FINAL PROJECT REPORT
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ACTIVE FIRE DETECTION USING THE HIMAWARI-8 SATELLITE

Final project report

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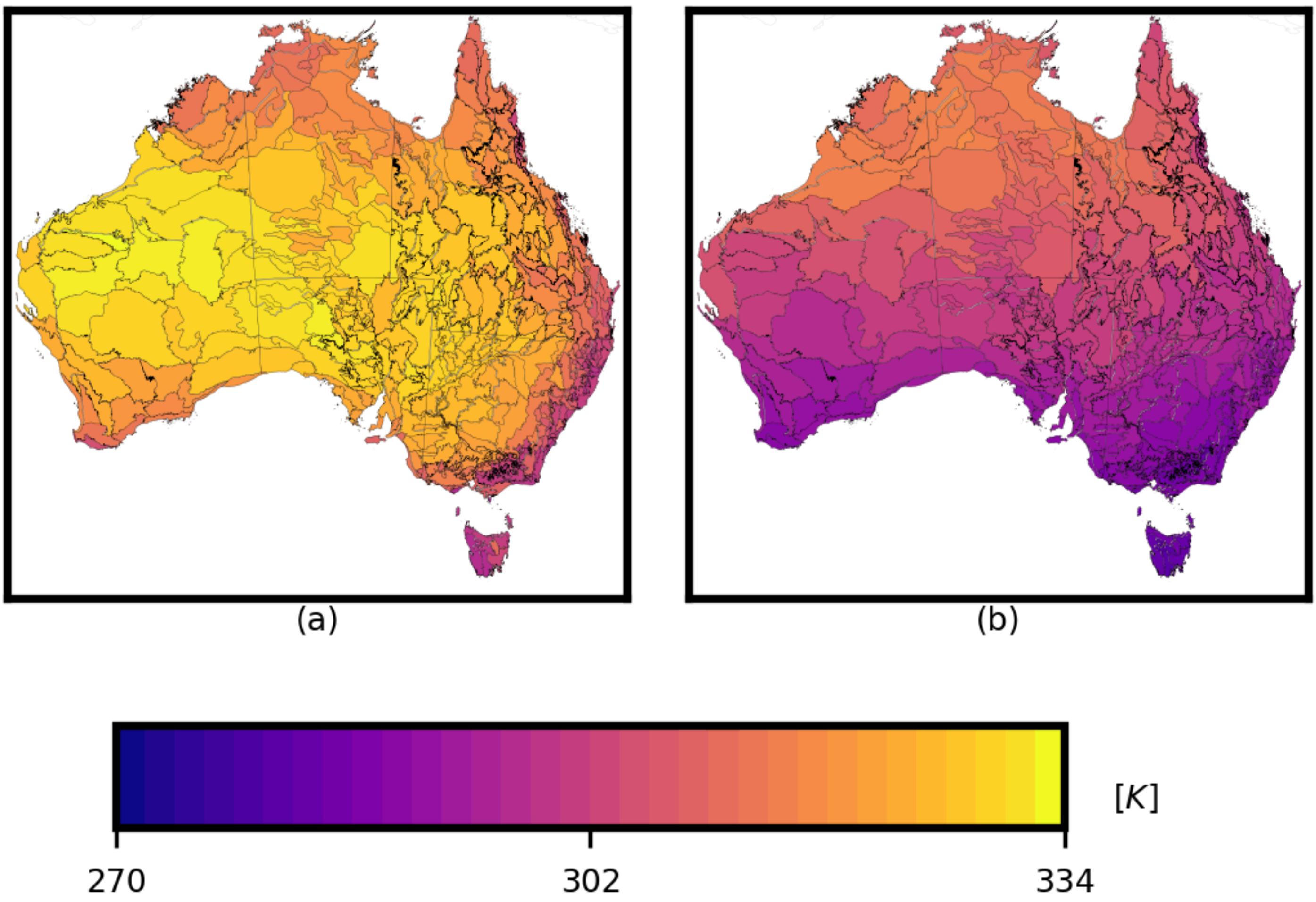
RMIT University & Bushfire and Natural Hazards CRC



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Cover: Maps of 04:00 UTC (14:00 EST) Bright media 3.9μm threshold values per interim biogeographical regionalisation of Australia (IBRA) sub-region for a) early-summer and b) early-winter, demonstrating the spatial and seasonal variations in Bright threshold values.

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ACKNOWLEDGMENTS

The project team gratefully acknowledge the assistance of end-users from across Australia including Naomi Withers and Stephen Salathiel from the Victorian Department of Environment, Land, Water and Planning, and Geoscience Australia, respectively, and in particular Stuart Matthews from the New South Wales Rural Fire Service, for supporting and hosting a near-real time trial of the new Himawari-8 hotspot algorithm. Acknowledgements also go to the National Computing Infrastructure (NCI) and RMIT (EOS) for providing important computing resources to support rapid processing of imagery and also to the Bureau of Meteorology for the real time access to Himawari-8 imagery. Each of these agencies' contributions facilitated timely improvements to the algorithm and enabled the practical and scientific merits of the solution to be demonstrated. The project team would also like to acknowledge the RMIT cloud computing team for their support while setting up and executing the 12-month verification dataset.

EXECUTIVE SUMMARY

Satellite sensors are an important source of observations of fire activity (or hotspots). Next generation geostationary satellites (Himawari-8, GeoKompsat 2A, GOES-16/17) provide earth observations very frequently (~every 10-minutes). This near-real time data provides opportunities for new and improved fire detection algorithms. Early fire detection algorithms that take advantage of such high frequency observations, and that are primed for Australian landscapes, are developed under this project.

The performance of new fire detection data forms part of the development phase. How well do they perform? What are their limitations? What are their advantages for observing fire under different fire scenarios and in different landscapes? One aspect of evaluation is how does the algorithm, and implementation of the algorithm as a processing chain, perform under operational circumstances. To this end, an end-user trial was hosted by NSW RFS for the near-real time implementation of the new Himawari-8 hotspot algorithm (March 2019-March 2021) and expanded to include Victoria over the 2019-2020 (black summer) bushfire season.

Results from the project developed algorithms compare extremely favourably with existing polar-orbiting fire detections and other Himawari-based approaches. This has led to wide interest and project outputs being adopted by end-users.

END-USER STATEMENT

Brad Davies, *Regional Fire Behaviour Analyst, NSW Rural Fire Service*

As a way of accelerating this exciting research toward industry utilisation, the NSWRFS proposed to the research team a real-world 'live' trial of the experimental satellite fire detection algorithm under development. The RMIT project leaders were keen to pursue the Near Real Time (NRT) trial to identify opportunities to refine their work in a practical setting, as well as obtain real-world performance data. The RFS invested the time and expertise to incorporate RMITs work into existing systems so it can run in parallel with currently operational satellite detection systems. Early industry utilisation has become a very important step in the research programme itself. That is, using an incomplete product in a trial within an agency prior to the conclusion of the research project has enabled the research team to develop, troubleshoot, and refine their work processes within an operational setting.

Naomi Withers, *Department of Environment, Land, Water and Planning, VIC*

Having timely information on wildfire is critical, being able to track the fire in as near real time would be ideal. But on days of extreme weather, and no other data source is available, we rely heavily on satellite hotspots, so having the RMIT Himawari-8 data coming in under 30 minutes changed the way we mapped fire and helped us to plan evacuations and provide public warnings with more lead time. This research has helped to provide critical information in decision making around community safety.

PRODUCT USER TESTIMONIALS

Stuart Matthews, *NSW Rural Fire Service*

Detection and monitoring of the location and behaviour of fires is critical for the NSW Rural Fire Service to coordinate its operational response and provide information and warnings to the community. We use a variety of methods to achieve this ranging from field intelligence, to linescanning aircraft and satellite fire detection. Satellite methods are useful because they are available at all times and locations, particularly for remote fires, at night, or when conditions are too dangerous to operate aircraft. NSW RFS has been using Himawari-8 images to subjectively monitor fire spread over the past three fire seasons but we have lacked methods to objectively assess accuracy or detect hotspots that are not obvious against background heat. This project has been an important step towards objective and reproducible fire hotspots from the Himawari 8 satellite. Working with RMIT to make the trial hotspots product available in our operational mapping systems has helped us to understand the potential of these hotspots and to refine the product. I am looking forward to future work to expand the hotspots to cover all of Australia and transition to a production system.

INTRODUCTION

This project is a critical part of the Bushfire and Natural Hazards CRC's value to the broader Australian government. The government run Sentinel Hotspots application is used by all levels of government, private sector, researchers and the public to access and visual real time wildfire information. This project forms part of the effort to equip the Australian government with fit-for-purpose Himawari-8 fire detection products for the Sentinel Hotspots system. Our vision is to create a world leading approach to monitor fire activity.

The aim of this project is to provide next generation, remote sensing satellite information to enhance Australia's operational capabilities and information systems for wildfire (bushfire) monitoring across a range of spatial scales and landscapes. Ultimately the outcomes of this research will enable measures of active fires in terms of presence / absence, areal extent and magnitude, which in turn will have the potential to inform decisions about bushfire response, fuel hazard management and ecosystem sensitivity to fire during fire events and post-fire rehabilitation efforts.

The following sections describe the background, research approaches, key milestones, utilisation study and outputs of our Himawari-8 active fire detection research.

BACKGROUND

Fire in Australia is a continuing natural hazard that needs to be monitored. Frequently and accurate monitoring of fires, particularly over such a large landmass, is complex particularly when using satellite data to highlight likely locations of fires. Humans can subjectively use satellite-data to detect fires, but automated detection of fires is more efficient, the algorithms more reliable, and the results can be more readily communicated and archived. Automated fire detections from polar-orbiting satellites such as Moderate Resolution Imaging Spectroradiometer (MODIS and Visible Infrared Imaging Radiometer Suite (VIIRS) are currently used via the Geoscience Australia Sentinel (now Digital Earth Australia hotspots) website.

In October 2014, the Japanese Meteorological Service launched a new geostationary satellite with the potential to detect fires over all of Australia every 10-minutes. The Himawari-8 satellite orbits centered on 140.7°E, with Australia located well within its full-disk area. The Japan Meteorological Service, in co-operation with the Bureau of Meteorology, graciously make Himawari-8 observations available to Australian researchers. Himawari-8 observes 16 channels, ranging from visible to LW infrared, with spatial resolutions (IFOV from 500m to 2000m), taking full-disk scans every 10-minutes. Such real time information lets us frame the question: *is it possible to use Himawari-8 satellite data to automatically detect fires over Australia every 10-minutes?*

Himawari-8 does have the remote-sensing channels required to detect active fires but developing a fire detection algorithm for Himawari-8 data is complex. Fires radiate strongly in the middle-infrared channel (MIR). They radiate so strongly that even fires taking up a small fraction of a pixel can raise the pixel MIR value. But, an increase in the MIR value is hard to determine without a fixed pre-fire or "background" value. Pre-fire or "background" MIR values change due to diurnal, seasonal and meteorological fluctuations. To complicate matters further, reflected sunlight from clouds can also raise MIR values. The complexity of detecting fires in satellite data increases further when the pixel size (heterogeneity) increases (i.e. from 1000m to 2000m). Satellite pixels represent observations over a geographic area. The physical properties of an area may be homogenous, but they may also be heterogenous; fire and non-fire; cloud and non-cloud. Larger pixels may not be able to resolve these small-scale physical differences. Instead, these processes become integrated along with the other landcovers, altering the dominant value proportionally. This "blurring" of small-scale processes presents a challenge, and some fires may present as relatively small changes in non-stationary datasets.

New approaches are required to efficiently detect active-fires using the Himawari-8 satellite data. Existing active-fire detection algorithms tailored to polar-orbiting algorithms rely on the higher spatial resolution of these datasets. Polar-orbiting fire detection algorithms (Giglio et al. 2016; Schroeder et al. 2014) typically using a region growing contextual method to determine background temperature and allow for *some* residual noise due to heterogeneity, but the amount of these unresolved processes is assumed to be small. Increasing the amount of unresolved processes may cause the algorithm to become degraded. Existing geostationary algorithms, like WF-ABBA which has been applied to Australia (Schmidt et al. 2012), cope with unresolved processes by adding in numerical weather prediction information. Numerical weather prediction information is complex, undergoes frequently updates and is difficult to source in real-time. The aim of this project is to create new Himawari-8 active-fire detection algorithms that can cope with unresolved processes while not using additional numerical weather prediction information.

RESEARCH APPROACH AND FINDINGS

The research into active fire detection was conducted in five phases, with four separate approaches investigated. One active fire detection approach (BRIGHT) was selected and developed further and tested in a semi-operational setting.

IMPLEMENTATION OF A HIMAWARI-8 CLOUD MASK FOR AUSTRALIA

Rationale

Fires when viewed from space produce positive anomalies in mid-Infrared (MIR) satellite channel data. But, in order to correctly and accurately identify if a MIR value is a positive "anomaly", researchers try to capture the "normal", or "background" MIR value. Capturing a "normal" clear-sky MIR distribution is non-trivial because MIR values are sensitive to *both* thermal radiation *and* solar radiation reflected from clouds (as well as other land surfaces). Therefore, to capture a "normal" clear-sky MIR distribution it is important to remove data containing clouds. Imprecise assumptions regarding thresholds that delineate clear- from cloudy-sky can lead to either clouds getting into the dataset, or more clear-sky or fire pixels being omitted from the prediction. Cloud-contaminated datasets have the potential to have lower the "background" Thermal-InfraRed (TIR) and higher "background" MIR expected values. A lowered background TIR value could lead to more pixels being deemed as fires, and an increased background MIR could lead to more fire-pixels being treated as clear-sky pixels. Therefore, it is important to pre-process image datasets for cloud as accurately as possible. The absence of an operational cloud mask for Himawari-8 imagery over Australia was necessary to support the development of early research into fire detection.

Method and results

For the initial implementation of a cloud mask for Himawari-8, the work by fire-detection researchers (Xu et al. 2010) was used. The Xu et al. (2010) cloud mask over land uses Visible, Mid-Infrared and Thermal-Infrared Satellite Channels, along with solar information to delineate between daytime and night-time areas. The algorithm conducts six tests to decide on the likelihood of a satellite pixel containing cloud. An example output is shown in Figure 1. (Note: The Landsat dataset has a much higher spatial resolution (30m) than the Himawari dataset (2km), accordingly the Landsat cloud mask was re-gridded from its native resolution to the coarser Himawari grid resolution before conducting the comparison.)

The Landsat and Himawari-8 cloud masks compare favourably. However, it is important to note that the results were limited to northern Australian case studies and the suitability of the Xu et al. (2010) cloud masking algorithm declined in coastal and southern areas of Australia and this is likely due to the original algorithm being calibrated and validated in equatorial environments. Examination of outputs using the published Xu et al. (2010) albedo threshold identified as too low for the Himawari-8 satellite across the Australian continent.

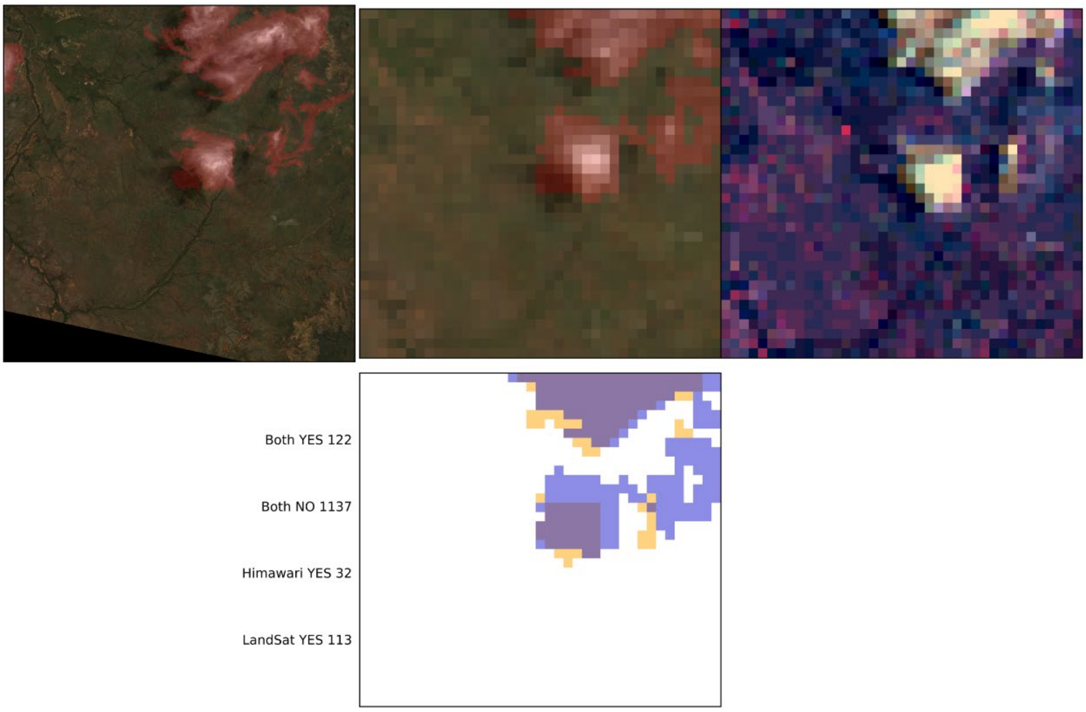

FIGURE 1 EXAMPLE SHOWING THE LANDSAT/HIMAWARI CLOUD MASK COMPARISON. ON THE LEFT IS THE LANDSAT TRUE COLOR + LANDSAT CLOUD MASK (RED), IN THE MIDDLE IS THE SAME INFORMATION BUT ON THE 2KM HIMAWARI-8 GRID. ON THE RIGHT IS THE HIMAWARI-8 2KM (MODIFIED) TRUE COLOR + HIMAWARI-8 DERIVED CLOUD MASK (ORANGE) BASED ON THE WORK BY XU ET AL 2010, 2016). ALL IMAGES SHOWN FOR SAME GEOGRAPHICAL AREA. BELOW, THE LANDSAT CLOUD MASK (BLUE, SEMI-TRANSPARENT) IS OVERLAID ON THE HIMAWARI CLOUD MASK (YELLOW, SEMI-TRANSPARENT). STATISTICS ON THE SIDE OF THE LEGEND SHOW THE NUMBER OF PIXELS HAVING CLOUD IN BOTH, NEITHER, OR ONLY ONE OF THE HIMAWARI AND LANDSAT CLOUD MASKS.

Initial results were found to be suitable for use over northern Australia but were significantly compromised in southern parts of the continent. The work by Xu et al. (2106) was based on thresholds developed on equatorial environments, and therefore not suited across an entire continent such as Australia.

Outputs

- The implementation of a cloud mask for Himawari-8 provided the product necessary for ongoing research and algorithms underpinning both the time series approach for early fire detection, and the multi-resolution approach for improved fire line mapping using Himawari-8.

TIME SERIES APPROACH FOR EARLY FIRE DETECTION

Rationale

Fire detection and monitoring relies on an accurate estimate of the background temperature of a fire's location. This cannot be directly measured from the fire's pixel signal due to obscuration caused by the infrared emission of fire. Previous methods of background temperature estimation have relied on using a target's adjacent background conditions in a contextual manner to estimate this temperature. This method can be used effectively for background estimation in ideal conditions but deteriorates when exposed to ephemeral factors such as cloud cover and smoke, and in areas of land surface heterogeneity. Identification of these locations and conditions of poor background temperature recovery have led to investigations of the use of multi-temporal data for background temperature estimation, which when matched with signal fitting and smoothing techniques can lead to a more robust method of temperature estimation than via context.

Method and results

Multi-temporal methods of estimation utilise the pixel's time series history to make inferences about its current attributes. These can be as simple as interrogating the pixel at the same time of day for a number of days and making a temperature estimate based upon this. In reality, there are a number of periodic signals which make up the temperature signal of a location over a period of time. The largest influence over background temperature is time of day - incident solar radiation not only increases radiation through reflectance during the daytime, but also increases thermal emission from the surface through convection. These two components make up a strong diurnal signal which is exhibited by almost all cloud-free land surface pixels. Given that solar radiation has such a strong influence, it follows that we may be able to use this underlying signal to provide temperature estimations of a pixel when an obscuring factor is present, such as cloud or fire. Multi-temporal temperature estimations at pixel level suffer from similar problems to the use of single-timepoint contextual methods, in that obscuration by cloud in particular makes temperature recovery difficult. In some areas, periodic cloud cover can completely inhibit the use of temperature data during critical times for fire activity. This research proposes the **Broad Area Training** (BAT) method to provide a more robust method of temperature estimation by using land surface areas at similar latitudes to provide a version of the expected diurnal signal of a pixel. This signal can then be scaled using the pixel's immediate history to reflect the current conditions of the pixel, and subsequently then used for background temperature prediction. The BAT method for fire background temperature estimation has been assessed both for reliability and robustness as compared to other background estimation methods, and for its general applicability for fire detection as part of a simple thresholding method. The general applicability of the method for temperature estimation looked at the BAT technique for general applicability and performance over Australia, in comparison to both contextual temperature estimates and per-pixel multi-temporal estimation.

A comparison between the traditional pixel-based and BAT methods was conducted from random pixels across the Australian continent during the month of November 2015. The relative accuracy of each of the temperature fitting processes in comparison to the raw brightness temperatures recorded by the Advanced Himawari-8 Imager (AHI) sensor were computed, after measurements flagged as cloud are eliminated. The pixel-based training method performed more accurately than the BAT method for either ten or thirty days of training data and was expected, as the data derived from an individual pixel will perform far better with regard to localised effects on pixels such as land cover composition. In general, the study found an overall increase in estimation effectiveness compared to per-pixel multitemporal methods, and increased robustness to incidences of cloud (see Table 1).

TABLE 2 COMPARISON OF RMS ERROR FOR THE DIFFERENT FITTING TECHNIQUES FOR ESTIMATING BRIGHTNESS TEMPERATURES RECORDED BY THE ADVANCED HIMAWARI-8 IMAGER (AHI) SENSOR. (NOTE: RMSE CALCULATED AFTER ELIMINATING INCIDENCES OF CLEAR SKY PROBABILITY (CSP) OF LESS THAN ONE FROM THE EVALUATION DATA (FROM HALLY ET AL. (2017).

Fitting technique	**RMS Error (K)**				
Incidences of CSP < 1	≤ 10	$11 - 30$	$31 - 50$	$51 - 70$	> 70
Pixel-based training	0.78	1.01	2.28	3.25	10.40
BAT (30 days)	0.94	0.94	1.11	1.48	4.19
BAT (10 days)	1.15	1.21	1.40	2.10	6.31
Contextual temperature	0.33	0.42	0.41	0.40	0.42
Number of samples	*903*	*741*	*768*	*851*	*2345*

The BAT method was also extended into a study which pitted the use of simple thresholds for thermal anomaly identification against commonly used fire products in part of Northern Australia (Hally et al. 2018). Fire locations were identified using a burned area product, and the associated active fires were examined using Low Earth Orbiting (LEO) fire products, such as VIIRS VNP14 and MODIS MXD14, against thresholds above estimated background temperature using AHI imagery. The study showed an increase of fire detections overall when using the AHI imagery, with low omission rates and improvements in time of fire detection (see Table 2).

TABLE 3 DETECTION RESULTS OF THE THRESHOLDING ALGORITHM ON 150 FIRE INCIDENTS IN EACH DETECTION GROUPING PER TEMPERATURE THRESHOLD. DETECTIONS OCCUR WHERE AT LEAST ONE BRIGHTNESS TEMPERATURE MEASUREMENT EXCEEDS THE FITTED BRIGHTNESS TEMPERATURE BY THE SELECTED THRESHOLD. SYNCHRONOUS FIRE DETECTIONS ARE CLASSIFIED AS WHERE AN ANOMALY DETECTED BY ONE OR BOTH OF THE ACTIVE FIRE (AR) PRODUCTS HAS AT LEAST ONE CORRESPONDING DETECTION FROM THE THRESHOLD ALGORITHM WITHIN TWENTY MINUTES OF THE LEO (FROM HALLY ET AL. (2018)).

Group\Threshold	2 K		3 K		4 K		5 K	
n=150 for all	Detected	Synchronous	Detected	Synchronous	Detected	Synchronous	Detected	Synchronous
Burned area only	75.3%	N/A	63.3%	N/A	56.0%	N/A	50.0%	N/A
VIIRS AF only	95.3%	38.7%	88.0%	27.3%	84.7%	22.0%	77.3%	17.3%
MODIS AF only	97.3%	60.7%	97.0%	58.0%	91.3%	52.7%	86.0%	48.0%
Both AF products	99.3%	68.0%	98.3%	58.7%	92.0%	51.3%	89.3%	46.0%

Outputs

- Hally B, Wallace L, Reinke K, Jones S. *A broad-area method for the diurnal characterisation of upwelling medium wave infrared radiation.* Remote Sensing 2017;9(2):167.
- Hally B, Wallace L, Reinke K, Jones S, Engel C, Skidmore A. *Estimating Fire Background Temperature at a Geostationary Scale—An Evaluation of Contextual Methods for AHI-8.* Remote sensing 2018;10(9):1368.
- Hally B, Wallace L, Reinke K, Jones S, Skidmore A. *Advances in active fire detection using a multi-temporal method for next-generation geostationary satellite data.* International Journal of Digital Earth 2019;12(9): 1030-1045.
- Hally B, Wallace L, Reinke K, Jones S. *Assessment of the utility of the Advanced Himawari Imager to detect active fire over Australia*. Commission VIII, WG VIIVI, International Society for Photogrammetry and Remote Sensing, July 12 – 19, 2016 Prague, Czech Republic.
- Hally B, Wallace L, Jones S, Wickramasinghe C, Reinke K. *Assessment of the performance of the broad area training method to detect fires in varied locations and landscapes throughout the Asia-Pacific*. 11th EARSeL Forest Fire Special Interest Group Workshop, September 25-27, 2017, Chania, Greece.

- Jones S, Reinke K, Hally B, Wickramasinghe C, Wallace L. *Large area validation of Himawari-8 fire active fire products.* In 38th Asian Conference on Remote Sensing 2017: Space Applications: Touching Human Lives 2017. (*best paper award for conference)

MULTIRESOLUTION APPROACH FOR EARLY FIRE DETECTION

Rationale

AHI-FSA (Advance Himawari Imager - Fire Surveillance Algorithm) is a new wildfire surveillance algorithm that uses three independent threshold conditions to MIR, NIR and RED channels to detect fire-line pixels, and in doing so can map fire activity from a spatial resolution of 2km x 2km to 500m x 500m. This has potential benefits to fire detection using geostationary satellites which suffer from coarse spatial resolutions. Combined improvements in spatial resolution and high frequency of observations have the potential to provide information on fire activity in near-real time.

Method and results

In the AHI-FSA, a potential fire day image is compared to a non-fire day image that is a cloud and fire free composite image with the same timestamp as the fire day. These two images form the basis of implementing the conditions that result in fire line activity. The three conditions are designed to (1) detect thermal anomalies, (2) detect changes in vegetation cover due to fire, and (3) detect the edge between smoke and non-smoke pixels. The first condition is the "MIR condition" where thermal anomalies are detected using a contextual based approach and is a coarse method of initial detection. Outputs from the "MIR condition" provide the first layer of data available for fire surveillance named AHI-FSA 2 km detections. The second layer of data available is determined through a change in Normalised Difference Vegetation Index (NDVI) followed by a change in red reflectance for smoke differencing thus achieving the AHI-FSA 500m fire-line pixels. AHI-FSA 500m fire-line pixels are determined when all three AHI-FSA conditions are satisfied.

AHI-FSA was intercompared against LEO hotspot products (including MOD14, MYD14, and VNP14IMGTDL) and Landsat-8 burnt scars using case study. Initially, case study fires over the northern grass/woodlands of Australia were used for intercomparison where there is a relatively high number of wildfire activity in this region, as well as being an area well documented in the remote sensing of fire literature.

Preliminary results showed AHI-FSA was able to detect a single VIIRS hotspot, 40% of the time over the Northern Australian woodland. Schroeder et al. (2014) demonstrated VIIRS hotspots were able to detect fires 0.01 ha in size at 800k with 50% confidence suggesting the multi-resolution approach employed by AHI-FSA could be capable of mapping fires at a smaller resolution compared to 14 ha (375 m x 375 m) VIIRS single hotspots ground resolution. Case study fires demonstrated the improved fire surveillance capabilities of AHI-FSA 500 m fire-line pixels. Continuously tracking fire movement, every ten minutes, AHI-FSA 500 m demonstrated 25% Australia wide commission error when intercompared to

VIIRS hotspots. Over Northern Australia, this figure was 7% intercompared to Landsat-8 burnt scars suggesting correct detection by AHI-FSA. AHI-FSA 500 m tend to have high omission error when compared to near synchronous LEO hotspots. However, when a daily temporal window is considered, lower omission error is observed; AHI-FSA 500 m reported a low 7% omission error compared to MODIS in the Northern Australia when daily composite was used. Overall, this demonstrated AHI-FSA can be used for wildfire surveillance in remote parts of Australia where resources can only be deployed for a hand full of high-risk fires. AHI-FSA can be used to identify fires that are rapidly developing, suddenly changing direction and moving toward settlements and fires that gradually dying down.

Outputs

- Wickramasinghe C, Jones S, Reinke K, Wallace L. *Development of a multi-spatial resolution approach to the surveillance of active fire lines using Himawari-8*. Remote Sensing 2017;8(11): 932.
- Wickramasinghe C, Wallace L, Reinke K, Jones S. *Intercomparison of Himawari-8 AHI-FSA with MODIS and VIIRS active fire products.* International Journal of Digital Earth 2020;13(4):457-473,
- Wickramasinghe C, Wallace L, Reinke K, Jones S. *Implementation of a new algorithm resulting in improvements in accuracy and resolution of SEVIRI hotspot products.* Remote sensing letters 2018;9(9): 877-885.
- Wickramasinghe C, Wallace L, Reinke K, Hally B, Jones S. *Inter-comparison of Himawari-8 AHI fire surveillance with MODIS and VIIRS fire products*. 37th Asian Conference on Remote Sensing, October 17-21 2016, Colombo, Sri Lanka. (*best paper award for conference)
- Wickramasinghe C, Wallace L, Reinke K, Hally B, Jones S. *Improving the spatial resolution of active fire detections from geostationary satellites.* 11th EARSeL Forest Fire Special Interest Group Workshop, September 25-27, 2017, Chania, Greece.

BIOGEOGRAPHICAL REGION AND INDIVIDUAL GEOSTATIONARY HHMMSS THRESHOLD (BRIGHT) NON-REAL-TIME ALGORITHM

Rationale

Clear-sky satellite observations are linked to variables such as daytime radiation, atmospheric conditions and the underlying landscape characteristics. The amount of incoming radiation and hence heating of the ground can vary with time of day, season, proximity to the equator or pole, and weather conditions. Landscape conditions can vary greatly across the Australian continent. Hence not all areas of Australia are similar. A technique that accounts for these biogeographical and time of day variations should be better able to detect fires.

Statistical estimations increase in accuracy when the errors are small, or the sample size is large. The Himawari sensor has fixed accuracy specifications, and Himawari started archiving data in 2015. These cannot be changed. To increase the accuracy of the active fire detection we can increase the sample area upon which the statistics are based. Normally distributed populations have samples that are drawn from one single population. Variations in the underlying population can lead to a non-normal statistics and therefore inaccurate statistical estimations. To increase the sample size without distorting the statistic, we can group regions in terms of pixels that are representative of each other.

Method and results

Biogeographic regions are regions of land that are representative of each other in terms of certain biological, ecological and climatic conditions. Version 7 of the Interim Biogeographic Regionalisation for Australia (Environment Australia, 2000; hereafter IBRA) has broken up Australia in 89 regions and 419 sub-regions. These 419 sub-regions can be used to group representative areas of satellite data. In this work, we derive a IBRA sub-region specific, dynamically-varying definition of clear-sky albedo, MIR and TIR thresholds for a 12-month daytime dataset (1st December 2015 to 30th November 2016, inclusive). These Biogeographical Region and Individual Geostationary HHMMSS Threshold (BRIGHT) albedo, MIR and TIR clear-sky values differed greatly between IBRA sub-regions, and within individual sub-region sub-seasons and is illustrated in Figure 2. The "clear-sky" albedo, MIR and TIR definitions were used to detect potential fires in Himawari data.

Hotspots detected by the (non-real time) BRIGHT algorithm were compared against those detected by the MODIS polar-orbiting fire-hotspot algorithm (over Australia during the daytime). The (non-real time) BRIGHT hotspots matched with MODIS hotspots 88% of the time. MODIS hotspots matched with (non-real time) BRIGHT hotspots only 39% of the time, but this was likely related to their low radiative power. For more information on the (non-real time) BRIGHT algorithm and the intercomparison with MODIS hotspots during the daytime see Engel et al. (2021).

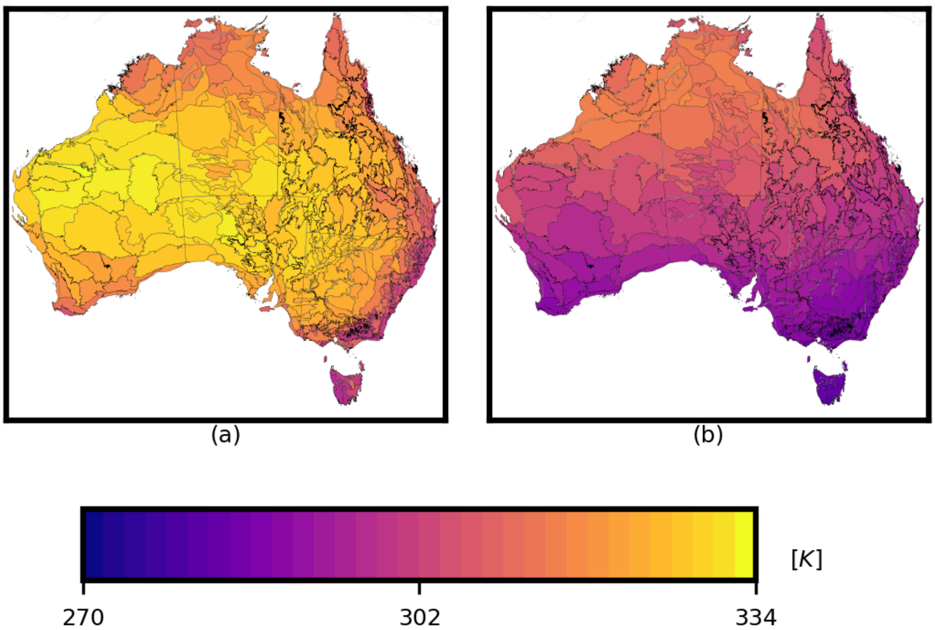

Figure 2. MAPS OF 04:00 UTC (14:00 EST) BRIGHT MEDIAN 3.9µm THRESHOLD VALUES PER IBRA SUB-REGION FOR (A) EARLY-SUMMER AND (B) EARLY-WINTER, DEMONSTRATING THE SPATIAL AND SEASONAL VARIATIONS IN BRIGHT THRESHOLD VALUES. (FOR FURTHER EXAMPLES AND A DESCRIPTION OF THE ALGORITHM SEE ENGEL ET AL. 2021 -- https://doi.org/10.1109/TGRS.2020.3018455).

Outputs

- Engel CB, Jones SD, Reinke K. *A Seasonal-Window Ensemble-Based Thresholding Technique Used to Detect Active Fires in Geostationary Remotely Sensed Data*. IEEE Transactions on Geoscience and Remote Sensing. 2021;59(6):4947-4956

BIOGEOGRAPHICAL REGION AND INDIVIDUAL GEOSTATIONARY HHMMSS THRESHOLD (BRIGHT) REAL-TIME ALGORITHM

Rationale

Detecting active fires is critical for the protection of lives and property. While many tools exist for detecting active fires in the Australian landscape, new techniques providing enhanced temporal coverage and real time capability are needed. One option being explored is remotely sensed data from the Himawari-8 geostationary satellite. Himawari-8 provides remotely sensed observations over Australia every 10-minutes. The non-real time BRIGHT algorithm to used to detect fires in Australia (Engel et al. 2021; presented in the previous section) generated interest in a real-time BRIGHT algorithm. Rather than using sub-seasonal thresholds, the BRIGHT real-time algorithm would be required to use thresholds that adapt to each region, date and time combination.

Method and results

Himawari-8 data was received in real-time from the Japan Meteorological Agency via the Bureau of Meteorology. Himawari-8 reflectance (0.64 , channel 3), mid-infrared (3.9, channel 7) and thermal infrared (10.7, channel 13) were stratified according to Interim Biogeographical Regionalisation of Australia (IBRA; Environment Australia, 2000) sub-regions and statistically compared with historical Himawari-8 data at the same time of day from the 4-weeks prior. Hotspots were determined using the thresholds and the latest real-time Himawari-8 data (Engel et al. 2021).

The real-time BRIGHT algorithm was developed in stages. The algorithm was first designed and trialled in NSW/VIC before being run/trialled over all of Australia.

Hotspots in the NSW/VIC real-time BRIGHT trial were delivered to the NSW RFS within two minutes of Himawari-8 data being received for processing. Real-time BRIGHT hotspots from the NSW/VIC trial were compared against Fire Information for Resource Management System (FIRMS) MYD14 hotspots (table 1). The NSW/VIC real-time BRIGHT hotspots had commission errors of 8% during the day (11% during the night). Omission errors were 51% during the day (37% during the night). The MYD14 satellite has higher resolving power (1km resolution) than the Himawari-8 (2km resolution) satellite, and the difference in power may bear impact on the statistics. The omission errors of 51% (day) and 37% (night) may reflect fires below the resolving power of the Himawari-8 satellite. The 8% (day) and 11% (night) commission error may reflect differences in the algorithms and/or the transient nature of fires. An example of real-time BRIGHT hotspots is shown in Fig. 3. The success of the NSW/VIC trial resulted in demand for an Australia-wide trial.

The algorithm was further developed to support dynamic day/night transition and settings valid for all of Australia during all seasons. A 12-month run (covering 1st April 2019 to 31st March 2020) was undertaken in "pseudo real-time". For a description of the final real-time BRIGHT algorithm and an evaluation of the BRIGHT active fire hotspots against MODIS and VIIRS see Engel et al. (2021).

The full Australian real-time BRIGHT trial operated from Oct 2020 to May 2021 with hotspots forwarded in real-time to fire representatives from each of the states of Australia within ~45 seconds from time of arrival[1]).

The code for this algorithm has now been transferred to Geoscience Australia so the algorithm can be made available on the Digital Earth Australia Hotspots service, and is currently being adopted into operations (as of Aug 2021).

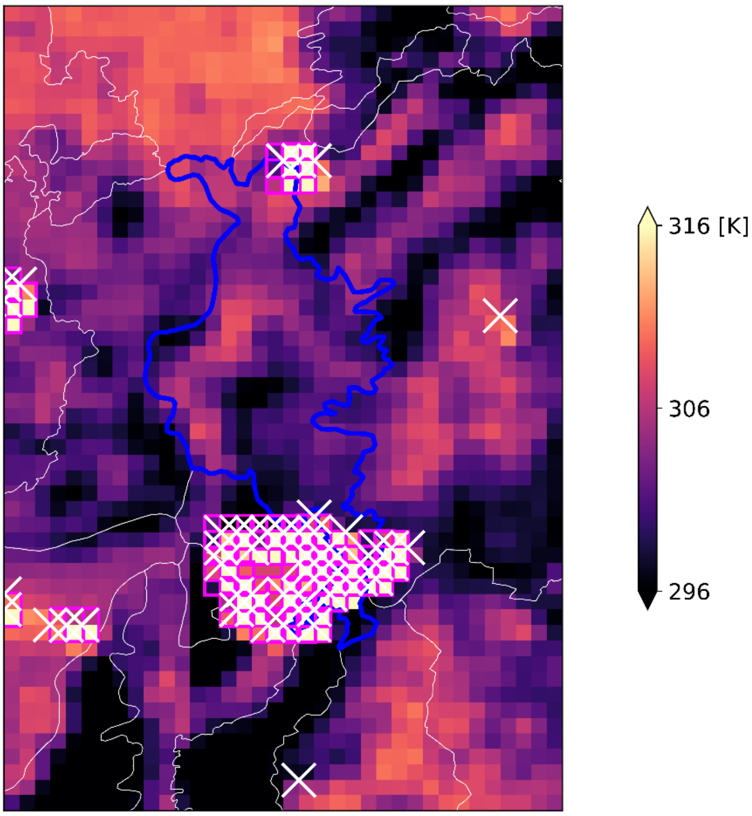

FIGURE 3 ABOVE: EXAMPLE HIMAWARI-8 DATA (3.9 µM, CHANNEL 7) CENTERED ON NSW NORTH COAST IBRA REGION NNC02 (OUTLINED IN THICK BLUE LINE; OTHER IBRA REGIONS SHOWN WITH THIN WHITE LINES) FOR 4 UTC ON 7TH SEPTEMBER 2019. OVERLAID ARE BRIGHT/HIMAWARI-8 (MAGENTA SQUARES) AND MYD14 (WHITE CROSSES) ACTIVE FIRE HOTSPOTS.

TABLE I MYD14 HOTSPOTS OVER NSW/VIC COMPARED WITH BRIGHT/HIMAWARI-8 HOTSPOTS FROM 15 MAR 2019 TO 10 JAN 2020. MYD14 ARCHIVAL QUALITY DATA WAS USED FOR 15 MAR 2019 TO 30 SEP 2019, AND NEAR REAL-TIME QUALITY DATA FOR 01 OCT 2019 TO 10 JAN 2020. MYD14 HOTSPOTS WITH PIXEL SIZE LESS THAN 1.7KM WERE KEPT AND ASSIGNED TO THE NEAREST HIMAWARI-8 PIXEL. AREAS WERE DEFINED USING THE MYD14 HOTSPOTS THAT FELL ON SPECIFIC DATE/TIMES. HOTSPOTS THAT FELL IN THE AREA (WITHIN +-10 MINUTES) WERE CONSIDERED CO-INCIDENT. MATCHES WERE DEFINED AS HOTSPOTS IN ONE DATASET THAT HAD AT LEAST ONE IN THE OPPOSING DATASET WITHIN +/- 1 PIXEL. STATISTICS WERE SPLIT INTO DAYTIME AND NIGHTTIME SETS.

Description	MYD14 (DAY)	MYD14 (NIGHT)
Number of BRIGHT/Himawari-8 hotspots in the MYD14 reconstructed swath	6398	5132
Number of BRIGHT/Himawari-8 hotspots detected within 1 pixel of a MYD14 hotspot	5881	4546
Commission error for BRIGHT/Himawari-8 hotspots	8%	11%
Number of MYD14 hotspots (collated on the Himawari-8 grid)	14247	7496
Number of MYD14 hotspots (collated on the Himawari-8 grid) detected within 1 pixel of a BRIGHT/Himawari-8 hotspot	7003	4751
Omission error for BRIGHT/Himawari-8 hotspots	51%	37%

[1] The Australia wide trial ran faster than the combined New South Wales and Victoria trial due to concentrated efforts made to speed up the delivery of hotspots.

Outputs

- Engel CB, Jones SD, Reinke KJ. Real-Time Detection of Daytime and Night-Time Fire Hotspots from Geostationary Satellites. Remote Sensing. 2021;13(9):1627.
- Python code designed, developed and tested to deliver near real time Himawari-8 derived hotspots. Code handed over to Geoscience Australia in May 2021.

INTER-COMPARISON OF REAL-TIME BRIGHT HOTSPOTS WITH OTHER OPERATIONAL PRODUCTS

Rationale

To provide an understanding of the performance of the BRIGHT algorithm, an inter-comparison was conducted with operational MODIS burnt areas and Landgate (Firewatch) Himawari-8 hotspots for the period April 2019 – March 2020.

Method and results

To provide another form of inter-comparsion between geostationary satellite observations and low earth orbiting satellite observations that removed the complexity of timing between observations, the BRIGHT hotspots were compared to the MODIS burnt area product (MODIS MCD64A1). A BRIGHT detection was considered to be valid where an associated burn scar, indicative of a wildfire event overlapped with the MCD34A1 product within one month following the fire detection.

The assessment showed a high degree of accuracy for the BRIGHT algorithm when compared to the MODIS burnt area mapping product. Using NASA's MCD64 product for MODIS as a reference burned area dataset, the BRIGHT algorithm had a commission rate of 11.30% and omission rate of 4.25% when assessed on a month-by-month basis.

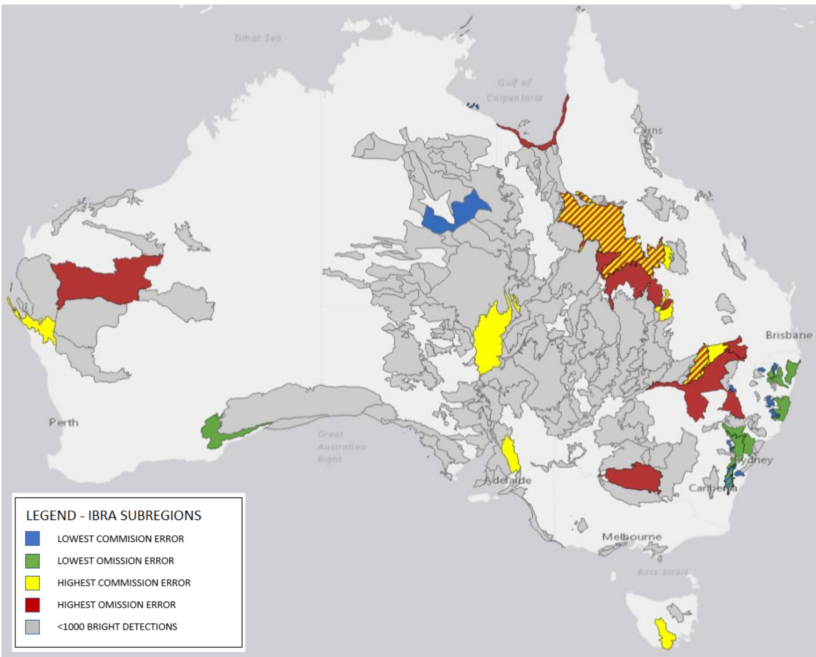

FIGURE 4. AUSTRALIAN IBRA SUBREGIONS REPORTING THE 10 HIGHEST AND LOWEST ERRORS OF COMMISSION AND OMISSION WITH MORE THAN 1000 DETECTIONS FOR THE PERIOD APRIL 2019 - MARCH 2020.

The lowest rates of commission and omission primarily occurred in New South Wales (as shown in Figure 4) where over the summer period large areas of forest burned in the 2019-2020 summer. 10.24% of all errors of commission occurred within the Dieri IBRA subregion within South Australia, where 44137 false detections were attributed to Lake Eyre. Commission rates are lowest during the summer fire season, between October and January, while omission rates are lowest for a greater period, between July and January, coinciding with an increase in the count of monthly BRIGHT detections reflecting an increase in fire activity.

The strong agreement between the BRIGHT algorithm and the MCD64 burned area product confirms the BRIGHT algorithm can effectively identify the presence of fire. By confirming the presence of an associated burn scar using the MCD64 product, this assessment establishes confidence in the AHI sensor and algorithm potential for active fire detection and monitoring.

The next assessment was conducted against the Landgate Firewatch algorithm that also uses Himawari-8 imagery. The aim for this analysis was to compare the BRIGHT hotspots with the Landgate Firewatch hotspots and report on agreement. This was performed in two parts: the first investigated the compatibility between the two products for direct comparison, and the second reported on agreement between the two products.

It was found that despite the BRIGHT algorithm detecting more hotspots in the year, ~4.4 million compared to Landgate Firewatch hotspots ~2.3 million, the Landgate Firewatch hotspots appear to be more spatially extensive and displaying less spatial autocorrelation between detections. This difference can be seen in Figure 5 below. Further investigation showed that many of the Landgate Firewatch hotspots occur as an isolated, single instance fire (that is, one detection for a pixel for a given 10-minute instance for whole of the year).

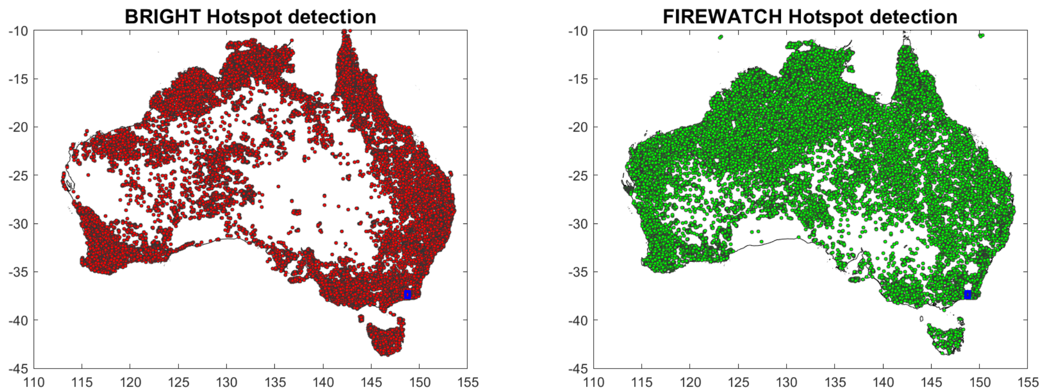

FIGURE 5. BRIGHT AND LANDGATE FIREWATCH HOTSPOT DISTRIBUTION BETWEEN APRIL 2019 – MARCH 2020 ACROSS AUSTRALIA.

The spatial compatibility between products for facilitating inter-comparison was complicated by the different algorithms using different coordinate systems. The Landgate Firewatch algorithm used the Geographic Coordinate System WGS84 (GCS WGS84), remapping the image prior to hotspot determination in comparison to BRIGHT hotspots which used the native Normalised Geostationary Projection. Whilst remapping the image to a regular (square) grid, this has the potential to eliminate pixel values and remap some pixel values more than once, thereby changing the original pixel value composition of the image. Truncation used in the Landgate Firewatch hotspot coordinates was also observed to shift some hotspots by up to 1 pixel or ~2 km in some areas of Australia.

Agreement between the two datasets was reported using confusion matrices to illustrate the rate of omission and commission between the two datasets, and was performed in two ways. One where BRIGHT hotspots were considered the "truth" and the second where Landgate Firewatch hotspots were considered the "truth". In general, it was found the the BRIGHT algorithm was able to detect more Landgate Firewatch hotspots than Landgate Firewatch was able to detect BRIGHT hotspots. For large fires, good agreement was found and similar trends in the proportion of total detections stratified by months were also observed. The majority of the unmatched Landgate Firewatch hotspots occurred in the Northern Territory and Western Australia. When these unmatched Landgate Firewatch hotspots were compared to the MODIS burned area product for verification of their accuracy, most of these hotspots showed no associated burn scar.

(*Please note, since preparation of this report, newer versions of both the BRIGHT and Landgate Firewatch algorithms have been implemented).

Outputs

- Two internal reports submitted to the Bushfire and Natural Hazards CRC.

KEY MILESTONES

2017-2018

Key milestones included: development of fire detection algorithms, supporting products (cloud masks) and the development of intercomparison datasets and methods, and end-user trials.

Two algorithms were developed and evaluated in case study situations. The next phase examined these across longer time periods and over greater areas. As part of the validation process, a new approach was developed to derive errors of omission and commission for algorithm outputs. This was necessary to facilitate the comparison of hotspot products that are created from sources with very different spatial resolutions and temporal frequencies.

Both the time-series based fire detection algorithm and multi-resolution fire line mapping algorithm required a cloud mask for implementation of each algorithm, and to perform an accuracy assessment. In Australia, an accurate cloud mask for Himawari-8 was not available. Without a cloud mask it was not possible to implement the algorithms or undertake a thorough validation analysis. As a result, the literature was reviewed and a publication by Xu et al. (2010) was implemented to generate the necessary cloud mask. This was implemented for 2016 Himawari-8 data Australia-wide. Further analysis showed a decreasing reliability in the cloud mask along coast areas and in southern Australia. However, it was an improvement on what was currently available.

Following the implementation of the cloud mask a third, new fire detection algorithm (non-real-time BRIGHT) based on regional and seasonal statistical thresholds was developed. The advantage of the approach was that it did not rely on a cloud mask, rather embedding these types of anomalies within the algorithm process itself. Preliminary results of intercomparisons with low earth orbiting satellite hotspot products were favourable, and comparisons with WF-ABBA indicated that the non-real-time BRIGHT algorithm significantly reduced false alarms, a well-known issue with WF-ABBA.

A near real time trial (with NSW RFS and with data support from the Bureau of Meteorology) for the new detection algorithm was rolled out in early 2019. The scope of the trial and metrics for capturing performance were developed in partnership with end-users.

2018-2019

Cloud-mask datasets were created to support PhD student submissions, active fire mapping algorithm development, and associated publications.

The non-real-time BRIGHT fire detection algorithm was developed, based on regional and seasonal statistical thresholds. The key steps in developing the non-real-time BRIGHT algorithm were:

- Design of new non-real-time fire detection technique for Himawari-8
- Implementation of the non-real-time BRIGHT technique using Himawari-8

- Testing of non-real-time BRIGHT algorithm on a full-year dataset over all of Australia Analysis of output and revision / minor tweaks.
- Present non-real-time BRIGHT algorithm at AFAC.

At the same time a real-time fire detection algorithm based on regional and seasonal statistical thresholds was developed in readiness for a real-time time with NSW RFS. Preparation for the trial involved:

- Proposal of the real-time BRIGHT fire detection technique for Himawari-8
- Implement data processing chain from satellite data ingestion from BoM through to delivery to end-user agency.
- Set up NSW RFS trial and receive feedback.
- Modification of algorithm.

Validation was done on all three (real-time) versions of Himawari-8 active fire detection algorithms.

2019-2020

The key milestones for the year were support of the live, near-real time trial of Himawari-8 hotspots for south-eastern Australia. This involved finalising the initial fire detection algorithm (that was able to perform in the absence of an operational cloud-mask), processing multi-band imagery and delivering outputs to end-users in a near-real time capacity, every 10 minutes. The key steps involved were:

- The paper describing the non-real-time BRIGHT algorithm published in *IEEE Transactions on Geoscience and Remote Sensing.*
- The real-time BRIGHT fire algorithm for Himawari-8 was implemented and tested in a live trial, near-real-time in partnership with NSW RFS and expanded to Victoria.
- The real-time BRIGHT fire algorithm was adapted due to feedback in near-real time.
- Results from the real-time BRIGHT fire algorithm trial in south-eastern Australia were presented at AFAC 2019 in partnership with end-user from NSW RFS
- The real-time BRIGHT fire algorithm was implemented on Amazon Web Services to apply and test the detection technique on full-year dataset across Australia. 2019 - 2020 (12-month 24/7) Himawari-8 hotspot dataset for all Australia, with output successfully created.
- The real-time BRIGHT fire algorithm was presented in an AFAC Predictive Services sponsored Webinar to end-user community for feedback.

2020-2021

The key milestones for the year continued support of a live, near-real time trial of Himawari-8 hotspots but this time for all of Australia. The key steps involved were: The key steps involved were:

- Finalisation of the real-time BRIGHT approach to handling day/night transition and setting chosen that were valid for all of Australia during all season for Himawari-8.
- The paper describing the real-time BRIGHT method published in *Remote Sensing*.
- Implementation of real-time BRIGHT technique (using Himawari-8) in a live trial, near-real time in partnership with representatives from all states in Australia.
- Delivery of real-time (within 45 seconds of receipts of Himawari-8 data) BRIGHT outputs over all of Australia to end-users from multiple fire agencies in a near-real time capacity, every 10 minutes.
- Handover of real-time BRIGHT system to Geoscience Australia.

UTILISATION AND IMPACT

REAL-TIME TRIALS

Summary

The RMIT hotspot trial (started in Feb 2019, algorithm stable from 15th March 2019) was continued until 23rd March 2020. Hotspots were computed in real time for Victorian and NSW, and made available to NSW RFS in near real-time (typically 2 minute hotspot processing and delivery time), with hotspots delivered to Vic DEWLP E-map from Jan 2020. Both NSW RFS and Vic DEWLP E-map were able to access, utilise and provide feedback on their using the BRIGHT hotspots during the trial period which encompassed the Black Summer period.

Output

RMIT used Himwari-8 data made available by the Bureau of Meteorology, stable from 15th March 2019 to 23rd March 2020, to deliver active-fire hotspots to NSW RFS (and later VIC RFS) in near real-time. Processing time for the algorithm from the receipt of the Himawari-8 imagery through to final hotspot delivery was typically 2 minutes.

Engel C, Jones S, Reinke K, Matthews S, Holmes A. *Detecting Active-Fires using Himawari-8: a report from the NSW Trial.* Non-peer reviewed research proceedings from the Bushfire and Natural Hazards CRC & AFAC conference. Melbourne, Australia, 25 – 28 August 2019. (oral)

Engel, C., Reinke K, Jones S, Matthews S, Withers N. 2020: *Multivariate spatiotemporally adaptive threshold (MSTAT) Himawari-8 hotspots*. AFAC predictive services webinar 5th June 2020.

Engel CB, Jones SD, Reinke K. *A Seasonal-Window Ensemble-Based Thresholding Technique Used to Detect Active Fires in Geostationary Remotely Sensed Data*. IEEE Transactions on Geoscience and Remote Sensing. 2021;59(6):4947-4956.

Extent of use

- RMIT delivered active-fire hotspots to the NSW RFS in near real-time, and onwards to Vic DEWLP E-map from Jan 2020.
- NSW RFS made active-fire hotspots available to operational users via a graphical interface that included both location and timing information.
- Vic DEWLP E-map also made active-fire hotspots available to operational users via a graphical interface that included both location and timing information.
- The hotspots were used in an exploratory fashion and to support night-time observations as the only empirical source of fire activity.
- RMIT monitored hotspots locally (to ensure the trial was running and outputs were as expected).

Utilisation potential

- Hotspots available from Himawari-8 every 10 minutes, 24 hours a day, processing and delivery times of hotspots typically within 2 minutes for NSW and Victoria.
- Highlights areas with anomalous MIR values over NSW/VIC.
- For detection, monitoring and fire-fighting purposes.

AUSTRALIA-WIDE 12-MONTH VERIFICATION DATASET

Summary

The BRIGHT hotspots algorithm was expanded to encompass all of Australia for an entire year using all observations (ie every 10 minutes, 24 hours a day, 356 days). This work involved significant algorithm and implementation development. The code was ported to Amazon Web Services (AWS) and a 12-month verification dataset over all of Australia was produced.

Output

The NSW/VIC RMIT hotspot trial demonstrated the potential for an Australia-wide trial as a next step. Work was undertaken to expand the geographical extent of the trial to include all of Australia, and to further explore the reliability of the hotspots when compared to other operational datasets and satellite products. The algorithm was enhanced to cope with different time zones and day/night handling across multiple time zones. The code was ported from traditional computing environment to AWS to enable a 12-month Australia-wide verification dataset from the 1st April 2019 to 31st March 2020.

Engel CB, Jones SD, Reinke KJ. *Real-Time Detection of Daytime and Night-Time Fire Hotspots from Geostationary Satellites*. Remote Sensing. 2021;13(9):1627.

Extent of use

- Datasets used to support comparison and validation activities by researchers with other operational products and data streams.

Utilisation potential

- Transferability of algorithm and implementation into commercial cloud-computing environments demonstrative of scale-ability of solution for global implementation.
- The research is the foundation for an upcoming real-time Australia wide RMIT Hotspot trial in real-time using Himawari-8 imagery.
- Inter-comparison results highlights current algorithm performance and areas for development.
- Provides spatially and temporally rich dataset for other researchers to work from.
- Verifying triple zero call-ins (example below)

Example: To assess the potential of BRIGHT detections for verifying current incident reports, the spatial and temporal agreement between BRIGHT detections and triple zero calls was assessed. Three methods were developed to investigate the best approach to the matching of BRIGHT detections with Public Incident Reports (PIR) reports in an automated manner. Method one attempted to match observations that were closest geographically, method two by finding the observations closest in time, and method three by finding observations which were closest both geographically, and temporally. Results from each of the three methods were interrogated and evaluated via comparison with a manually interpreted subset of the data to validate the matches generated.

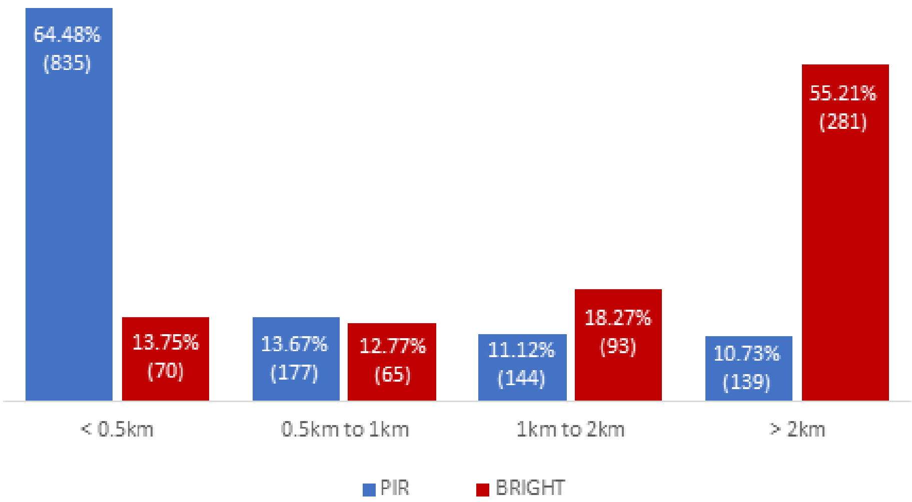

FIGURE 6. THE PERCENTAGE OF FIRES REPORTED BY PUBLIC INCIDENT REPORTS (PIR) AND BRIGHT HOTSPOTS CATEGORISED BY THEIR DISTANCE AWAY FROM ROAD CENTRELINES. THE ACTUAL NUMBER OF FIRES FOR EACH CATEGORY IS GIVEN IN BRACKETS.

The study found the spatial accuracy of the dataset was influenced by factors including the reliance placed on the caller's ability to accurately pinpoint a fire location, noting the influence of external factors such as proximity of caller to the fire event, availability of landmarks to identify location, and topographical obscuration that each affect the accuracy by which a caller reports fire location. For example, the majority of PIR reports were made within 0.5 km of a road, compared to Himawari-8 hotspots which showed most fire hotspots to occur more than 2km from the nearest road. The lack of resulting matches suggested that the proposed methodologies and dataset combinations were not capable of compensating for such spatial uncertainties and/or data entry error.

AUSTRALIA-WIDE REAL-TIME TRIAL

Summary

The BRIGHT Australia-wide hotspot trial (started in Oct 2020) was continued until 21st May 2021. Hotspots were made available to all Australian fire management offices in near real-time. Representatives from all Australian fire management agencies were able to access hotspots in real-time.

Output

RMIT used Himwari-8 data made available by the Bureau of Meteorology, stable from Oct 2020 to May 2021, to deliver active-fire hotspots to all Australian RFS offices in near real-time. Processing time for the algorithm from the receipt of the Himawari-8 imagery through to final hotspot delivery was typically around 45 seconds.

Extent of use

- External Stakeholders were able to receive BRIGHT active fire detections in real-time (available, on average, 45 second after receipt Himwari-8 satellite imagery becoming available).
- NSW RFS made active-fire hotspots available to representatives from all Australian RFS offices.
- The hotspots were used in an exploratory fashion.
- RMIT monitored hotspots locally to ensure hotspots were being delivered and were performing as expected.
- The Australia-wide real-time system was handed over to Geoscience Australia in May 2021.

Utilisation potential

- Hotspots available from Himawari-8 every 10 minutes, 24 hours a day, processing and delivery times of hotspots within 45 seconds for whole of Australia
- Highlights areas with anomalous MIR values over Australia.
- For detection, monitoring, and fire-fighting purposes.

CONCLUSION

This project developed and evaluated fire detection and attribution algorithms for new generation geostationary (high frequency of observation) satellites. All case studies were undertaken with Himawari-8 but the products could be adopted for GeoKompsat 2A, GOES-16/17.

All project algorithms were assessed for accuracy and feasibility for near-real time operations. The final cloud-resilient, real-time products were intercompared to the standard polar-orbiting fire detection products for the whole of Australia for a full calendar year. The success of these products led to a full user trial that happened to coincide with the black summer bushfires. The utility of the products during this trial led to the real-time hotspot detection algorithm code (BRIGHT hotspots) being implemented in AWS for the whole of Australia and a formal handover of this code to Geoscience Australia.

The performance of new data products forms part of the development phase. How well do they perform? What are their limitations? What are their advantages for observing fire under different fire scenarios and in different landscapes? One aspect of evaluation is how does the algorithm, and implementation of the algorithm as a processing chain, perform under operational circumstances. To this end, an end-user trial was hosted by NSW RFS for the near-real time implementation of the new Himawari-8 hotspot algorithm (March 2019-March 2021) and expanded to include Victoria over the 2019-2020 (black summer) bushfire season.

Results from the project developed algorithms compare favourably with existing polar-orbiting fire detections and other Himawari-based approaches. This has led to wide interest and project outputs being adopted by end-users.

NEXT STEPS

The BRIGHT system has been handed over to Geoscience Australia to become operational on the DEA-Hotspots system. Research will continue into methods to produce timely and accurate fire information from remotely sensed satellite observations.

PUBLICATIONS LIST

PEER-REVIEWED JOURNAL ARTICLES

1 Hally B, Wallace L, Reinke K, Jones S. *A broad-area method for the diurnal characterisation of upwelling medium wave infrared radiation*. Remote Sensing 2017;9(2):167.

2 Wickramasinghe C, Jones S, Reinke K, Wallace L. *Development of a multi-spatial resolution approach to the surveillance of active fire lines using Himawari-8*. Remote Sensing 2017;8(11): 932.

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4 Wickramasinghe C, Wallace L, Reinke K, Jones S. *Implementation of a new algorithm resulting in improvements in accuracy and resolution of SEVIRI hotspot products*. Remote sensing letters 2018;9(9): 877-885. https://doi.org/10.1080/2150704X.2018.1484955.

5 Hally B, Wallace L, Reinke K, Jones S, Engel C, Skidmore A. Estimating Fire Background Temperature at a Geostationary Scale—An Evaluation of Contextual Methods for AHI-8. *Remote sensing* 2018;*10*(9):1368.

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7 Engel CB, Jones SD, Reinke K. *A Seasonal-Window Ensemble-Based Thresholding Technique Used to Detect Active Fires in Geostationary Remotely Sensed Data*. IEEE Transactions on Geoscience and Remote Sensing. 2021;59(6):4947-4956. https://doi.org/10.1109/TGRS.2020.3018455.

8 Engel CB, Jones SD, Reinke KJ. *Real-Time Detection of Daytime and Night-Time Fire Hotspots from Geostationary Satellites*. Remote Sensing. 2021;13(9):1627. https://doi.org/10.3390/rs13091627.

CONFERENCE PAPERS

1 Hally B, Wallace L, Reinke K, Jones S. *Assessment of the utility of the Advanced Himawari Imager to detect active fire over Australia*. Commission VIII, WG VIIVI, International Society for Photogrammetry and Remote Sensing, July 12 – 19, 2016 Prague, Czech Republic.

2 *Wickramasinghe C, Wallace L, Reinke K, Hally B, Jones S. *Inter-comparison of Himawari-8 AHI fire surveillance with MODIS and VIIRS fire products*. 37th Asian Conference on Remote Sensing, October 17-21 2016, Colombo, Sri Lanka.

3 Wickramasinghe C, Wallace L, Reinke K, Hally B, Jones S*. *Improving the spatial resolution of active fire detections from geostationary satellites*. 11th EARSeL Forest Fire Special Interest Group Workshop, September 25-27, 2017, Chania, Greece.

4 Hally B, Wallace L, Jones S, Wickramasinghe C, Reinke K. *Assessment of the performance of the broad area training method to detect fires in varied locations and landscapes throughout the Asia-Pacific*. 11th EARSeL Forest Fire Special Interest Group Workshop, September 25-27, 2017, Chania, Greece.

5 Jones S, Hally B, Reinke K, Wickramasinghe C, Wallace L, Engel C. July. *Next Generation Fire Detection from Geostationary Satellites*. In IGARSS 2018 - 2018 IEEE International Geoscience and Remote Sensing Symposium (pp. 5465-5468). IEEE.

6 Jones S, Reinke K, Hally B, Wickramasinghe C, Wallace L. Large area validation of Himawari-8 fire active fire products. In38th Asian Conference on Remote Sensing 2017: Space Applications: Touching Human Lives 2017.

*best paper award for conference

EXTENDED ABSTRACTS

1 Engel C, Jones S, Reinke K, Matthews S, Holmes A. *Detecting Active-Fires using Himawari-8: a report from the NSW Trial.* Non-peer reviewed research proceedings from the Bushfire and Natural Hazards CRC & AFAC conference. Melbourne, Australia, 25 – 28 August 2019. (oral).

2 Engel C, Jones S, Reinke, K. *Performance of fire detection algorithms Using Himawari-8.* Non-peer reviewed research proceedings from the Bushfire and Natural Hazards CRC & AFAC conference. Perth, Australia, 5 – 8 September 2018. (oral).

3 Hally B, Wallace L, Reinke K, Jones S. *Assessment of the utility of the advanced himawari imager to detect active fire over Australia*. International Archives of the Photogrammetry, Remote Sensing & Spatial Information Sciences. 2016 Jul 19;41.

TEAM MEMBERS

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Mr Johann Tiede

Mr Simon Ramsey

Mr Nur Trihantoro

END-USERS

End-user organisation	End-user representative	Extent of engagement (Describe type of engagement)
NSW Rural Fire Service	Stuart Matthews	Stuart Matthews has been engaged with the development of the algorithm via providing feedback on the detection performance of the algorithm in NSW, through the provision of data to help support ongoing inter-comparison of Himawari-8 hotspots by RMIT, and importantly through hosting of the BRIGHT hotspots the NSW (and Victoria) live trial over Summer 19/20. Stuart Matthews has been a co-presenter with RMIT at AFAC led presentations.
VIC Department of Environment, Land, Water and Planning	Steve Salathiel	Steve Salathiel has provided feedback on the performance the algorithm via specific case studies and provided detailed examples of hotspot activity relative to

		other sources of fire intelligence.
VIC Department of Environment, Land, Water and Planning	Naomi Withers	Naomi Withers has been a co-presenter with RMIT at AFAC led presentations.
Geoscience Australia	Simon Oliver	Simon Oliver is leading and has provided technical details for data formatting and attribution requirements for potential hosting by GA of RMIT national hotspots.

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