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ACTIVE FIRE DETECTION USING THE HIMAWARI-8 SATELLITE

Annual report 2019-2020

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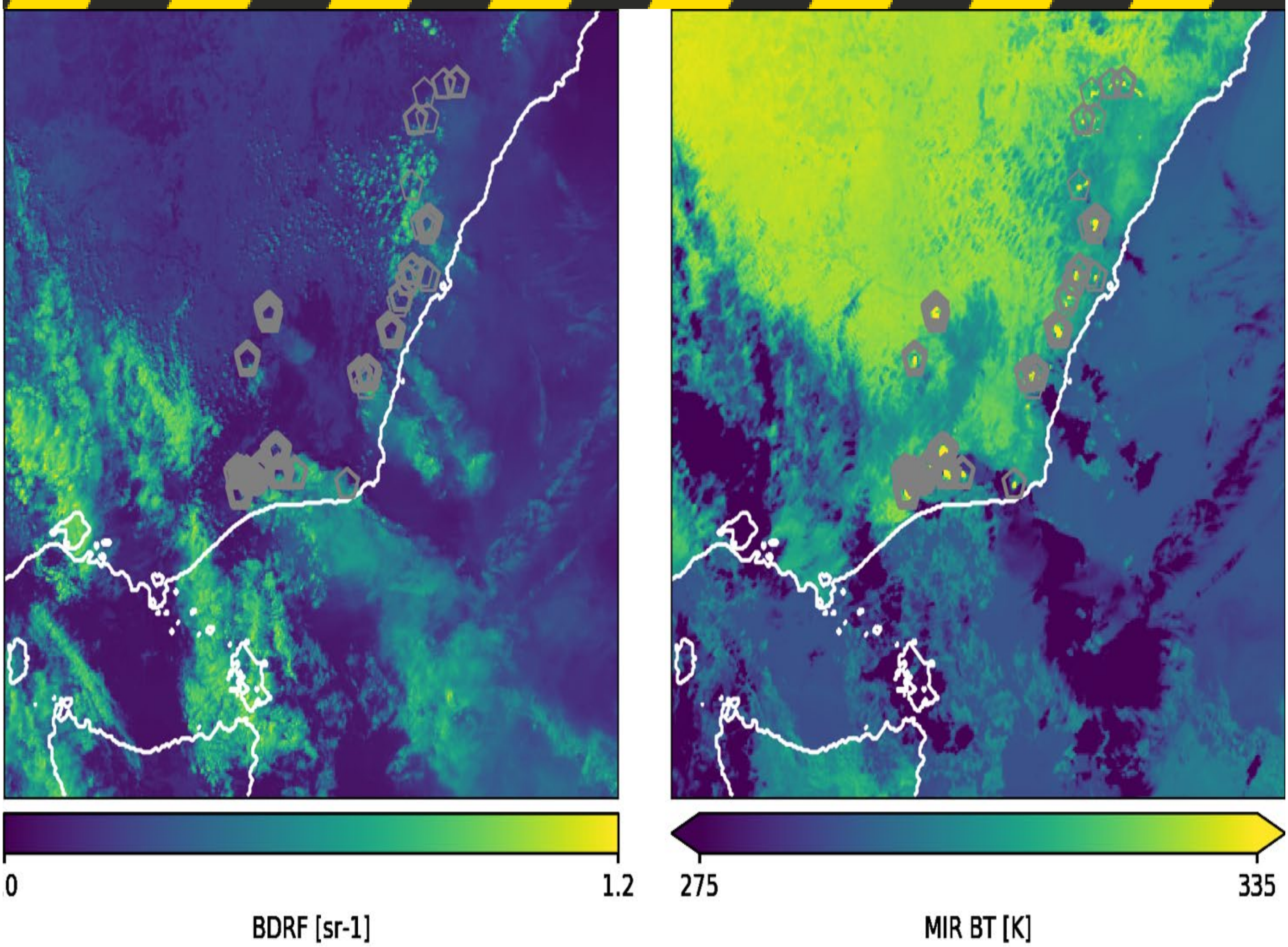
RMIT University



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Cover: 15:50 AEDT 30 December 2019, visible (left) and mid-infrared (right) Himawari-8 data overlaid with RMIT hotspots (grey pentagon). Area shown is highlighted in inset.

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ACKNOWLEDGMENTS

The project team gratefully acknowledge the assistance of end-users from across Australia including the Victorian Department of Environment, Land, Water and Planning, Geoscience Australia, and in particular, 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 immediate 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 completing the 12-month Australia-wide verification dataset.

EXECUTIVE SUMMARY

Satellite sensors are an important source of observations of fire activity in the landscape, and the advent of recent geostationary satellites such as Himawari-8 provide earth observations 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 fitness for purpose 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, and expanded to include Victoria over the 2019 bushfire season.

END-USER PROJECT IMPACT STATEMENT

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

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 Himwari-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 BNHCRC'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. This project will assist the Australian government to develop and validate Himawari-8 as a data source for the Sentinel Hotspots application. Our vision is to create a world leading approach to monitor fire activity. To achieve this, we propose the use of remote sensing technologies for active fire detection and monitoring.

This project is a critical part of the BNHCRC's value to Geoscience Australia and the broader Australian government. The Sentinel Hotspots application is used by all levels of government, private sector, researchers and the public – this system would not be trusted by those parties without sound validation. This project will continue to assist the Australian government in developing and validating the capability of the Himawari-8 data source. Further, the project will assist in the ongoing improvement of vital bushfire information acquired through state-of-the-art remote sensing technology as needed by fire and emergency management now, and into the future.

The aim this project is to next generation, remote sensing satellite information to enhance Australia's operational capabilities and information systems for 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 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 over 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 communicable and archivable. Automated fire detections from polar-orbiting satellites such as MODIS and VIIRS are currently used via the Sentinel website.

In October 2014, the Japanese Meteorological Service launched a new geostationary satellite that has 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 infrared, with spatial resolutions from 500m to 2000m, taking full-disk scans every 10-minutes. With such a wealth of information suddenly available, the question becomes: 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, a raise 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 and meteorological fluctuations. And 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 increases (i.e. from 1000m to 2000m). Satellite pixels represent observations over an area. The physical properties of an area may be uniform, but they may also be discontinuous; fire and non-fire; cloud and non-cloud. Larger pixels may not be able to resolve these small-scale physical processes. Instead, these processes become "blurred" along with the other data, 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 Himwari-8 satellite data. Existing active-fire detection algorithm tailored to polar-orbiting algorithms rely on the higher-resolving power of those datasets. The polar-orbiting fire detection algorithms allow for *some* residual noise due to unresolved processes, but the amount of 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, 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 APPROACHES

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. In 2018, the RMIT team designed an algorithm to detect fires in Australia using historical Himawari-8 data (Engel et al. 2020). This previous work created the desire for a similarly designed real-time algorithm.

METHOD AND RESULTS

A real-time RMIT Himawari-8 active fire algorithm was created and run over the whole of New South Wales and Victoria from 15th March 2019 to 23rd March 2020 (BRIGHT_NRT). Himawari-8 data was received in real-time from the Japan Meteorological Agency via the Bureau of Meteorology. Himawari-8 reflectance (0.64 μm, channel 3), mid-infrared (3.9 μm, channel 7) and thermal infrared (10.7 μm, channel 13) were stratified according to Interim Biogeographical Regionalisation of Australia (IBRA) 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 real-time data and delivered to the NSW RFS in real-time (Engel et al., 2020).

Active-fire hotspots were delivered to the NSW RFS within two minutes of Himawari-8 data being received for processing. RMIT/Himawari-8 hotspots were compared against Fire Information for Resource Management System (FIRMS) MYD14 hotspots (table 1). RMIT/Himawari-8 (BRIGHT_NRT) hotspots had commission errors of 8% during the day (11% during the night). Omission errors were 51% during the day (37% during the night).

DISCUSSION

The trial demonstrated that RMIT/Himawari-8 (BRIGHT_NRT) NSW/VIC hotspots could be delivered in real-time to NSW RFS.

The MYD14 satellite has higher resolving power (smaller IFOV) than the Himawari-8 satellite, and the difference in power may influence the statistics. The omission errors of 51% (day) and 37% (night) may be reflecting fires below the resolving power of the Himawari-8 satellite. The 8% (day) and 11% (night) commission error may also reflect differences in the algorithms and/or the transient nature of fires.

Our team is currently investigating ways to improve the RMIT/Himawari-8 algorithm. The real-time algorithm was modified to enable it to work over all of Australia. A trial was run to create a 12-month, all of Australia dataset. Various modifications to algorithm were trialled for further improvement.

Our team is also working on innovative ways to interrogate the reliability of RMIT/Himawari-8 hotspots outside of the MYD14 overpass times.

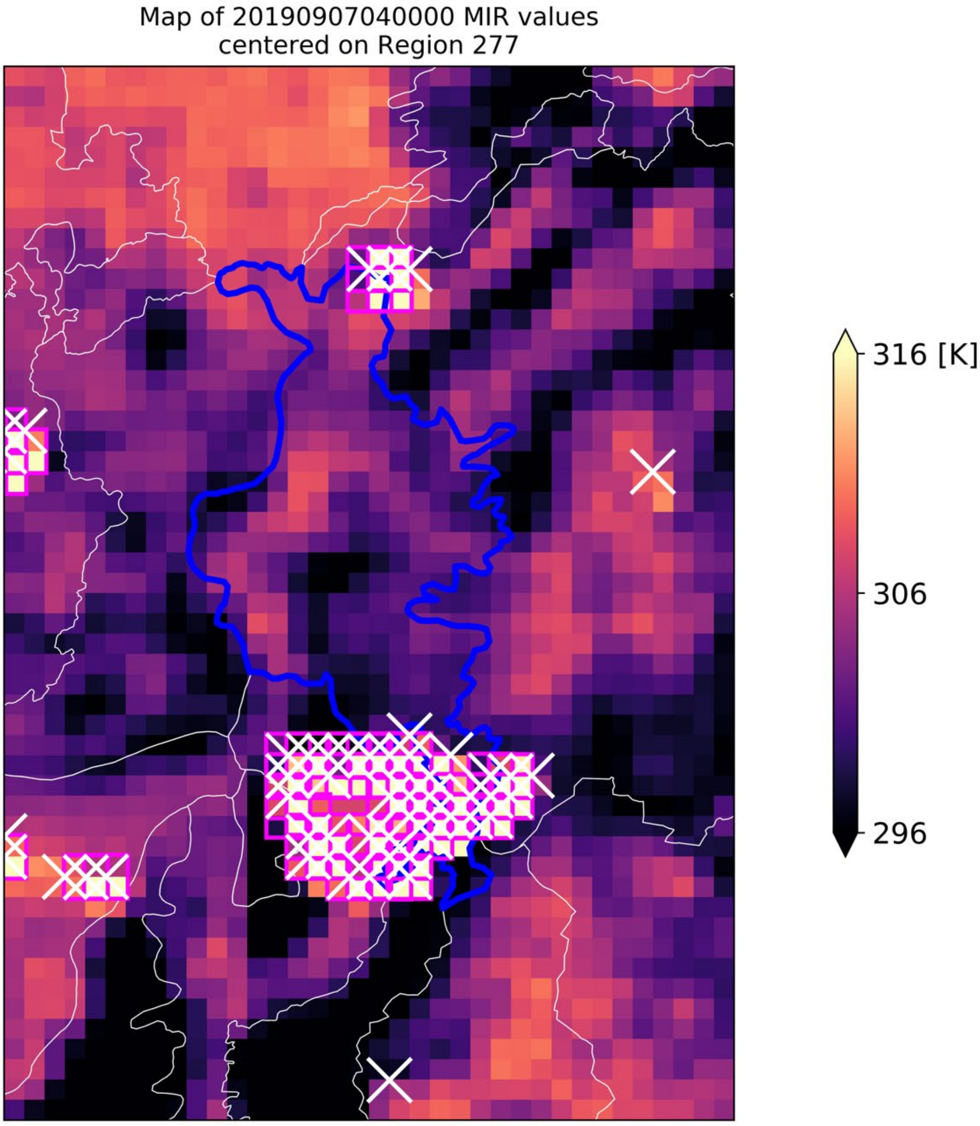

FIGURE 1. EXAMPLE HIMAWARI-8 DATA (3.9 μM, CHANNEL 7) CENTERED ON NSW NORTH COAST IBRA REGION NNC02 (OUTLINED IN THICK BLUE LINE; OTHER IBRA REGIONS SHOWN WITH THIN WHITE LINES) FOR 4 UTC ON 7TH SEPTEMBER 2019. OVERLAID ARE RMIT/HIMAWARI-8 (MAGENTA SQUARES) AND MYD14 (WHITE CROSSES) ACTIVE FIRE HOTSPOTS.

TABLE I MYD14 HOTSPOTS OVER NSW/VIC COMPARED WITH RMIT/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 RMIT/Himawari-8 hotspots in the MYD14 reconstructed swath	6398	5132
Number of RMIT/Himawari-8 hotspots detected within 1 pixel of a MYD14 hotspot	5881	4546
Commission error for RMIT/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 RMIT hotspot	7003	4751
Omission error for RMIT/Himawari-8 hotspots	51%	37%

Outputs

- Engel, C., Jones, S. and Reinke, K., 2020. A seasonal-window ensemble-based technique to detect active fires in geostationary remotely sensed data, *IEEE Transactions on Geoscience and Remote Sensing.* (in press).

KEY MILESTONES

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

- Finalisation of approach to handle cloud affected pixels in the fire detection algorithm for Himawari-8. Method submitted to peer-review in IEEE Transactions on Geoscience and Remote Sensing.
- Implementation of new fire detection technique for Himawari-8 in a live trial, near-real time in partnership with NSW RFS and expanded to Victoria.
- Adapt algorithm to feedback in near-real time.
- Presentation at AFAC 2019 in partnership with end-user from NSW RFS
- Implement the solution 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. Output successfully created.
- AFAC Webinar to end-user community for feedback.

UTILISATION AND IMPACT

SUMMARY

The RMIT hotspot trial commenced in Feb 2019, algorithm stable from 15th March 2019, and ran until 23rd March 2020. Hotspots were made available to NSW RFS in near real-time, with hotspots onward delivered to Victorian DELWP from Jan 2020. The trial enabled NSW RFS a chance to gain more experience with the RMIT hotspots and Himawari-8 data during differing fire seasons; and Victorian DELWP to gain experience with RMIT hotspots and Himawari-8 data.

OUTPUT #1: REGIONAL TRIAL

RMIT used Himwari-8 data made available by the Bureau of Meteorology, from 15th March 2019 to 23rd March 2020, to deliver active-fire hotspots to NSW RFS (and later Victorian DELWP) 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.

Extent of use

- RMIT delivered active-fire hotspots to the NSW RFS in near real-time, and onwards to Victorian DELWP from Jan 2020.
- NSW RFS made active-fire hotspots available to operational users via a graphical interface that included both location and timing information.
- Victorian DELWP 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.
- RMIT also monitored hotspots in a more localized way.

Utilisation potential

- Hotspots available from Himawari-8 every 10 minutes, 24 hours a day.
- Highlights areas with anomalous MIR values over NSW/VIC.
- For detection, monitoring and fire-fighting purposes.

Utilisation impact

Engel, C., S. Jones, K. Reinke, S. Matthews and A. Holmes. 2019: 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, 25 – 28 August 2019. (oral)

Engel, C., S. Jones, K.Reinke, S. Matthews and N.Withers, 2020: Multivariate spatiotemporally adaptive threshold (MSTAT) Himawri-8 hotspots. FBAN webinar 5th June 2020.

SUMMARY

The RMIT hotspots algorithm was expanded to encompass all of Australia. This work involved significant algorithm development. The code was ported to Amazon Web Services (AWS) and a 12-month verification dataset over all of Australia was produced.

OUTPUT #2: AUSTRALIA-WIDE VERIFICATION DATASET

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 all of Australia. The algorithm was enhanced to cope with different time zones and day/night handling. The code was ported from traditional computing environment to AWS to enable a 12-month Australia-wide verification dataset to be produced for verification purposes.

Extent of use

- The RMIT hotspot algorithm was modified to produced day/night hotpots across multiple time zones.
- Code was ported to high performance (AWS) environment to enable the timely production of a 12-month Australia wide verification dataset.
- 1st April 2019 to 31st March 2020.
- Hotspots were compared against MODIS hotspots.
- Hotspots were also investigated graphically to assess performance over Australia.

Utilisation potential

- The research is the foundation for an upcoming real-time Australia wide RMIT Hotspot trial. Hotspots will be made available from Himawari-8 every 10 minutes, 24 hours a day.
- Highlights current algorithm performance and areas for development.
- Provides a long duration, high temporal frequency, dataset of Himawari-8 hotspots against which inter-comparisons with other operational hotspots can be made.
- Provides a benchmark for testing updates to algorithm for measuring cost / benefits.

Utilisation impact

Work was completed on 25 June 2020. Utilization impact yet to be shown.

NEXT STEPS

- Inter-comparison and verification of Himawari-8 hotspots against other active fire data products. This will consist of three levels of activities:
    - Level 1 validation and intercomparison data compilation, analysis, statistics, and performance report of RMIT hotspots with NSW incidents
    - Level 2 validation and intercomparison data compilation, analysis, statistics, and performance report of RMIT hotspots with other operational products (MODIS, VIRRS, WF-ABBA) for Australian continent for minimum one years' data.
    - Level 3 validation and intercomparison data compilation, analysis, statistics, and performance report of RMIT hotspots against operational Burnt Area Products for Australian continent for minimum one years' data

- Project setup, preparation and access to additional High Performance Computing resources for live, real-time continental trial of RMIT Himawari-8 hotspots. Support of live trial, end-user feedback, and customisation of thresholds across continent.

PUBLICATIONS LIST

PEER-REVIEWED JOURNAL ARTICLES

1 Chermelle B. Engel, Simon Jones, and Karin Reinke (2020 in press) A seasonal-window ensemble-based thresholding technique used to detect active fires in geostationary remotely sensed data, Transactions in Geoscience and Remote Sensing -2020-00058

EXTENDED ABSTRACT

1 Engel, C., S. Jones, K.Reinke, S.Matthews and A. Holmes, 2019: 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, 25 – 28 August 219.

TEAM MEMBERS

RESEARCH TEAM

Professor Simon Jones

Dr Karin Reinke

Dr Chermelle Engel

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 RMIT 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 has provided technical details for data formatting and attribution requirements for potential hosting by GA of RMIT national hotspots.