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DISASTER LANDSCAPE ATTRIBUTION: FIRE SURVELLIANCE AND HAZARD MAPPING, DATA SCALING AND VALIDATION

Annual project report 2015-2016

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Cover: Maps showing the tracking of fire temperature during a controlled burn in western Melbourne, Victoria, April 2015.

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ABSTRACT

This project attributes fire landscapes using the latest satellite based thermal earth observation systems for active fire surveillance. 3D remote sensing technologies have been trialed, and Structure from Motion (SfM) and Terrestrial Laser Scanning (TLS) technologies and techniques used to quantify and map changes in the landscape before, and after, a fire event. The 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.

Combining these two aspects of this project allows for remote sensing to become a key tool in mitigating the risk of disaster caused by wildfire. Results demonstrated from the work completed in this project with feedback from project end-users highlight the potential for remote sensing tools to contribute to existing landscape management processes.

This report provides a background to the project, 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 2015-2016 have included:

- Four international/national conference presentations completed.
- Two journal publications and three manuscripts currently in review, all in high impact publication outlets.
- Research featured in Australia Fire magazine and Asian-Pacific Fire magazine, interest from AFAC.
- Pre and post burn data collected for three Victorian prescribed burn events.
- Pre-beta development of Fuels3D, an android app for mapping and estimating fuel hazards. A workshop attended by local and interstate end users was held in December 2015 resulting in preliminary testing and data collection by end users in Victoria and South Australia. Two field

days showcasing Fuels3D and seeking end user feedback have been scheduled for two days in July 2016 with participants attending from SA DEWNR, ACT Parks and Wildlife, Vic DELWP, Vic CFA, Parks Victoria and Melbourne Water.

- New PhD and Master candidates join the research team.
- BNH CRC funded PhD student, Bryan Hally, on exchange to the University of Twente in the Netherlands.
- Project spin-offs, collaborations and opportunities from local (Loddon-Mallee region, DEWLP), national (Geoscience Australia) and international (USGS and Scion NZ) researchers and fire managers.
- New end users and collaborations with Geoscience Australia and Melbourne Water
- Invitation from EMSINA to present project developments at the AFAC development program, AFAC, Brisbane, 2016.

END USER STATEMENTS

Simeon Telfer, *DEWNR, South Australia*

"This project has engaged end users through development of prototype products, workshops and circulating outcomes and published materials. The Fuels3D mobile phone app has been of particular interest. This app has the potential to reduce fire fuel sampling times from hours per site to minutes. This would enable many more data points to be collected, benefiting several emergency management areas, including:

- improving knowledge of prescribed burn efficacy
- improved inputs into fire behaviour modelling
- improved knowledge in put into risk assessment and planning

These improvements will improve knowledge or risk and treatment options across landscapes and thereby improve resilience of communities. The Department of Environment Water and Natural Resources (DEWNR) in South Australia has been testing the prototype application, and would benefit greatly from further development of an operational product."

David Hudson, *Geoscience Australia, Australia*

"This project is a critical part of the BNH CRC'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. The Disaster Landscape Attribution project has assisted the Australian government in including the Himawari-8 data source to Sentinel Hotspots in time for the 2016/17 fire season. In addition the project has delivered an evaluation of TET-1 and a new technique to compare hotspot inter-comparison with independent evaluation. The project will assist in the collection of vital bushfire information acquired through state-of-the-art remote sensing technology as needed by fire and emergency management now and in the future."

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 specifications 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 that enable integration with remotely sensed observations 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.

THE PITCH

What is the problem?

Monitoring bushfires requires timely information on their 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 vigour to existing fuel hazard estimation practices.

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 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.

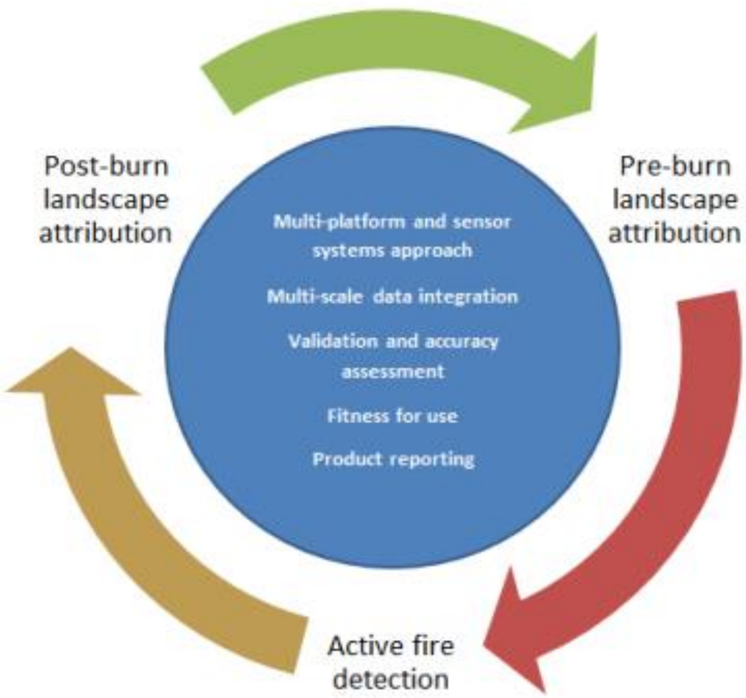

Figure 1. Overview of core research activities and application areas.

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. BIRD/TET-1 can detect fires with a smaller area and lower temperatures (indicators of fires in early stages of burning) 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 observation interval compared to days and weeks re-visits).

This work package will use MODIS, TET-1 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. Evaluation of sensors and supporting hotspot products forms a core component of this work package.

Field experiments are used to validate sensor information and this is an ongoing activity of this work package. In collaboration with research partners and end users, a complex data collection campaign continues to develop. It will involve deploying in-situ fire loggers and pyrometers on the ground to record temperature (and duration) of fire during a prescribed burn. Aerial imagery via UAV will be captured during the time of the burn, and will also be synchronous to data collection taken during satellite sensor pass over. This will result in a truly multi-scale and synchronous dataset of a fire event. Supporting the empirical study, 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 will is described for Australia based on state fire history records. Further, generalised fire types, based on spatial and temporal characteristics, provide justification for the different fire scenarios used during simulation studies.

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 at the same time, aims 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 3D remote sensing technologies including, 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 and land managers.

PROGRESS AND ACHIEVEMENTS

WORK PACKAGE 1: REMOTE SENSING FOR ACTIVE FIRE SURVEILLANCE

All milestones relating to work package 1 are on track. The main focus over the past twelve months has been finalizing the evaluation of the TET-1 satellite system and a migration to Himawari-8 applications. Himawari-8 and associated hotspot products are being evaluated through the use of in-situ fire experiments and a fire simulation / virtual evaluation environment. Details for key research areas are described in the following sections.

Evaluation of TET-1 for Fire Detection and Tracking

Related research outputs: #1, #3, #11

The utility of the TET-1 hotspot detection and characterization algorithm was tested for accurately detecting and characterizing fires and to determine the limits of operation, with the TET-1 being investigated with respect to the higher spatial resolution available as compared to other satellite based systems used for active fire detection and monitoring. To do this, fires of various sizes and temperatures are simulated and subjected to the algorithm. The results indicate the sensitivity of the TET-1 detection and characterization algorithm to fires range in area from 1 m² through to 100,000 m² and for temperatures between 450 K and 1200 K. The algorithm was shown to be able to detect fires of a very small area, albeit with high temperatures from 1000 K for the 1 m² case, but that the temperature limit drops off rapidly with increasing area. This demonstrates that the TET-1 system may detect small area or low temperature fires under ideal conditions, as well as being able to detect spot fires ahead of the main fire body. The ability of TET-1 to detect large areas at low temperatures, suggests it may have utility in mapping recently burnt areas. The errors found for the estimated fire characteristics have been shown to be low systematic errors, with the area variation ranging between ±12% and the temperature varying between ± 3%. Despite the improvement in the estimation of fire characteristics when compared to sensors with coarser spatial resolutions, TET-1 has a very low temporal resolution making it significantly limited in its ability for early detection and surveillance operations. The advent of additional satellites to the FireBird constellation (as planned) will resolve this temporal limitation.

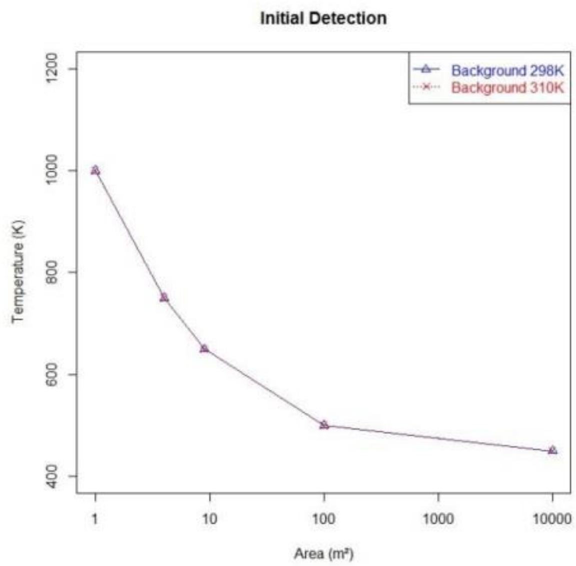

FIGURE 2 THE TET-1 SENSING SYSTEM INITIAL DETECTION OF A FIRE. THIS GRAPH IS BASED ON THE COMBINATION OF THE LOWEST TEMPERATURE AND SMALLEST AREA THAT A FIRE WILL BE FIRST DETECTED. THE GRAPH ALSO SHOWS THAT FIRES WITH A SMALL AREA REQUIRE A CORRESPONDING HIGH TEMPERATURE BEFORE THE SENSOR WILL MAKE A DETECTION, BUT THAT AS THE FIRE AREA GROWS, THE TEMPERATURE REQUIREMENT BECOME LESS.

The Year Ahead:

- TET-1 evaluation has been completed.

Evaluation of Himawari-8 for Fire Detection and Tracking

Related research outputs: #5, #7

A preliminary analysis of Himawari-8 images and the derived experimental hotspot product (WF-ABBA) for the early detection of fire has been completed based on data available via the National Computing Infrastructure, Australia. This work has been accomplished in collaboration with the 10-minute bushfire project being conducted by Geoscience Australia and with the support of the Victorian Department of Environment, Land, Water and Planning. The validation process was conducted in two parts, the first involving a visual evaluation with Himawari-8 imagery against known fire occurrences, and the second, involving reconciliation between the WF-ABBA hotspot product and the earliest known fire occurrences. A validation of the available Himawari-8 images and hotspot products is reported against the documented fire history for Victoria, Australia for January 2016, and summarized in Table 1 indicating the current hotspot detection algorithm can be improved.

Total or Final Burn Area	Time Difference with Visual Assessment	Time Difference with Hotspot Detection
142 ha	15 mins after	45 mins after
104 ha	11 mins after	61 mins after
29 ha	20 mins before	10 mins before
22 ha	21 mins before	no detection
15 ha	21 mins before	no detection
5 ha	125 mins after	145 minutes after
2 ha	42 mins after	44 minutes after

TABLE 1 DIFFERENCE BETWEEN THE REPORTED START TIME OF DETECTED FIRES AGAINST THE TIME OF FIRST DETECTION USING VISUAL ASSESSMENT OF HIMAWARI-8 IMAGERY AND WF-ABBA HOTSPOT FOR A SAMPLE OF FIRES TAKEN FROM THE FIRE HISTORY RECORDS IN VICTORIA DURING JANUARY 2016.

Empirical assessment of Himawari-8 for detection and mapping of fires has also been achieved for three burns over the last year. These three prescribed burns were jointly managed by Melbourne Water and the Country Fire Authority. The primary experimental burn was conducted on private land as part of a Firescape Community Project in Christmas Hills, Victoria to meet fuel reduction and ecological objectives. The dominant vegetation, Burgan, was slashed and left to cure prior to the burn event. 20 fire-loggers were deployed across the 2ha site to record in-situ temperature. Temperatures ranged from 25-800 degrees Celsius, and conditions were clear and sunny with a slight N-E breeze. However, the fire was not detected using existing AHI hotspot algorithms, possibly due to the fire area being too small. It is difficult to accurately calculate fire area, and subsequently fire radiative energy, from point based measures alone. This has led to the purchase and integration of a thermal microbolometer camera with a raspberry pi to be deployed on a UAV for synoptic and total sampling data acquisition.

FIGURE 3. TESTING THE THERMAL MICROBOLOMETER (THERM-APP) IN HAND AT THE CHRISTMAS HILLS FIRESCAPE BURN.

The Year Ahead:

- Evaluation of 10 minute bushfire study extended to all of Summer 2015/2016.
- Ongoing, additional multi-scale validation field campaigns with prescribed burns (opportunistic to piggy back off fuel hazard change experiments with planned burns).
- Integrated microbolometer (ThermApp) camera and raspberry pi deployment onboard a rotary UAV for total sampling of prescribed burns to be used for up-scaling and validation with Himawari-8 observations and products. (Note: rotary UAV is owned, CASA certified and operated by RMIT. CASA UAV flight restrictions to be eased later in 2016.)

Improvements in the Use of Himawari-8 for Fire Detection and Tracking

Related research outputs: #5, #7

Two areas of improvement are being investigated under this activity. The first aims to take advantage of the high temporal resolution offered by Himawari-8 to improve the way background land surface temperature information is estimated. Background land surface temperature is a critical input into fire detection and mapping algorithms. The second aims to improve the ability of Himawari-8 to map and track sub-pixel fires by introducing a tri-scale approach to existing hotspot algorithms.

The recent launch of the Advanced Himawari Imager (AHI) has provided an opportunity to investigate methods of fire detection using temporal algorithms. Such algorithms take advantage of the rich stream of time-series information currently neglected by conventional contextual fire algorithms. Recent research has focused on the estimation of the background surface temperature of fire pixels, in order to identify the ignition time of fire pixels suffering varying degrees of occlusion during the period of fire. To achieve this, Himawari-8 imagery has been provided through the support of Geoscience Australia, the National Computing Infrastructure of Australia and the Bureau of Meteorology. Scripting routines have been developed to enable efficient data acquisition and processing. The robust method of diurnal temperature cycle determination identified can reduce errors associated with stacking pre-fire time series information for statistical fitting, and provides users with a far less computationally intensive process compared with similar time-series based algorithms. By utilising a swath of pixels of similar latitude to the target pixel (see Figure 4), the wide area method constructs a DTC model by aggregating brightness temperatures according to local solar time. This is a new and significant innovation to the traditional approach of detecting fire from space.

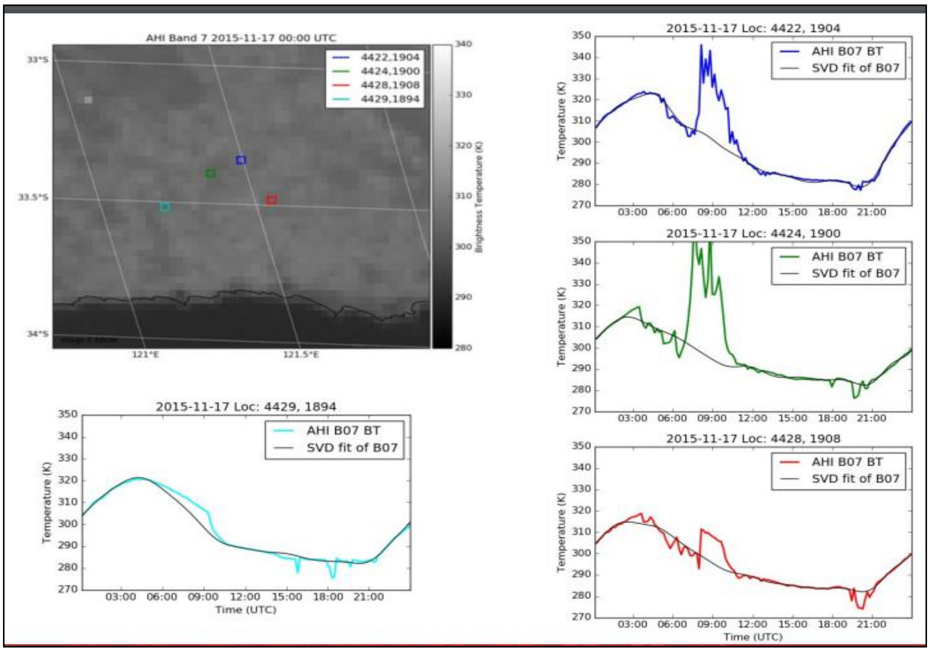

FIGURE 4. EXAMPLE RESULTS USING THE WIDE AREA METHOD TO ESTIMATE BACKGROUND TEMPERATURE FOR USE IN FIRE DETECTION ALGORITHMS. BRIGHTNESS TEMPERATURES FROM THE MEDIUM WAVE INFRARED BAND 7 OF AHI, 1600 AWST. COLORED LINES; RAW BRIGHTNESS TEMPERATURES OF SELECTED PIXELS (DENOTED ON THE IMAGE), BLACK LINES; SVD FITTING OF DTC.

The majority of existing active fire detection algorithms depends on the middle infrared (MIR) and thermal infrared (TIR) channels to detect fire. Even though sub-pixel fire detection algorithms can detect much smaller fires, the location of the fire within the AHI 2x2km (400ha) MIR/TIR pixel is usually unknown, and thus limiting the application of AHI as a wildfire surveillance sensor. A new multi-spatial resolution approach is being developed that utilizes the available medium resolution channels in AHI. The proposed algorithm is able to map the active fire line at a much higher spatial resolution. Initial results based on three case studies carried out in Western Australia showed the algorithm was able to continuously track the fire during the day at the improved spatial resolution of 500m. The results also hint at the possibility of the algorithm to detect low intensity fires when compared with the MODIS thermal anomalies products.

The Year Ahead:

- Develop dynamic fitting techniques (factor analysis and Kalman filtering) to counter over-fitting of background surface temperatures, and incorporate environmental factors such as land surface emissivity to improve surface temperature.
- Apply, and refine, the tri-scale algorithm to a greater number of case-study fires to achieve statistical significance. Report on errors of omission (missed detection) and commission (false detection).
- Test new techniques in Indonesia in collaboration with the Asian Institute of Technology by invitation Dr. Lal Samarakoon, Director, Geoinformatics Center, Asian Institute of Technology.
- Conference and journal publications to be submitted.

Simulation Environment for Satellite Sensor Performance Testing

Related research outputs: #2, #3, #8

Investigations into fire detection and attribution have identified a lack of objective active fire validation as a weakness with the use of current satellite sensor based algorithms. Indeed, the majority of validation relies on inter-comparison with other sensors and products. To address this shortcoming, work has commenced on modelling the capture of active fire by remote sensors, with an emphasis placed upon simulation of fire signal in a varied environment and simulation of the image acquisition process of which the fire landscape simulator component has been completed. A number of sensor systems have been identified as of vital importance to fire detection operations, including the recently launched Himawari-8. Priority will be placed on investigation of the operational limits of fire detection using this sensor.

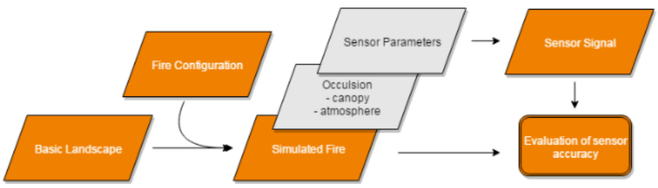

FIGURE 5. BASIC FRAMEWORK FOR THE VIRTUAL ASSESSMENT ENVIRONMENT FOR EVALUATING SENSOR PERFORMANCE FOR THE DETECTION OF ACTIVE FIRE.

The Year Ahead:

- Implement Himawari-8 sensor parameters and signal.
- Conduct evaluations against a range of fires (stratified for fire size and temperature) to determine operational limits.

WORK PACKAGE 2: PRE AND POST BURN ATTRIBUTION

All milestones relating to work package 2 are on track. Evaluating 3D remote sensing technologies for under-canopy measurement and mapping of fuel hazards and burn severity has led to the development of Fuels3D. Fuels3D is android App used to rapidly collect imagery in the field and use computer vision and photogrammetric techniques to calculate measures of fuel and severity metrics. As part of this development, sampling protocols are being investigated and tested with end-users. In addition to conference and journal publications, Fuels3D has been a major outcome for this work package. Details for key research areas are described in the following sections.

The Use of Image Based Point Clouds for Measuring Fuel Hazards

Related research outputs: #4, #6, #10

A field campaign was undertaken in July, 2015 with the aim of developing an image based point cloud data capture protocol. Terrestrial laser scanning and visual assessment data was captured at the same time as image networks with varying image count and ground sampling distances. Several plots representative of the priority landscapes identified by end-users were used and are shown in Figure 6.

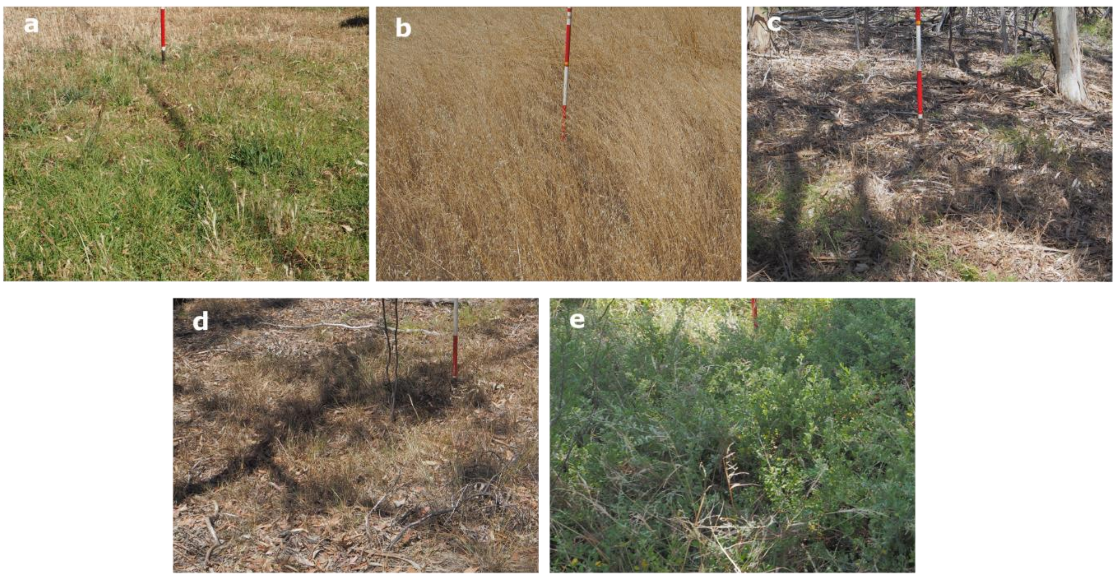

FIGURE 6. PHOTOS OF THE FIVE VEGETATION TYPES EXAMINED IN THIS STUDY.

Comparisons were made between the TLS data, visual assessments and resultant image based point clouds (Figure 7). These first comparisons allowed decisions on the required image overlap, maximum ground sampling distance and network configuration required to capture representative image based point clouds as well as the utility of this technology in different environments. From this work, Structure from Motion became the focus for continued work due to its cheap and easy implementation, and good correlation with laser scanning results. Increasing camera resolution and modifying sampling protocol is expected to further improve the results achieved using SfM.

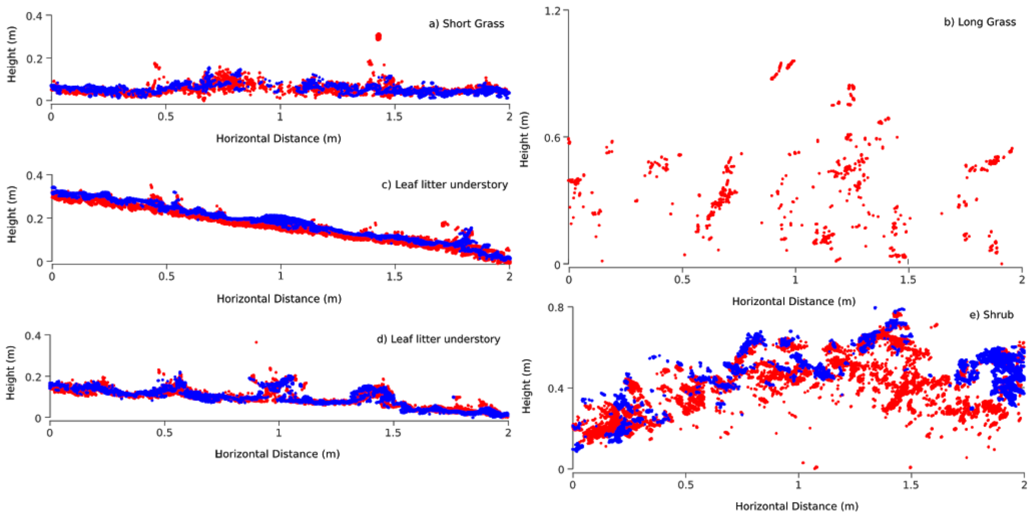

FIGURE 7. POINT CLOUDS GENERATED FROM IMAGE BASED (RED) AND TERRESTRIAL LASER SCANNING (BLUE) TECHNIQUES.

The Year Ahead:

- Ongoing research to refine image based techniques, comparisons to be made against visual assessments and destructive sampling methods as ground-truth.
- Field sampling protocol refined.
- Determination of existing fuel hazard metrics and burn severity metrics used by fire and land managers that can be "measured" using image based techniques.
- Determination of potential new metrics to be offered to end-users.

Developing a Smartphone App for Estimating Fuel Hazard

Related research outputs: #4, #6, #10

An android based smartphone app (Fuels3D) has been developed to collect imagery describing fuel hazard. These images are used to create 3D point cloud assessments of the fuel hazard. The app uses the location and imaging capabilities of a smartphone to allow user to collect a set of imagery. Computer vision techniques are then applied to the imagery to produce a 3D representation of the vegetation. When captured in unburnt landscapes, this 3D representation can provide valuable information describing fuel hazards. Results demonstrate that metrics extracted from the 3D data are strongly correlated (r2 = 0.75 - 0.9) to indicators of fuel volume and fuel connectivity. When captured at multiple points in time (i.e. pre and post prescribed fire) the data can be used to map changes in fuel and provide an indication of efficacy of the burn.

The development of this app included the design of a processing and information exchange workflow as shown in Figure 8, a quadrat to define the sample area and provide scale and an image capture protocol. In December, 2015 a workshop was held with various project end-users to convey this information and provide them with an alpha version of the app. Subsequently, end-users have collected close to 100 Fuels3D samples and associated fuel load measurements. This information is being used to refine the processing workflow and calibrate the app. This App which was featured in the Australian and Asia Pacific magazine has attracted potential collaborations. For example, internal funding has been applied for with regional areas of DELWP for developing long-range remote sensing of fuel hazards using Fuels3D.

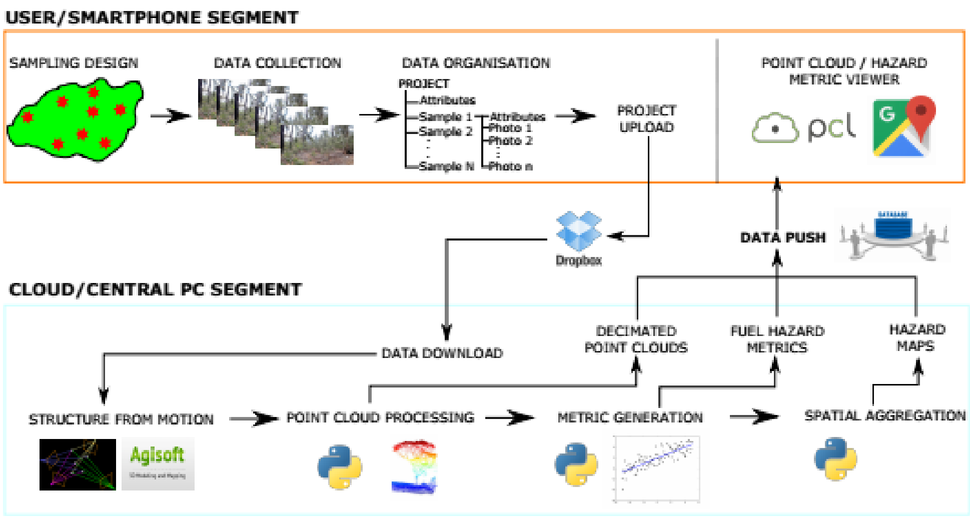

FIGURE 8. SCHEMATIC SHOWING THE PROPOSED IMPLEMENTATION OF THE FUELS3D WORKFLOW.

The Year Ahead:

- End-user field day to trial and comment on Fuels3D scheduled for July 2016. Participants attending include representatives from SA DEWNR, ACT Parks and Wildlife, VIC DELWP, VIC CFA, Melbourne Water and Parks Victoria.
- Field data collection with end-users (to run simultaneously as field day trials) to: (1) investigate the repeatability or variability in measures that may exist between different data collectors when using Fuels3D, and (2) compare the accuracy of Fuels3D outputs and traditional visual assessments against dry weights of surface and near-surface fuels.
- Conference and journal publications submitted.

Monitoring a Fire Altered Landscape

Related research outputs: #6, #9, #12

In April and May 2016 field campaigns were conducted to assess the utility of image based point clouds to monitor change in surface and near-surface. Prior to this, methods for extracting change information from Terrestrial Laser Scanning surveys were developed based on earlier campaigns that have since been published. A set of software tools has been developed that allows change in fuel height and fuel cover/fragmentation has been developed and adapted to suit image based approaches.

Image based point clouds were collected to describe six 10 m radius plots in the forests of Silvan and Emerald Reservoir, Victoria prior to prescribed burns managed by Melbourne Water. Although the Silvan site was not visited following the burn, due to dangerous tree hazards, co-located post-burn point clouds were collected for the three plots at the emerald site. Images were collected with a mid-range consumer camera and the Fuels3D app for comparison purposes. Visual assessments and dry weight data was collected both pre and post burn.

Innovative techniques and processing algorithms have been developed to assess change based on this rich dataset. This includes field methods and algorithms to co-register multi-temporal point clouds containing significant change, and algorithms to extract metrics useful in describing site evolution. Initial results extracted from this rich dataset (an example is provided in Figures 9 and 10) highlight that the data can describe change in surface and near surface with detail not available from other remote sensing techniques.

FIGURE 9 - EXAMPLES ORTHOPHOTOS DERIVED FROM IMAGES COLLECTED USING FUELS3D OF THE CARDINIA SITE PRE AND POST BURN.

FIGURE 10 – EXAMPLES OF PRE AND POST BURN IMAGE BASED POINT CLOUDS.

The Year Ahead:

- Re-visit Silvan plots to capture post-burn imagery and destructive samples.
- Key questions to be addressed are: (1) what is the optimum sampling strategy for estimating change; co-incident locations versus numerous random samples? and (2) what is the temporal window for collecting post-burn images?
- Meeting with Professor David Roy, co-chair USGS / NASA Landsat Science team at upcoming ISPRS conference to discuss field collaboration for Spring 2016 to validate the new Landsat-8/Sentinel-2 burned area estimates including combustion completeness and fraction of pixel burned.

EQUIPMENT

- ***Thermal camera, lenses, raspberry pi and batteries.*** The ThermApp thermal camera provides a low cost solution for imaging fire hotspots. This camera when paired with the raspberry pi single board computer will allow researchers to monitor fires in-situ for later comparison to satellite imagery.
- ***Motorola MotoG smartphone.*** A standard smartphone (camera > 8MP) to be loaned to our end users to allow them to trial and collect data using the Fuels3D app being developed. Currently on-loan in South Australia.
- ***IR converted 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.

NEW APPOINTMENTS AND COMPLETIONS

Masters candidate commencement. Christine Spits commenced her Masters degree in Jan 2016. She has a Bachelor of Science (Conservation biology) from Monash University and a GradDip of Environmental Science (Charles Sturt University). Since graduating from her Bachelor degree, Christine has spent the majority of her career in the private sector, largely as an environmental consultant and ecologist. Christine's research will focus on an accuracy assessment of surface and near-surface fuel measurements derived from a phone app (Fuels3D) and Structure from Motion (SfM) technology, and will investigate the variability in measures that may exist between data collectors when using Fuels3D.

PhD candidate and BNH CRC associate student commencement. Chathura Wickramasinghe commenced his PhD in December 2015 and has since been approved as a BNH CRC associate student. Chats has a Bachelor of Surveying and completed a Master's in Remotes sensing and GIS. His PhD research will focus on using multi-temporal and multi-resolution techniques to improve wildfire detection using the Himawari-8 satellite. Himawari-8 thermal bands have 2km spatial resolution, inadequate for wildfire surveillance. Thus two new algorithms are being developed and tested to improve the fire surveillance from 2km to 500m spatial resolution.

PhD candidate and BNH CRC associate student submission. Vaibhav Gupta submits his PhD, titled "Detecting changes in burnt Australian dry sclerophyll forest understorey using Terrestrial Laser Scanning and Hyperspectral Remote Sensing" for examination.

Masters candidate submission. Simon Mitchell submits his Masters by Research thesis titled "Validating the TET-1 satellite sensing system for detecting and characterizing active fire 'hotspots'" for examination.

Masters candidate completion. Sam Hillman completes his Masters course-work degree and thesis, titled "Evaluating new terrestrial techniques for estimating surface and near-surface biomass".

END USER REPRESENTATIVES

John Bally (Cluster Lead)
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
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Country Fire Authority, Victoria

Andrew Sturgess
Queensland Fire and Emergency Services

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

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Office of the Inspector-General Emergency Management, Queensland

Andrew Grace
Attorney-General's Department

David Hudson
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RESEARCH TEAM & COLLABORATIONS

Mr. Tim Sanders
*Ms. Sharon Merritt**
Melbourne Water (*secondment from CFA)

Dr. Andreas Eckhardt
Mr. Frank Lehmann
German Aerospace Agency - Deutsches Zentrum für Luft und Raumfahrt (DLR)

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Professor Andrew Skidmore
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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 2015-2016

1. Jones, S. D.; Reinke, K. J.; Gupta, V.; Soto-Berelov, M.; Holden, L.; Held, A.; Mitchell, S.; Eckhardt, A. **Attributing disaster landscapes: wildfire surveillance and hazard mapping**. *27th International Cartographic Conference, August 23-28, 2015, Rio de Janeiro, Brazil*.

2. Jones S.D.; Reinke K.; Wallace L.; Oliveira S.; Soto-Berelov M.; Gupta V.; Holden L.; HELD A.; Grant I.; **Understanding wildfire spatial and temporal patterns in Australia and associated hazard Mapping ,** EARsel FFSIG2015, November 2-5, 2015, Limasoll, Cyprus.

3. Jones SD; Reinke K; Gupta V; Soto-Berelov M; Holden L; Held A; Mitchell S; Eckhardt A; Lehmann F; Skidmore A; Grant I, **Spatial and temporal patterns of Australian wildfires and associated hazard mapping**, New Zealand Geospatial Research Conference, University of Canterbury, 7–9 December 2015

4. Wallace, L.; Hally, B.; Reinke, K.; Jones, S.; Hillman, S. **Leveraging smart phone technology for assessing fuel hazard in fire prone landscapes.** *Proceeding for the 5th International Fire Behaviour and Fuels Conference, April 11-15, 2016, Melbourne, Australia.*

5. 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.*

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

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

*Forthcoming, accepted conference presentations.

**Forthcoming, to be approved conference presentations.

JOURNAL PUBLICATIONS June 2015 - 2016

8. Oliveira, S. L. J.; Soto-Berelov, M.; Jones, S. D.; Reinke, K. J. (in review) **Changes in the Australian Fire Landscape: An Investigation into the Spatio-Temporal Patterns and Trends of Fire across Southern Australia.** *PLoS ONE*, 34pp.
(impact factor: 3.234)

9. Wallace, L.; Gupta, V.; Reinke, K.; Jones, S. (in review) **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 Special Edition. New Sensors, Multi-Sensor Integration, Large Volumes, New Opportunities and Challenges in Forest Fire Research,* 13pp.
(impact factor: 3.180)

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

11. Mitchell, S.; Jones, S.; Reinke, K.; Lorenz, E.; Reulke, R. (2016) **Assessing the utility of the TET-1 hotspot detection and characterisation algorithm for determining wildfire size and temperature.** *Journal of Remote Sensing,* DOI: 10.1080/01431161.2016.1204026.
(impact factor: 1.640)

12. Gupta, V.; Reinke, K.J.; Jones, S.D.; Wallace, L.; Holden, L. (2015) **Assessing metrics for estimating fire induced change in the forest understorey structure using Terrestrial Laser Scanning**. *Remote Sensing*, *7*(6), 8180-8201, DOI: 10.3390/rs70608180.
(impact factor: 3.180)

ADDITIONAL RELEVANT NON-BNHCRC FUNDED JOURNAL PUBLICATIONS June 2015 - 2016

13. Woodgate W.; Armston JD.; Disney M.; Jones SD.; Suarez-Baranco L.; Hill MJ.; Wilkes P.; Soto-Berelov M. (2016) **Quantifying the impact of woody material on leaf area index estimation from hemispherical photography using 3D canopy simulations**, Agricultural and Forest Meteorology 226 (2016) 1–12. DOI: 10.1016/j.agrformet.2016.05.009.
(impact factor: 3.389)

14. Wallace, L.; Lucieer, A.; Malenovský, Z.; Turner, D.; Vopěnka, P. (2016). **Assessment of Forest Structure Using Two UAV Techniques: A Comparison of Airborne Laser Scanning and Structure from Motion (SfM) Point Clouds**. *Forests*, *7*(3), 62. DOI: 10.3390/f7030062.
(impact factor: 1.583)

15. Phil Wilkes.; Simon D Jones.; Lola Suarez.; Andrew Haywood.; Andrew Mellor.; William Woodgate.; Mariela Soto-Berelov.; Andrew K. Skidmore. (2015) **Using discrete-return ALS to quantify number of canopy strata across diverse forest types.** *Methods in Ecology and Evolution*. DOI: 10.1111/2041-210X.12510.
(impact factor: 6.554)

16. Phil Wilkes.; Simon D. Jones.; Lola Suarez.; Andrew Haywood.; Andrew Mellor.; William Woodgate.; Mariela Soto-Berelov.; Andrew K. Skidmore. (2015) **Mapping Forest Canopy Height Across Large Areas by Upscaling ALS Estimates with Freely Available Satellite Data**. Remote Sensing, 7(9), 12563-12587. DOI:10.3390/rs70912563
(impact factor: 3.180)

17. Woodgate W.; Jones SD.; Suarez-Baranco L.; Hill MJ.; Armston JD.; Wilkes P.; Soto-Berelov M.; Haywood A.; Mellor A. (2015) **Understanding the variability in ground-based methods for retrieving Canopy Openness, Gap Fraction, and Leaf Area Index in diverse forest systems**, Agricultural and Forest Meteorology 205, 83–95. DOI: 10.1016/j.agrformet.2015.02.01.
(impact factor: 3.389)