outlined in Hally et al. (2017) to provide a fitting of the background land surface temperature of an individual pixel using training information gathered from areas of similar latitude. This fitting then has a simple threshold placed over it to determine pixels affected by positive thermal anomalies, which may be indicative of fire. This study compares fire detection results back to a commonly used burned area product developed for the study area (Maier, 2010), and describes some of the issues involved with fire detection using temporal-based techniques.

2. METHOD

2.1 STUDY AREA

The study area is situated in north-western Australia, bounded by latitude 15°S and 20°S and longitude 125°E and 130°E, as shown in Figure 1. This area, straddling the NT-WA border, comprises of open savannah woodlands in the north, with dry and arid areas further south. The study period was during the northern dry season, from 1st to 28th August 2016, when a significant portion of yearly fire activity occurs and cloud cover in the area is limited in comparison to other times of the year. This minimises the effects of cloud activity on diurnal model fitting, and provides an indication of the method's utility in optimal conditions.

2.2 DATA AND INTERCOMPARISON

The study utilises medium wave infrared imagery (Band 7, 3.8 - 4μm, 2km x 2km pixels) from the AHI for the period of August 2016. Pixels were randomly selected for location and time, and a cloud mask based upon CLAVR-x (Heidinger, 2004) was applied to eliminate cloud affected pixels. Once a pixel is identified as non-cloud affected, a 24-hour period of brightness temperature from each pixel was fitted using the Broad Area Training method described in Hally et al. (2017). Anomalies were identified as brightness temperatures that exceeded the fitted background temperature by more than 4 Kelvin. This threshold was selected based upon initial analysis of differences between background temperatures and fire detections in the study area.

To obtain information about the commission and omission rates of the method, the recorded potential fire detections were compared to a burned area product sourced from the TERN AusCover project, as outlined in Maier (2010). This burned area product uses MODIS imagery to determine locations and times of fire-induced change. The times and locations of AHI detections were related to this burned area product, with emphasis placed upon examination of burned area detections that occurred in the 48 hours after the AHI fitting commences. To minimise the effects of co-registration issues causing burned areas to be missed, a buffer of one pixel was used around each AHI detection.

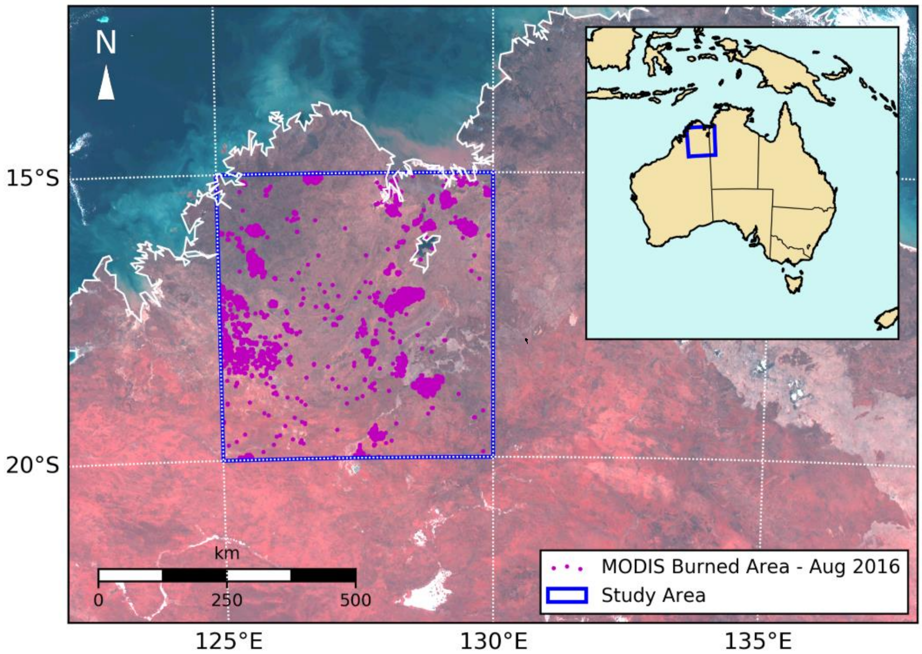

Figure 1 - Map showing the location of the study area and the location of burned area detections taken from the TERN AusCover MODIS Burned Area product for August 2016.

2.3 EXAMINATION OF DETECTION CAUSES

A consistent issue with the use of this method for fire detection is the correct attribution of perturbing influences. To examine these influences, a visual assessment was conducted on AHI pixel fittings that were determined as detections. Anomalies were classified by the apparent cause of the anomaly: (1) clouds not detected by the cloud product used, causing poor fittings; (2) fires, which appear as sudden increases in temperature in the diurnal observation set; and (3) anomalies which have no obvious explanation, which could be considered the actual commission rate. Examples of fittings displaying these behaviours can be found in Figure 2. These classification sets were split by the existence of a burned area product detection within the study period after the start of each temperature fitting.

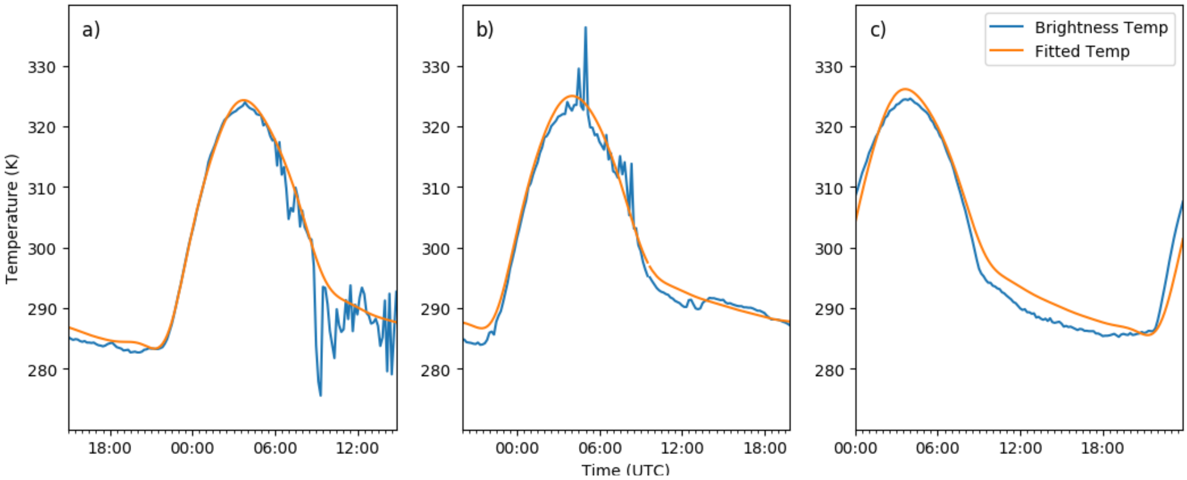

Figure 2 - Examples of the classifications used to determine the cause of detection – a) shows a fitting affected by cloud, which lowers the mean brightness temperature of the diurnal cycle and causes false attribution when temperature returns to normal; b) shows a temperature profile typical to fire, with a sharp initial spike in temperature; and c) is an example of a detection with neither cloud nor fire as an obvious cause.

3. RESULTS

Initial analysis of detections found a raw detection rate using this method on AHI imagery of around 0.6% of all fitted pixels over the study period. For the same period, the burned area product recorded approximately 4% of the study area as being fire affected. The rate of AHI fire detection correlates well with the burned area figures, as fire activity may continue in a pixel over many days. Table 1 depicts the breakdown of possible causes of detections from the 602 pixels that have detections. From the pixel fittings that recorded a detection, around 63% of those had an associated detection in the burned area product at the same location or immediately adjacent to it. In cases where a burned area detection is present or adjacent, obvious fire activity accounts for 79% of AHI detections. The cloud mask used in this study misattributes almost 15% of detections in this case. Where a burned area detection does not exist, fires account for approximately 7% of AHI detections, with two thirds of AHI detections in this case due to poor model fitting caused by cloud.

TABLE 1 - CAUSES OF ANOMALIES IN THE 4K DETECTION DATASET DETERMINED BY VISUAL ASSESSMENT. A FITTING APPEARS IN THE BURNED AREA COLUMN IF EITHER THE PIXEL IN QUESTION OR AN ADJOINING ONE HAVE A CORRESPONDING BURNED AREA DETECTION DURING THE STUDY PERIOD

Anomaly Type	Burned Area Detection	No Burned Area Detection
Fire	79.2%	7.2%
Cloud	14.5%	66.8%
Other	6.3%	26.0%
Total	379	223

Separating out AHI detections that occur within the 48 hours prior to a burned area detection shows that 96% of all AHI detections determined to be caused by active fire. Based upon the visual assessment of detections the commission rate (the percentage of detections not explained by fire or cloud) of this method for fire detection is 26%.

4. DISCUSSION AND CONCLUSION

This study assesses the ability of the AHI geostationary sensor to detect fire, with verification against a commonly used burned area product. The method used here does demonstrate a relatively high commission rate, but this is less of a concern in an early detection system, where ensuring complete capture of potential hotspots remains the primary concern. Whilst this demonstration is meant to be assessing the algorithm's effectiveness on clear sky days, deficiencies in the cloud mask used, both in commission and omission, mean that the set of results given here may not be wholly reflective of results under ideal weather conditions. A review of effective cloud masking for the AHI sensor is required to improve the accurate flagging of cloud-affected model fittings.

This cloud masking issue is also apparent when breaking down the time of day of AHI detections which have no apparent cause. Of the 602 total detections in the 4K threshold set, 82 of these had no obvious explanation – detections were caused by an inability of the diurnal fitting model to adapt to changing conditions in a pixel, especially in the case of anomalous physical phenomena. Out of the 82 anomalous fittings, 59 of the detections occurred immediately after sunrise, when the brightness temperature of a pixel changes most dramatically. The propensity of the fitting model to produce false detections during the morning was noted in a similar study by Roberts & Wooster (2014), who attributed the anomalous detections to increased solar reflection off low cloud. If a significant portion of the false detections in mornings are related to this phenomenon, the true commission rate of the method would reduce even further.

The visual assessment of the 4K dataset seems to confirm the effectiveness of the MODIS burned area product in this area. Most of the AHI detections associated with a burned area detection have active fire in them, and those without a burned area detection have active fire in only 7% of cases. These figures are encouraging given the spatial disparity between the two products – the burned area product works with low earth orbit data, which is of a much higher spatial resolution. The results seem to suggest that the advantages of the increased temporal resolution available from the AHI sensor outweigh the coarser spatial resolution of the available imagery.

Further expansion of this work will look to address the effectiveness of this fire detection method versus commonly used low earth orbit active fire products, such as those from MODIS and VIIRS, to ascertain the ability of the method to provide synchronous fire detection. This work will also look to extend the evaluation of the method to other areas of Australia, with a focus on the heavily populated coastal areas of south-eastern Australia.

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