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DISASTER LANDSCAPE ATTRIBUTION: THERMAL ANOMOALY SURVEILLANCE AND HAZARD MAPPING, DATA SCALING AND VALIDATION

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"Disaster Landscape Attribution: Thermal Anomaly Surveillance and Hazard Mapping, Data scaling and Validation"

Project Participants

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RMIT UNIVERSITY

CSIRO

CFA

Australian Government Geoscience Australia

DLR

Australian Government Bureau of Meteorology

State Government Victoria Department of Environment and Primary Industries

Executive Summary

The "Disaster Landscape Attribution: Thermal Anomaly Surveillance and Hazard Mapping, Data scaling and Validation" project brings together researchers from around the world, including RMIT, the German Aerospace Agency DLR, CSIRO, the University of Twente and the Bureau of Meteorology. The project will attribute fire landscapes using the latest satellite based thermal earth observation systems foractive fire surveillance. It will use laser scanning and hyperspectral technologies and techniques for quantifying and mapping changes in the landscape before, and after, a fire event.

The project is divided into three work packages. The first work package focuses on the accuracy and utility of existing and emerging earth observation systems for providing information that support active fire detection and mapping activities. The second and third work packages look to develop new metrics and approaches to describe and measure pre and post fire landscapes respectively, in ways that are meaningful to end users. Together these combine to provide a rich dataset for analysing change in the fire altered landscape.

This report provides a background to the project and discusses the key research questions being asked, and how these can help support end user operations. The methodology used to address each of the research questions is outlined, and achievements to date are described. This year deliverables have focused on: background literature reviews, field work and desktop experimental design and set up, appointment of PhD candidate and continuing end user discussions to feedback into project directions and outcomes. The report concludes with activities planned for the year ahead and a list of currently integrated project members.

HIGHLIGHTS OF 2013-2014

- New datasets collected (field work, aerial and satellite imagery) of long term monitoring fire affected sites.
- Prototype fire loggers and pyrometers tested and ready to go into production / deployment.
- TET-1 imagery received and processed, and trial data downlink negotiated with GA.
- New PhD student appointed / commenced in April, 2014.
- New end users from Department of Environment and Primary Industries and CFA join project.
- Literature review for work package 1 nearing completion and ready for end user feedback and review.
- Literature review for work packages 2 and 3 initiated.
- Work on synthetic landscape modelling for fire detection and tracking initiated

Background and Justification

There is a need for accurate observation and monitoring of active fires in the landscape, and 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 about utilizing existing data sources and procedures 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.

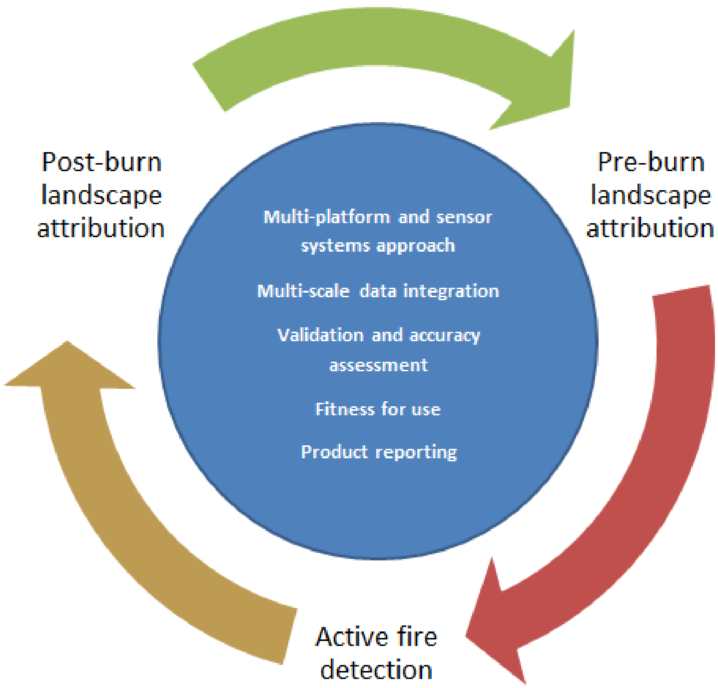
The project has practical significance to end users involved in fire ecology, wildfire mitigation and management activities. In particular, government land management agencies involved in the management of wildfire and terrestrial ecosystems will benefit from the recommendations made in terms of operational 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.

Project Description

RESEARCH QUESTIONS AND APPROACH

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 seek 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 will be placed in "priority landscapes" as identified by 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 project tasks and applications.



WORK PACKAGE 1: REMOTE SENSING FOR ACTIVE FIRE SURVEILLANCE

Several earth observing satellites have the capacity for active fire detection. 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.

The aim is to be able to accurately map: 1) the fire area, 2) the fire temperature and 3) the fire configuration of active wildfires and prescribed burns.

This work package will use MODIS, TET-1 (and investigate the use of geostationary satellite systems, such as Himawari-8 –when they come on stream) for active fire surveillance. A *literature review* is underway to look at existing and emerging thermal technologies, and review these against the information sources utilised by fire management agencies. In addition, an *end user survey* will be conducted to determine definitions of "active fire" in terms of user interpretation, and in terms of the data and information requirements necessary to support fire mapping activities.

Field experiments will be used to validate sensor information and this will be a core activity of this work package. In collaboration with research partners and end users, a complex data collection campaign will be undertaken. 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 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*" of thermal sensor capabilities. 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 be described for Australia, and comparisons between states and major cities will be made. Further, generalised fire types, based on spatial characteristics, will provide justification for the different fire scenarios used during simulation studies.

WORK PACKAGES 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. 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, or satellite earth observation, 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 offers repeat total sampling in a consistent regular framework. The goals here are to go beyond simply reporting the area burnt, to one that captures the spatial complexity or mosaic of 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.

These two work packages consider the typical methods used to map and describe the pre-burn landscape (e.g. fuel hazard elements) and the post-burn landscape (e.g. burn severity elements); and 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. New sensor technology such as LiDAR may offer utility that has remained largely unexplored.

A *literature review* of metrics and methods uses for estimating fuel hazard and landscape change due to fire is underway to provide a comprehensive view of current practices and data sources utilised for measuring fuel and changes in fuel following fire. In this work package we will demonstrate the use of laser scanning for quantifying and mapping the change in the landscape, as changes in vegetation or fuel – both live and dead – for a given area. *Field experiments* will be used to collect laser scans of the same site (St. Andrews, Victoria) before, and after, a fire event. A second experiment will be conducted to collect laser scans of the same vegetation community but stratified by time since fire. 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* (e.g. laser scans) of the environment into measures that have context and meaning to fire managers.

Progress

RESEARCH ACHIEVEMENTS

- *New datasets.* LiDAR data has been collected at an existing study area two years post burn event as a measure of vegetation recovery and fuel accumulation, complementing existing LiDAR and hyperspectral data of this study area 2 weeks pre-burn and 2 weeks post-burn.

Figure 2. (Left) Study area in St. Andrews, Victoria where the effects of fire have been monitored using visual assessments, field spectroscopy and laser scanning in collaboration with staff from Parks Victoria and the Department of Environment and Primary Industries. (Right) Students using an ASD to collect spectral signatures of target land covers in the study area before the prescribed burn takes place.

Figure 3. Researchers and students collecting data on post burn severity and changes to the landscape after a prescribed burn in Wilson's Promontory National Park.

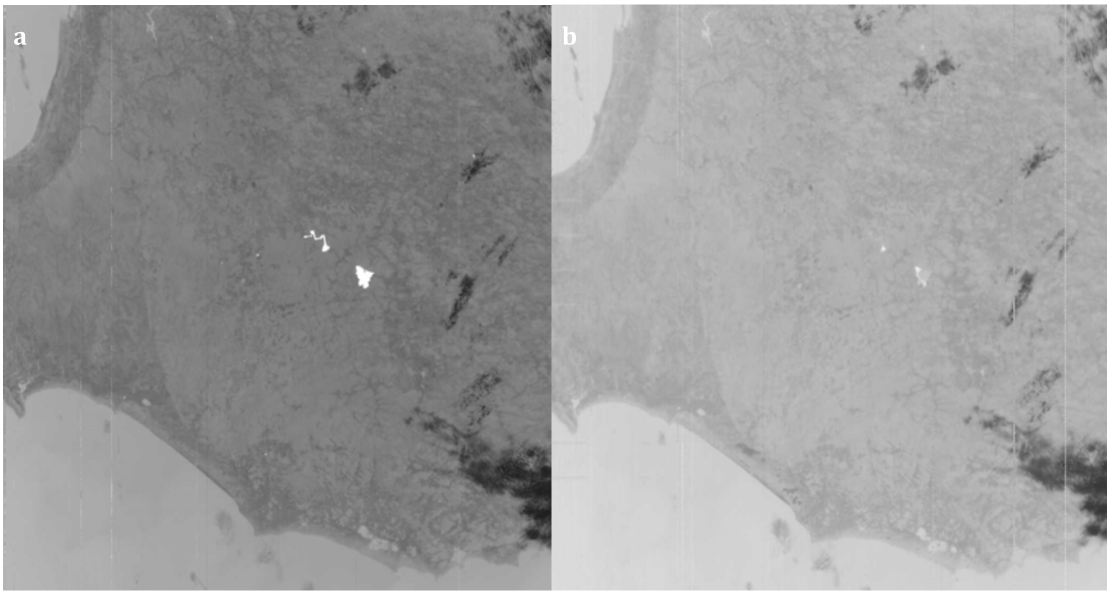


Figure 4. Perth planned burns 5th April 2014. a) MWIR b) LWIR.

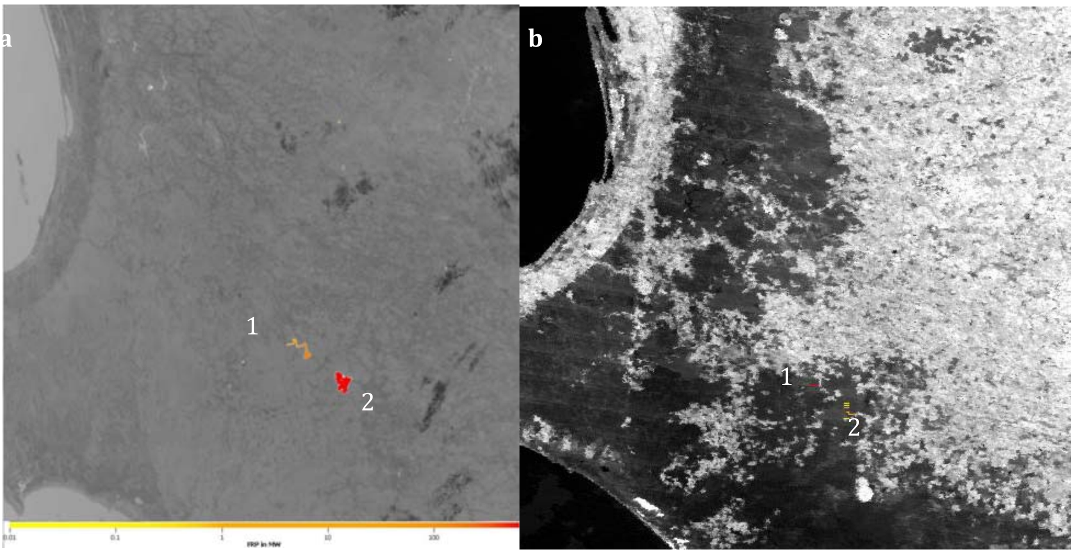


Figure 5. Perth planned burns a) TET-1 MWIR FFRP b) MODIS MOD14 overlayed on NIR band (note the scale difference).

- *Literature review* of earth observing systems for active fires is near completion for a review by end users. A reference table of system specifications for existing, and on the horizon, systems will supplement the review.
- *Literature review* of active fire surveillance and monitoring practices agencies involved in fire management in Australia, and internationally, underway. Currently 51 organisations have been identified in Australia and will be short-listed to those key agencies directly involved with fire management. The same will be completed for international organisations.

EQUIPMENT

- *Fire Loggers and Pyrometers.* Electronic fire loggers and manual pyrometers have been built to prototype and tested in fire conditions for robustness and accuracy and are now ready to proceed into production. It is estimated to have a total of 30 fire loggers and 200 manual pyrometers available for fire severity (and duration) assessments and validation of remote sensing data sources.
- *Filips Electronic Rising Plate Meter* purchased for supporting field estimates of ground fuel loads.

EVENTS

- *Research Advisory Forum, Adelaide, March 2014*, attended by Jones and Reinke.
- *DLR – RMIT – GA meeting, Melbourne, February 2014: Memorandum of understanding re: GA trialing the downlink of data from TET-1 as a first step toward inclusion of TET-1 products on Sentinel, to this end agreement on carrier frequency tests, image data download tests was reached*

PARTNER AND END USER ENGAGEMENTS

- *Priority landscapes* nominated by end users and finalized as peri-urban, mallee/desert scrub and closed (or multi-canopy) forest.
- *New end users* (Manager and A/Manager Statewide Fire Mapping, Information and Communications Technology Unit, Department of Environment and Primary Industries) join the project.
- *Data collection campaigns* under discussion between RMIT, DLR and DEPI to have synchronous data collection of prescribed burns from space – air – ground for validation experiment. Options for under flying TET-1 over the duration of a wildfire in the coming fire season explored with DEPI. TET-1 satellite to be tasked over Australia for this period. Provision of TET-1 flight path to be provided to DEPI by DLR.
- *Data downlink agreement* between DLR and GA to trial download of TET-1 data for provision into Sentinel.

APPOINTMENTS

- *Postdoctoral Fellow* paper work initiated with RMIT (April – on contract signing) and anticipate appointment later this year.
- *PhD candidate* (James Leversha) commenced April 2014.
- *Research assistant* (Kelly Holland) appointed to review and compare current active fire detection and monitoring practices used by fire management agencies across Australia, and internationally.

SUMMARY OF THE YEAR AHEAD

The coming year will see literature reviews and reports completed and distributed to end users. Experimental designs and instrumentation will be finalised, ready for data collection activities. New appointments are also expected to be completed within the next 12 months.

- *Literature review* of quantifying changes in the landscape in response to fire to commence.
- *Literature review* for work package 1 will be completed. Information from the two literature reviews will be cross-referenced to compare available technologies with government and industry practice.
- *End user group meeting* scheduled for August, 2014 to discuss outcomes to date and future activities.
- *End user survey* will be developed – both online and hard copy form - by the PhD candidate to understand end user definitions and interpretations of "active fires". It is anticipated this will be completed in time for the upcoming AFAC conference.
- *AFAC conference, Wellington, September 2014* will be attended by Leversha and Reinke.
- *Simulation* models of different active fire extent, intensity and configuration combinations generated to test fire detection algorithms under different fire scenarios. It is expected the number of simulations will be in the order of 1,000s per combination to support statistical analysis. The results will provide a theoretical assessment of active fire detection and mapping by selected earth observing systems and algorithms.
- *Flight campaigns* procedures for multi-scale data collection of active fire and validation of TET-1 to be finalised in priority landscapes. *Fire loggers* and *pyrometers* manufacturing will be complete and ready for deployment. The results will support an empirical assessment of active fire detection and mapping by selected earth observing systems and algorithms.
- *Laser scanning of fuel hazards* to be completed in a grassy dry eucalypt forest in peri-urban Melbourne and stratified for time since fire. This dataset will be used to quantify forest fuel and correlated against other measures of fuel and biomass.
- *Spatial analysis* of fire history in Australia since 2000 to explore such questions as: What are the spatial and temporal characteristics of active fire in Australia? How do these characteristics compare between states and major cities in Australia? Are they statistically significant? Results to be submitted for *Publication International Journal of Wildland Fire.*

List of Project Team Members

RESEARCHERS

RMIT University, Australia
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Dr. Karin Reinke
Professor Nicholas Chrisman

DLR, Germany
Dr. Andreas Eckardt
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Mr. Todd Gretton
Ms. Naomi Withers

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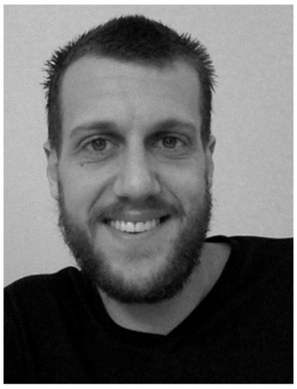
Dr. Andreia Siqueira

Country Fire Authority, Australia
Dr. Danielle Martin
Dr. David Nichols (Project Lead)

STUDENTS

MR JAMES LEVERSHA
PHD CANDIDATE, RMIT UNIVERSITY



My project sets out to investigate the fitness for use of space-borne thermal imaging sensors, for active fire hotspot detection and monitoring, and how to optimise the data derived from earth observation systems for fire management in Australia. As well as exploring the utility of this data in simple landscape systems such as grasslands and savannah systems, this research will explore fire events in complex systems with varying topography and canopy densities. Of particular interest are fire events, both intense active wildfires and low intensity prescribed fires, wet within closed canopy forests. Validation work will involve close collaboration with research partners and end users in order to synchronously collect data from space – air – ground.