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DISASTER LANDSCAPE ATTRIBUTION

Annual report 2016-2017

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Cover: Collecting data using the Fuels3D smartphone app to assess fuel hazard in the Mallee region of Victoria

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EXECUTIVE SUMMARY

Jones, S and Reinke, K, *School of Mathematical and Geospatial Sciences, RMIT University, VIC*

What is the problem?

Monitoring bushfires requires timely information on their early detection, location, intensity and configuration. Their management requires timely information on fuel hazard condition and the efficacy of fuel reduction measures. This project seeks to use remote sensing to acquire this information at multiple spatial scales.

Why is it important?

By enhancing the timeliness and accuracy of observations and measurements of bushfire threatened and affected landscapes, our mitigation activities and response capacities are further strengthened. The provision of quantitative fire severity assessments informs the way in which we protect against the increasing threat of bushfire and inform our immediate to long - term recovery and rehabilitation efforts in response to bushfire events.

How are we going to solve it?

Our project is evaluating and validating current satellite based remote sensing options for active fire detection and surveillance. Using simulations and real world experiments we are determining the accuracy with which fires can be detected, their temperature and shape determined, for a range of landscapes. Our project is also creating new techniques and protocols for the rapid attribution of fire landscapes (pre- and post-fire). These techniques seek to add quantitative rigour to existing fuel hazard estimation practices.

How have we done?

This project brings together researchers from around the world including RMIT, the German Aerospace Agency DLR, CSIRO, the University of Twente in the Netherlands, Geoscience Australia and the Bureau of Meteorology. The project attributes fire landscapes using the latest satellite based thermal earth observation systems for active fire surveillance. Structure from Motion (SfM) and Terrestrial Laser Scanning (TLS) technologies and techniques are used to quantify and map changes in the landscape before, and after, a fire event. This report provides a background to the project and discusses the key research questions being asked and describes the progress made. Key achievements over the last year are described and linked to research outputs and end user engagement and operations. The report concludes with activities planned for the year ahead and a list of currently integrated project members.

Highlights of 2016-2017 have included:

- Four international/national conference presentations completed.
- Five journal papers published in high impact publication outlets.
- New PhD candidates join the research team.
- New end users and collaborations with ACT Parks and Conservation, NSW Rural Fire Service and Melbourne Water.
- Project spin-offs with local participants (Loddon-Mallee region, DELWP).
- Two new promising algorithms for early fire detection and fire-line mapping developed and published for Himawari-8.

END USER STATEMENTS

"ACT Parks and Conservation participated in the Fuels 3D App trial and believes it has strong promise in standardising the methodology for near surface and elevated fuels estimation. The ACT has over 100 established fuel hazard sites which are assessed annually, and we find that different using observers each year causes considerable variability in results. The Fuels 3D method would help achieve much greater consistency, reliability and repeatability, and will reduce the variability of results between individual observers."

Tony Scherl

ACT Parks and Conservation

"Existing fire detection techniques must evolve alongside new sensor systems. Geoscience Australia supports this project that is developing innovative ways of handling real-time fire data sources. Efficient use of these sources can improve the timeliness and accuracy of active fire detection, and are complementary to other validation efforts on existing fire algorithms."

David Hudson

Geoscience Australia

"This project will assist agencies to detect, respond and monitor fires especially at those times during severe weather days when no other source of information is available. This has positive and real outcomes for our community. "

Naomi Withers

Department of Environment, Land, Water and Planning

INTRODUCTION

There is a need for accurate observation and monitoring of active fires in the landscape, and for new supporting attributes or metrics for assessment of post - fire effects across the landscape. Emerging earth observation technologies designed for monitoring fire and its effects, combined with the ubiquitous nature of remote sensing means there is an ongoing requirement to understand the fitness - for purpose of new data products. How well do they perform? What are their limitations? What are their advantages for observing fire under different fire scenarios and in different landscapes? Yet at the same time, it is also demands utilizing existing data sources and procedures that are currently in operation and developing flexible protocols for integrating current as well as future data products for our end users.

Our vision is to create a world leading approach for monitoring active fire extent and intensity, and subsequent quantification of bushfire severity. To achieve this vision two complementary research activities are proposed using remote sensing technologies for: (1) active fire detection and monitoring, and (2) enhancing pre and post burn landscape attribution.

The outcomes of the project are to build the capacity for integrating current fire information with existing, and next generation, remote sensing satellite information thereby enhancing Australia's operational capabilities and information systems for bushfire monitoring and mapping across a range of spatial scales and landscapes. Ultimately the outcomes of this research will enable measures of active fire and burn severity in terms of areal extent and magnitude to be made which in turn 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 project has practical significance to end users involved in fire ecology, wildfire mitigation and management activities. Recommendations will be made in terms of operational decisions relating to information utility and protocols necessary for the monitoring and management of wildfire management activities. Land managers, fire scientists and ecologists are turning to remote sensing as a tool for rapidly acquiring fire and vegetation related data over various spatial scales. By supplementing existing data collection and data integration protocols to include new variables we will be maximising the efforts made by ground crews plus enhancing capacity for accurate mapping of fire activity, and improving assessments of fire severity through the use of remote sensing technologies. Improving capacity for quantitative and accurate measures of fire - related variables will assist government reporting requirements and informing future wildfire mitigation work plans.

PROJECT BACKGROUND

The project will address the provision of timely and high quality information founded on multi- scale remote sensing and will develop enhanced metrics on active fire extent, intensity and configuration as well as bushfire landscape attributes. The project aims to bridge significant information and knowledge gaps that currently prevent optimal use of earth observing technology. These include accuracy and reliability issues in active fire surveillance, quantitative estimates of post-fire severity, a lack of product validation, and out-of-date approaches to collecting information on landscape condition. The project seeks to enhance Australian led existing disaster monitoring (e.g. the CSIRO/GA Sentinel Asia / Sentinel hotspots) and reporting systems with next generation earth observation technology and systems from the DLR, JMA and other agencies. The project will be delivered in three integrated work-packages which are summarised below. The research is placed in "priority landscapes" as identified by our end-users and which have been identified as peri-urban areas, desert/mallee systems and closed (multiple canopy) forests in Australia. Figure 1 provides an overview of core activities and application areas.

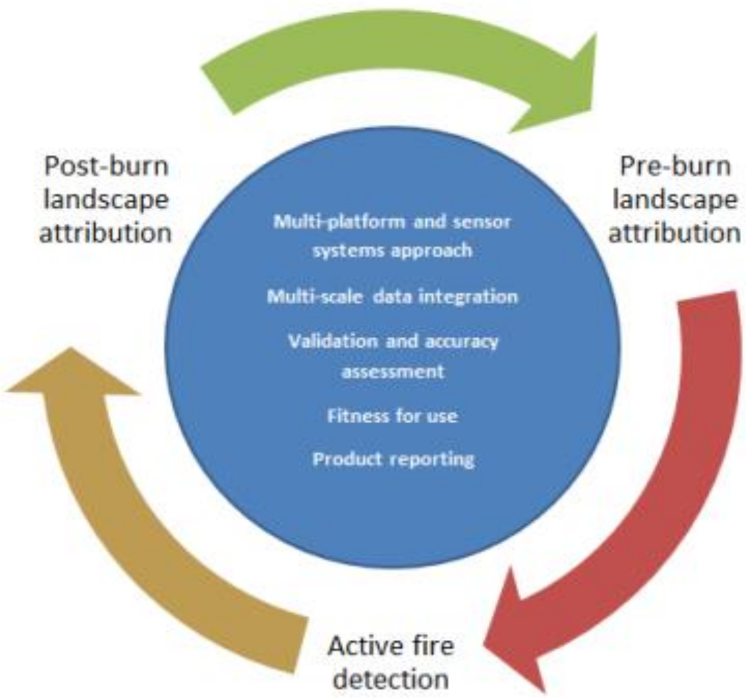

Figure 1. Overview of core research activities and application areas.

WORK PACKAGE 1: REMOTE SENSING FOR ACTIVE FIRE SURVEILLANCE

The current global fire detection system is based on the Moderate Resolution Imaging Spectrometer (MODIS) sensor. The TET-1 satellite and payload (launched in 2012), includes an infrared camera system designed for the detection of high temperature events, such as wildfires, evolved from the Bi-spectral Infrared Detector (BIRD) experimental satellite. TET-1 can detect fires with smaller areas and lower temperatures than the commonly used MODIS satellite sensing system due to its higher spatial resolution. In contrast, Himwari-8/AHI compromises on spatial resolution compared to TET-1 but offers a high temporal resolution (10-minute observations versus days' before re-visits).

This work package utilises MODIS, TET-1, SEVIRI and Himawari-8 for active fire surveillance. A literature review considers existing and emerging thermal technologies, and reviews these against the information sources utilised by fire management agencies. Development of new detection and monitoring algorithms, and evaluation of sensors and supporting hotspot products forms a core component of this work package.

Multi-scale, empirical field experiments are used to validate sensor information where feasible. Although previous field campaigns have been logistically and resource intensive. A comprehensive inter-comparison of fire information ranging from state fire history records, developmental algorithms such as WFABBA through to standard operational products such as MODIS, will also inform the performance of new algorithms and sensors for early detection and mapping of active fire. Supporting the empirical and inter-comparison studies, will be a "virtual assessment environment" of thermal sensor capabilities. The provision of a "virtual assessment environment" enables evaluation to be achieved without the high risk associated by field campaigns, and is independent of satellite imagery availability. Simulations of different active fire scenarios will be generated to theoretically determine the limits under which active fire detection and mapping accuracy can be achieved by different sensors under differing fire conditions and cross-referenced to empirical studies. An analysis of the spatial and temporal characteristics of wildfires is described for Australia based on state fire history records.

WORK PACKAGE 2 AND 3: PRE-BURN AND POST-BURN LANDSCAPE ATTRIBUTION

This work package considers the need for accurate observation and new supporting attributes or metrics for assessment of post-fire effects across the landscape. Fuel hazard and severity assessments, in particular, are largely subjective and have limited capacity for scaling up from the site to the landscape. The next step for these assessments is to move towards being quantitatively measured across the entire landscape of interest, and to have the important capacity to integrate with future information sources. Remote sensing offers the only means to routinely monitor and report on the status of landscape condition over large areas. It is both synoptic and systematic; and can offer repeat sampling in a consistent regular framework. Potential solutions are explored that can provide rapid implementation and deployment for land managers in the field.

The goals here are to go beyond reporting the area burnt, to one that captures the spatial complexity or mosaic of hazards and burn patterns. On ground technology, coupled with aerial and satellite images gives us a powerful way to validate and link what we see from space to what we see happening on the ground. We consider the typical methods used to map and describe the pre-burn landscape (e.g. fuel hazards) and the post-burn landscape (e.g. burn severity elements); and aim to complement traditional assessment approaches by developing new and reliable information through the addition and integration of remotely sensed metrics of emerging technologies such as LiDAR and SfM.

We investigate and demonstrate the use of laser scanning and SfM for quantifying and mapping fuel hazards and change in the landscape. Additional experiments will be conducted in other vegetation communities within Victoria and interstate. Fuel hazard and severity assessments will be made, and correlated against variables of fuel and/or biomass that will be collected through in-situ measurements, and destructive dry weight analyses. The final step will be to consider how we translate remotely sensed measures of the environment into measures that have context and meaning to fire managers.

PROGRESS

KEY RESEARCH ACHIEVEMENTS

Active Fire Detection and Characterisation of Land Surface Background Temperatures

Related research outputs: #1, #10

The launch of new geostationary satellites such as the Himawari-8 imager provide users with far richer sets of data than from previous geostationary sensors, especially with regard to image revisit rate and spatial resolution. These new data sets provide more detailed information about potential fire incidents, and give us the ability to create more detailed models of the diurnal cycle for background temperature estimation. The success of most fire detection algorithms relies on having an accurate estimation of the background surface temperature.

An algorithm (BAT) has been produced that enables the modeling of an individual pixels diurnal temperature cycle that avoids issues such as standing cloud which can introduce large errors into diurnal modelling. This algorithm uses larger portions of land in a standardised form to create an idealised model of the diurnal cycle at a specific latitude. This idealised cycle can then be used as training data for a temperature fitting process over individual pixels for a 24 hour period, and anomalies can be identified using deviation of brightness temperatures from the ideal curve. The method has been found to be less computationally intensive, be more robust against obscuring influences such as cloud, and be available for use over far larger areas than similar methods using pixel-based training data. Figure 2 shows the improved data availability possible using the BAT approach when compared against alternative standard methods.

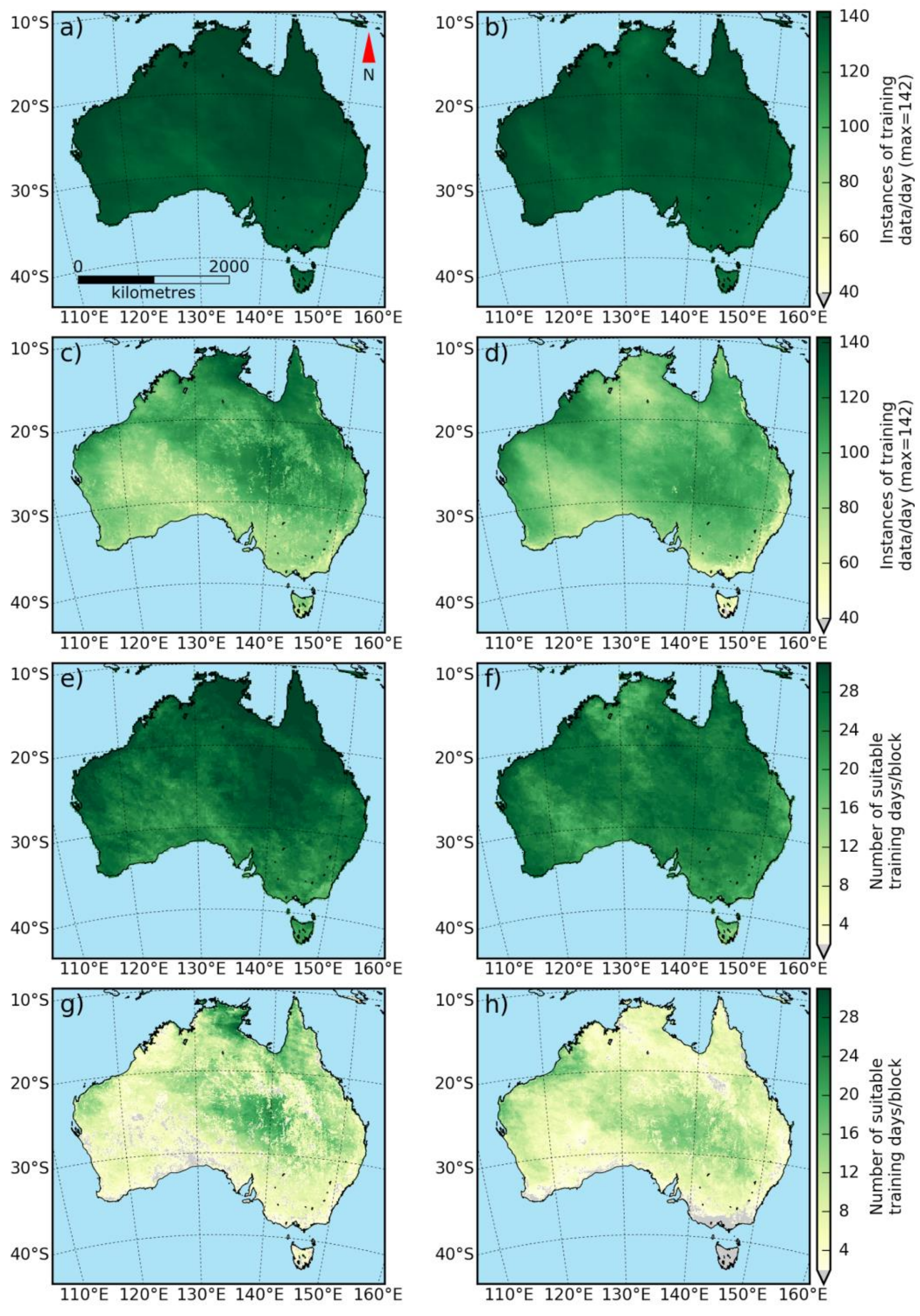

FIGURE 2: AVAILABILITY OF TRAINING DATA FROM THE BLOCK AND PIXEL BASED METHODS. (A,B) SHOW THE MEAN INSTANCES OF TRAINING DATA AVAILABLE USING THE BAT METHOD FOR OCTOBER AND NOVEMBER RESPECTIVELY; (C,D) SHOW THE TRAINING DATA AVAILABLE USING THE PIXEL METHOD FOR THE SAME MONTHS.(E,F) DEMONSTRATE THE NUMBER OF 24-H PERIODS THAT COULD BE UTILISED AS TRAINING DATA FOR EACH BLOCK IN OCTOBER AND NOVEMBER, AND (G,H) SHOW THIS SAME CRITERIA USING THE PIXEL BASED METHOD.

Work has been undertaken to apply this temperature fitting technique in response to active fire with the application of simple temperature thresholding. It also looks at the influence thermal (positive and negative) anomalies can have on the modelled background. This is shown in Figure 3. Following this, a study has been undertaken which applies the algorithm to fires in an area of northern Australia for August 2016, with inter-comparisons to commonly used active fire detections products from the MODIS and VIIRS low earth orbiting satellites. This study has shown that AHI detections have quite low omission rates in comparison to the LEO products, and that the number of fires detected increases due to more comprehensive image coverage. The study also shows improvements in average time of detection, with accuracy improving when the method is utilised in a near-real-time capability.

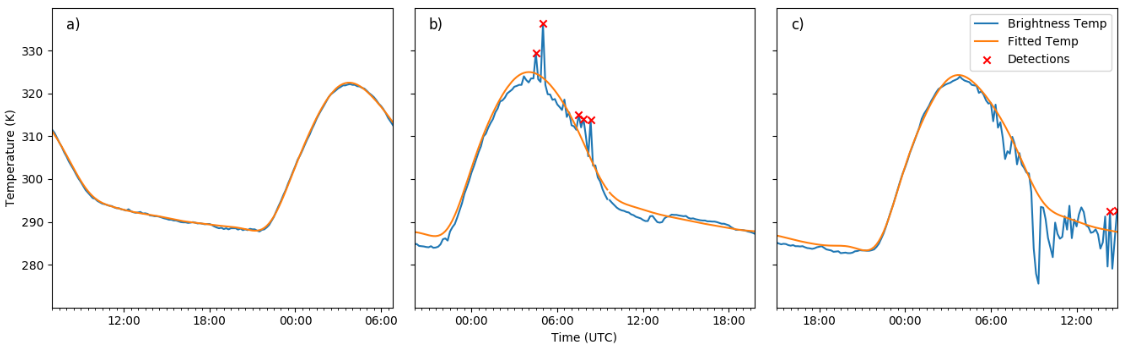

FIGURE 3: EXAMPLES OF FITTING ANOMALY TYPES. (A) NORMAL FITTING OF BACKGROUND TEMPERATURE, (B) FIRE AFFECTED FITTING SHOWING POTENTIAL FLAMING PERIODS, AND (C) SHOWING THE EFFECT OF CLOUD ON THE FITTING PROCESS.

The year ahead:

- Large area transect for algorithm evaluation to test performance over wider geographic and temporal domains (ie larger areas, range of landform and landcover types, seasonality).
- Inter-comparison with commonly used geostationary active-fire products including WF-ABBA and state fire history records for spatial agreement and detection times.
- Evaluation of alternative temperature fitting methods for potential improvement of fire attribution.

Active Fire Surveillance and Fire Line Mapping

Related research outputs: #2, #6, #11

The AHI-FSA (Advanced Himawari Imager - Fire Surveillance Algorithm) algorithm which demonstrate a high potential as a wildfire surveillance algorithm was validated in-depth over Northern Territory of Australia (1.4 million sqkm) over a 10 day period by comparing AHI-FSA to the well-established fire products from LEO satellites such as MODIS (Moderate Resolution Imaging Spectroradiometer) and VIIRS (Visible Infrared Imaging Radiometer Suite). The results indicate that the multi-resolution approach developed for AHI-FSA is successful in significantly improving fire surveillance, bringing the initial detection in the thermal middle infrared (MIR) band from 2km to 500 meter. When compared to the MODIS thermal anomaly products, AHI-FSA omission error was only 2%. High temporal frequency data results in AHI-FSA observing fires, at times, three hours before the MODIS overpass with much-enhanced detail on fire movement.

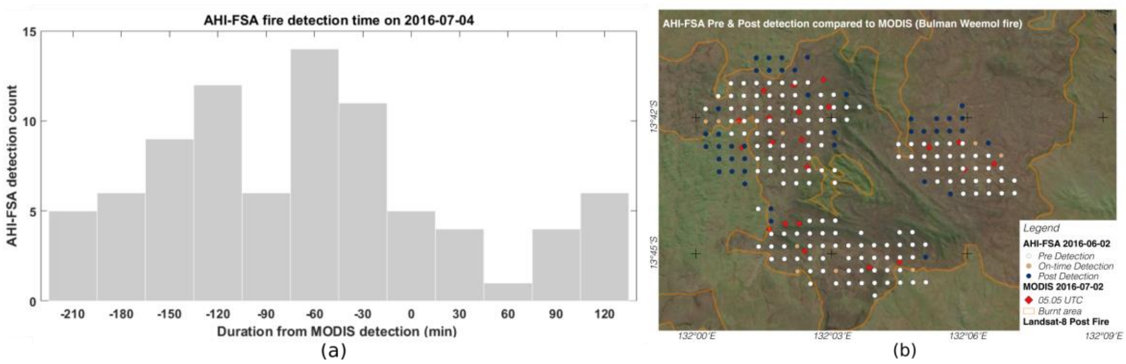

FIGURE 4. PLOTS THE TIME DIFFERENCE BETWEEN THE AHI-FSA DETECTION AND THE NEAREST MODIS DETECTION FOR A CASE STUDY FIRE NEAR BULMAN WEEMOL IN NORTHERN TERRITORY OF AUSTRALIA ON THE 2ND OF JULY 2016. THE HISTOGRAM IN FIGURE 02 (A) SHOWS THAT AHI-FSA FIRST DETECTED THE FIRE BEFORE THE MODIS AQUA OVERPASS BY APPROXIMATELY 3.5 HOURS. THE SPATIAL DISTRIBUTION OF THE DETECTIONS, AS ILLUSTRATED IN FIGURE FIGURE 02 (B) SHOW THAT THE CONTRIBUTION OF HIGH TEMPORAL OBSERVATIONS ALSO ALLOW AHI-FSA TO DESCRIBE THE AREA OF THE FIRE WITH GREATER DETAIL IN COMPARISON TO MODIS HOTSPOTS. TOTAL OF 97% OF THE AHI-FSA DETECTIONS WERE WITHIN THE VISIBLE BURN AREA ON THE LANDSAT-8 IMAGE CAPTURED ON 9TH JULY 2016.

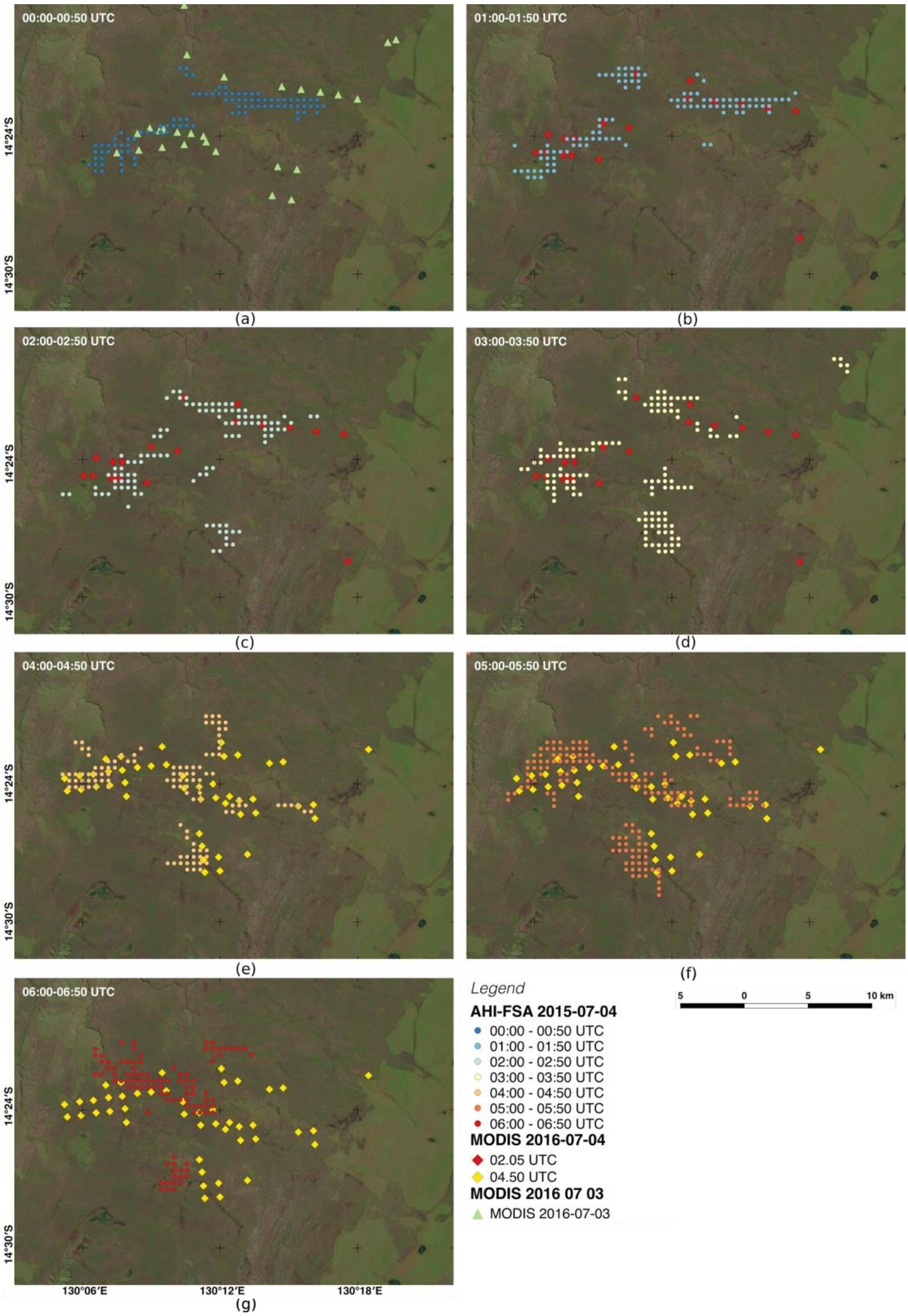

FIGURE 5. SINGLE FIRE MONITORING NEAR CLARAVALE, NORTHERN TERRITORY, AUSTRALIA VIA AHI-FSA AND MODIS ON 2016-07-04. THE FIGURE SHOWS THE SEQUENCE OF HOURLY AGGREGATIONS OF AHI-FSA FIRE-LINES OVERLAID WITH NEAR SYNCHRONOUS MODIS HOTSPOT DETECTIONS. IMAGES (A) TO (G) SHOW DETECTIONS FROM 00:00 TO 06:50 UTC AND (H) SHOWS THE TOTAL AHI-FSA DETECTIONS DURING THE DAY OVERLAID WITH MODIS TERRA AND AQUA DAYTIME DETECTIONS. LANDSAT-8 POST-FIRE IMAGERY WAS USED AS THE BACKGROUND, SHOWING DARK-GREEN/BROWN AREA AS BURN AREA.

The Year Ahead

- Validating the algorithm in closed canopy forest fires (VIC & NSW).
  - Currently AHI-FSA has been only tested in woodland/grass land fires in Northern Territory Australia. AHI-FSA depends on changes in top vegetation layer to detect the fire-line thus the algorithm could have lower accuracy when detecting close canopy fires compared to grassland fires.
- Further improve fire-line detection.
  - AHI-FSA initial fires detection is bounded by 2x2km MIR band. We will try to improve the AHI-FSA MIR band thermal anomaly detection through subpixel classification and time series analysis techniques.
  - Current AHI-FSA is limited to day time only detections due to its dependence on NIR and RED bands. MIR band thermal anomaly detections will be added to detect thermal hotspots during the night time.

The Fuels3D App

Related research outputs: #3, #4, #5, #9

An end-user field day was held in July 2016. Representatives from SA DEWNR, ACT Parks and Wildlife, VIC DELWP, VIC CFA, Melbourne Water and Parks Victoria were in attendance. The field day aimed to introduce end-users to the Fuels3D collection protocol and to assess its ease of use and repeatability between data collectors in comparison to traditional visual assessment techniques. Participants were asked to undertake a visual assessment and collect Fuels3D data at three plots as shown in Figure 6. Following, the data collection participants were asked to complete a survey evaluating the Fuels3D data collection workflow.

The results of the field trial indicated that surface and near-surface metrics related to fuel hazard can be measured with greater repeatability between different observers. This is demonstrated in Figure 7 where the range of surface cover and height is significantly lower across all plots than seen in the visual assessment approach.

FIGURE 6. EXAMPLES OF THE THREE SITES FROM WHICH PLOT LEVEL FUEL HAZARD ASSESSMENTS WERE CONDUCTED.

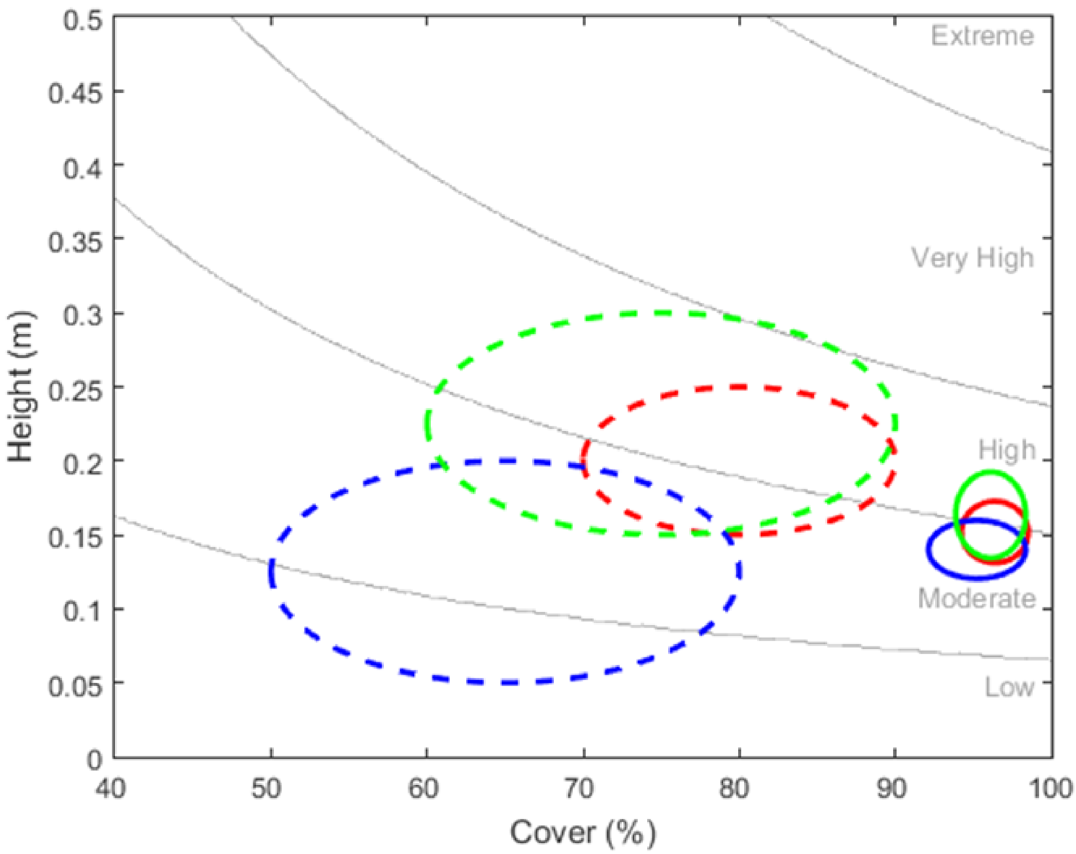

FIGURE 7. RANGE OF SURFACE FUEL HAZARD RATINGS ACROSS THREE PLOTS AS ASSESSED VISUALLY (DASHED LINES) AND USING FUELS3D METICS (SOLID LINES).

The survey indicated that the participants found the Fuels3D protocol easy to follow. This was further indicated by the collected data of which more than 90% of the image sets were able to be used in the Fuels3D processing method. From the results of this study several areas of improvement in the data collection and processing methods were identified.

A key area improvement identified was that the means for in-field scaling required improved accuracy and user friendliness and transferring this information into the digital dataset required further automation and robustness. To overcome this 3D printed targets have been designed and will be used along with wifi positioning boards and computer vision algorithms to provide a rapid means of scaling for the collected information.

The Year Ahead:

- Testing of the new in-field scaling method.
- Evaluation of the accuracy of Fuels3D metrics against more accurate sources of in-field information.
- Extension and testing of Fuels3D methods into other landscapes identified by end-users. Through an in-agency trial of the approach.
- Development of Fuels3D for iPhones

Monitoring Fire Affected Landscapes using Point Clouds

Related research outputs: #3, #4, #5, #8, #12

Field campaigns have been conducted in 2017 a field campaign to continue to assess the utility of image based point clouds to map and monitor fuel hazards. The specific goals of this campaign were to 1) revisit an area captured prior to a prescribed burn on the anniversary date of that burn, 2) to test methods for the validation of point cloud metrics derived using existing metrics and 3) to develop rule sets for the extraction of different fuel hazard layers from point cloud information.

In meeting the goal 1 these datasets have been processed to produce maps of changes in fuel hazard landscapes across 10m radius plots as shown in Figure 8. The results of these maps show good correlation with changes observed in the field and provide a quantified estimate of change. Processing of data to meet goals 2 and 3 are still on going.

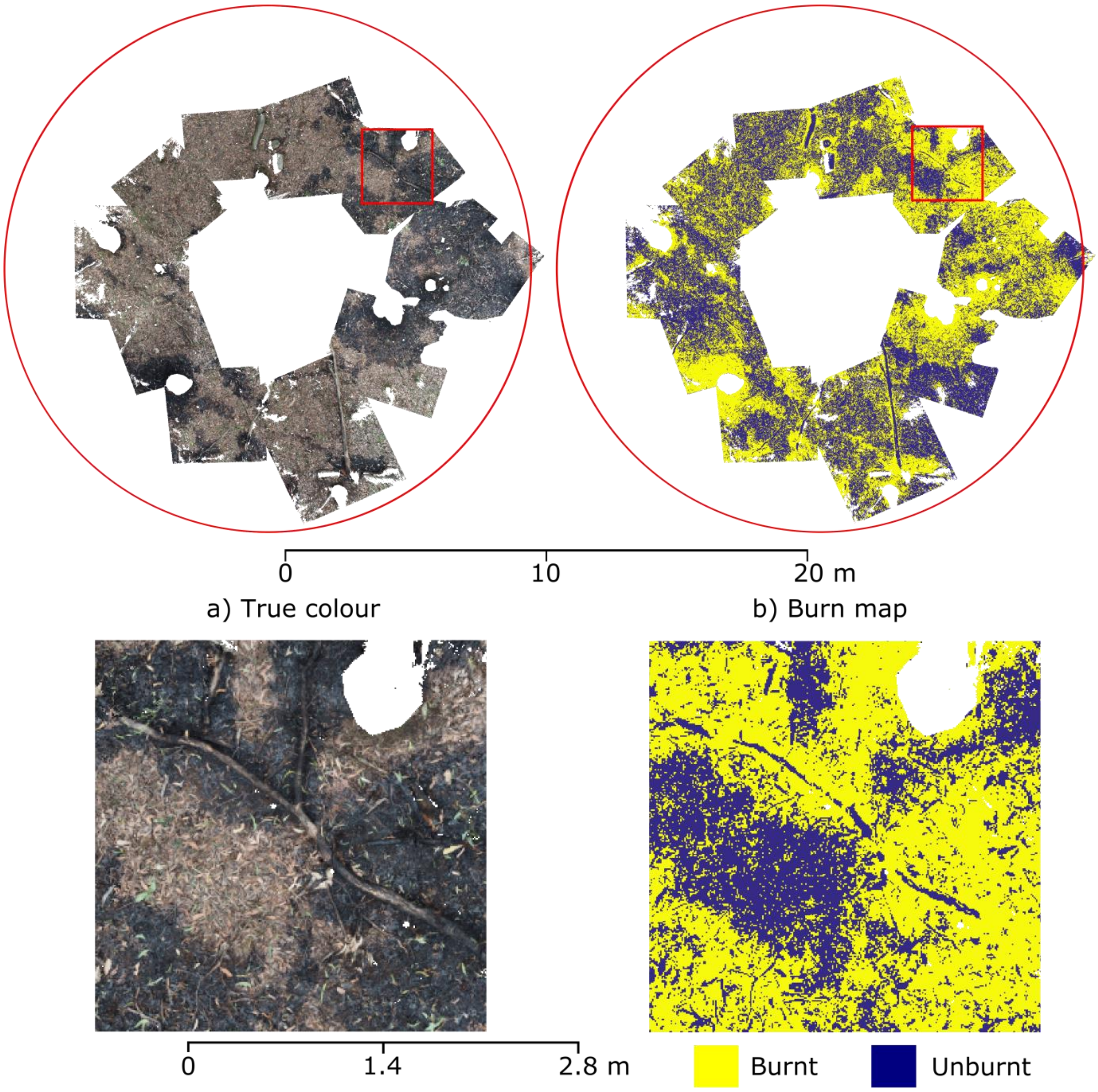

FIGURE 8. A) TRUE COLOUR ORTHOPHOTO AND B) MAP OF BURNT AREA DERIVED FROM THE POST FIRE POINT CLOUDS. THE UPPER IMAGES ARE OF THE ENTIRE PLOT WHILE THE LOWER IMAGES ARE TAKEN FROM THE RED INSET BOX.

The Year Ahead:

- Refinement and validation of methods to extract fuel hazard layers from point cloud information.
- A rigorous assessment of the accuracy of metrics derived from image based point clouds.
- Development of a rigorous method for the in-field scaling of point clouds.

EQUIPMENT

- ***IR converted Sony digital SLR camera***. A camera converted to be sensitive in the nearIR and to be used with data collecting and algorithms developed by the project to add a further dimension to the 3D point clouds. (InfraRed being sensitive to live vegetation.) Purchasing this piece of hardware will allow the research team to assess the improvements possible with the addition of the IR wavelengths in for mapping and monitoring fuel hazard.
- **Pozyx and 3D printed targets -** Pozyx wifi positioning boards were purchased in order to assess the advantages of using a less cumbersome positioning frame with fuels3D. Four 3D printed targets were including in this purchase to allow for automatic scaling of the final results.

NEW APPOINTMENTS AND COMPLETIONS

- ***Masters candidate completion.*** Christine Spits recently successfully completed her Masters. Her research focused on an accuracy assessment of surface and near-surface fuel measurements derived from a phone app (Fuels3D) and Structure from Motion (SfM) technology, and reported on the variability in measures that was found to exist between data collectors when using Fuels3D. Christine is now employed as a GIS officer within Forests and Fire with the Victorian Department of Environment, Land, Water and Planning.
- ***Masters candidate completion.*** Simon Mitchell successfully passed his Masters by Research completing his thesis titled "Validating the TET-1 satellite sensing system for detecting and characterizing active fire 'hotspots'" for examination.
- ***PhD candidate and BNH CRC associate student commencement.*** Sam Hillman commenced a PhD at RMIT University early in 2017. Prior to commencing his PhD, Sam graduated from RMIT University with a Masters of Geospatial Information in 2015. He continues to work as a seasonal firefighter and application developer for Forest Fire Management Victoria. Sam's research investigates the use of points for fuel hazard

estimation. The project will explore the use of image based point clouds generated from consumer-grade cameras and terrestrial laser scanners for describing cover, height and structure characteristics of below canopy vegetation. Terrestrial and airborne platforms will also be compared to identify the advantages and disadvantages of each technique in different landscapes.

END USER REPRESENTATIVES

John Bally / Simon Heemstra (Cluster Leads)
Bureau of Meteorology

David Taylor
Department of Primary Industries, Parks, Water and Environment, Tasmania

Simeon Telfer
Department of Environment, Water and Natural Resources, South Australia

David Nicholls
Danni Martin
Country Fire Authority, Victoria

Andrew Sturgess
Queensland Fire and Emergency Services

Adam Damen
Naomi Withers
Anthony Griffiths
Department of Environment, Land, Water and Planning, Victoria

Rowena Richardson
Office of the Inspector-General Emergency Management, Queensland

Andrew Grace
Attorney-General's Department

David Hudson
Geoscience Australia

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Dr. Alex Held
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Dr. Ian Grant
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University of Twente, Netherlands

Professor Simon Jones
Dr. Karin Reinke
Dr. Luke Wallace
Dr. Sofia Oliveira
Dr. Mariela Soto-Berelov
Mr. Vaibhav Gupta
Mr. Bryan Hally
Mr. Chat Wickramasinghe
Ms. Christine Spits
Mr. Simon Mitchell
RMIT University / Bushfire and Natural Hazards CRC

RESEARCH OUTPUTS

CONFERENCES June 2016-2017

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. Wallace, L.; Reinke, K.; Spits, C.; Hally, B.; Hillman, S.; Jones, S. **Mapping the efficacy of fuel reduction burns using image-based point clouds**. *ForestSat Conference,* November 14-18, 2016, Santiago, Chile.

4. Wallace, L.; Reinke, K.; Hally, B.; Wickramasinghe, C., Jones, S. **Managing wildfire risk across the Australian landscape using remote sensing**. *World Engineering Conference on Disaster Risk Reduction*, December 5-6, 2016, Lima, Peru.

Forthcoming, accepted conference presentations.

5. Hillman, S.; Wallace, L.; Hally, B.; Reinke, K.; Jones, S. **Terrestrial image based point clouds for mapping near surface vegetation: potential and limitations**. *Silvilaser 2017, October 10 - 12, 2017, Virginia, USA*.

6. 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, Chania, Greece*.

7. 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, Chania, Greece*.

JOURNAL PUBLICATIONS June 2016 - 2017

8. Wallace, L., Gupta, V., Reinke, K. and Jones, S., 2016. **An assessment of pre-and post fire near surface fuel hazard in an Australian dry sclerophyll forest using point cloud data captured using a terrestrial laser scanner.** *Remote Sensing*, *8*(8), p.679. (impact factor: 3.244)

9. Spits, C.; Wallace, L; Reinke, K. J. (2017) **Investigating surface and near-surface bushfire fuel attributes: a comparison between visual assessments and image-based point clouds.** *Sensors,* 17(4), p.910.
   [impact factor: 3.244]

10. Hally, B.; Wallace, L.; Reinke, K.; Jones, S. (2017) **A broad-area method for the diurnal characterisation of upwelling medium wave infrared radiation.** *Remote Sensing*, 9(2), p. 167.
    (impact factor: 3.244)

11. Wickramasinghe, C.; Jones, S.; Reinke, K.; Wallace, L. (2017) **Development of a multi-spatial resolution approach to the surveillance of active fire lines using Himawari-8.** *Remote Sensing,* 8(11), p.932.
[impact factor: 3.244]

12. Wallace, L.; Hillman, S.; Reinke, K.; Hally, B. (2017) **Non-destructive estimation of surface and near-surface biomass using terrestrial remote sensing techniques.** *Methods in Ecology and Evolution* , 25pp.
(impact factor: 6.554)