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TOPICS IN THIS EDITION | FORECASTING | MODELLING | SEVERE WEATHER | REMOTE SENSING

MONITORING AND PREDICTING NATURAL HAZARDS

ABOUT THESE PROJECTS

This is an overview of the *Monitoring and prediction* cluster of Bushfire and Natural Hazards CRC research projects. This cluster has five linked studies:

- 1. Improved predictions of severe weather to reduce community impact** – Dr Jeff Kepert, Dr Kevin Tory, Dr Will Thurston, Simon Ching, Dr Robert Fawcett, Dr Dragana Zovko-Rajak, Bureau of Meteorology. Contact jeff.kepert@bom.gov.au
- 2. Disaster landscape attribution** – Prof Simon Jones, Dr Karin Reinke, Dr Luke Wallace, Dr Sofia Oliveira, Vaibhav Gupta, Bryan Hally and Chathura Wickramasinghe, RMIT University. Contact karin.reinke@rmit.edu.au
- 3. Mapping bushfire hazard and impacts** – Dr Marta Yebra, Prof Albert van Dijk, A/Prof Geoff Cary, The Australian National University. Contact marta.yebra@anu.edu.au
- 4. Mitigating the effects of severe fires, floods and heatwaves through improvements to land dryness measures and forecasts** – Dr Imtiaz Dharssi, Dr Vinod Kumar, Claire Yeo, Dr Jeff Kepert, Dr Peter Steinle, Dr Adam Smith, Dr Ian Grant, Bureau of Meteorology; Prof Jeffery Walker, Monash University. Contact i.dharssi@bom.gov.au
- 5. Improving flood forecast skill using remote sensing** – A/Prof Valentijn Pauwels, Prof Jeffery Walker, Dr Stefania Grimaldi, Dr Yuan Li, Monash University. Contact valentijn.pauwels@monash.edu.au

CONTEXT

The ability to understand, predict, forecast and monitor natural hazards is fundamental to improving resilience through better planning, preparedness, risk management and response. The focus of the *Monitoring and prediction* cluster is to improve present predictive capabilities through expanding the underpinning data as well as the range of monitoring and modelling techniques.



▲ Above: RESEARCH IS IMPROVING MODELLING FOR EAST COAST LOWS – HERE IS DAMAGE AT JIMMY'S BEACH IN NSW FROM THE APRIL 2015 EAST COAST LOW. PHOTO: OFFICE OF ENVIRONMENT AND HERITAGE NSW.

IMPROVED PREDICTIONS OF SEVERE WEATHER TO REDUCE COMMUNITY IMPACT

BACKGROUND

This project uses high-resolution modelling and a range of meteorological observations to better understand and predict important meteorological phenomena such as fire weather, East Coast Lows and tropical cyclones. Outcomes will contribute to reducing the impact and cost of these hazards on people, infrastructure, the economy and the environment.

RESEARCH ACTIVITY

Ember transport

The study has been developing understanding of how fire embers generated during bushfires can be lifted into the atmosphere and carried by winds ahead of a fire front, potentially starting new fires downwind. The team has undertaken simulations for ember transport for a wide range of wind speeds and ember fall speeds. It is important to consider a range of fall speeds, since different types of embers have different densities and aerodynamic properties which affect how far they are carried.

2013 Blue Mountains fires

Although the Blue Mountains fires of October 2013 persisted for several weeks, much of the fire spread occurred on 17 October. This day was expected to be a day of high fire risk, but the extreme fire spread was not anticipated and the causes were unknown. The State Mine fire grew

from 1,036 hectares at 11:56am to 12,436 hectares by 9:46pm, an increase in area of over 11,000 hectares in about 11 hours. There was a period of unusually strong winds and a very marked reduction in humidity, both of which approximately coincided with the major fire run. Subsequent analysis focused on determining the meteorological processes that caused these factors.

Pyrocumulonimbus

Plume modelling has also been utilised to study pyrocumulonimbus clouds (PyroCb). Intense fire plumes in suitably moist environments can lead to PyroCb development, with the possibility of strong downbursts which can exacerbate already extreme fire conditions. A survey of current understanding and forecast techniques has been completed, and the team will be working towards developing improved techniques in the coming year.

April 2015 East Coast Low

East Coast Lows are intense low-pressure systems that form adjacent to the east coast of Australia, most commonly along the New South Wales coast. Research has analysed the April 2015 low, which resulted in flooding and three fatalities in the NSW town of Dungog, using, for the first time, an ensemble of 24 simulations rather than just a single forecast.

RESEARCH OUTCOMES

Ember transport

Research has confirmed that the mean travel distance of firebrands for a given fire intensity depends mainly on wind speed. However, the spread in the landing positions shifts from being substantially cross-wind at light winds, to dominantly along-wind at high winds. This spread is greatly increased by the turbulence in the plume, and the maximum spotting distance can be more than double the mean for this reason. This aspect of the project is complete. These sophisticated and computationally intensive calculations will now be used to inform the development of physically realistic and computationally cheap parameterisations of ember transport for use in fire models, and inform fire behavior analysts of the potential downwind distances that spotfires may occur.

DISASTER LANDSCAPE ATTRIBUTION

BACKGROUND

Earth observation technologies are rapidly evolving, creating new opportunities for remotely detecting and tracking fires. Fire and land management agencies need to understand the potential application of these new data products, as well as their limitations. This project seeks to develop active fire mapping and detection capabilities from these new satellite-based data sources.

RESEARCH ACTIVITY

The project is evaluating and validating current satellite-based remote sensing options for active fire detection and surveillance. Using simulations and experiments, the team is determining the accuracy with which fires can be detected, along with their temperature and shape.

The project is also creating new techniques and protocols for the rapid attribution of fire landscapes (pre- and post-fire). Past work focused on the Moderate Resolution Imaging Spectrometer (MODIS) sensor, which is soon to be decommissioned. Current work is focusing on:

- TET-1, a polar-orbiting satellite providing high-resolution imagery every three to four days.
- Himawari-8, a geostationary satellite providing lower resolution imagery than TET-1, but every 10 minutes.

In addition to satellite imagery analysis, the project is also creating new ground-based techniques and protocols for the rapid

2013 Blue Mountains fires

High resolution simulations have shown that the downward extension of high upper-level winds to the vicinity of the fire ground, caused by mountain wave activity (wind oscillations that can occur when the wind blows across a mountain or hill), were a factor in the extreme fire spread experienced. In addition, the marked wind change on that day was associated with a dry slot, a relatively long narrow band of dry air, often associated with a wind change, and that can cause sudden drops in humidity. However, the underlying cause of the dry slot seems to be different to previously documented cases. This will be documented in further detail in a future *Hazard Note*. The research phase of this component of the project is now complete.

PYROCUMULONIMBUS

The team has analysed the processes that lead to PyroCb clouds, with special attention

on the relative importance of moisture from the atmosphere and combustion. Findings show that the influence of moisture from combustion is close to negligible. This knowledge will be used to develop a forecast tool for PyroCb formation.

April 2015 East Coast Low

Collectively, the ensemble simulations accurately predicted the position and intensity of the low, the strong winds and the rainfall. The differences between them give insight as to the forecast uncertainty, the overall envelope of areas at some risk, and the areas at highest risk. The ensemble also enables insight into the processes that lead to the rapid intensification of these systems. The team is continuing to learn from ensemble simulations about predictability of East Coast Lows and how to use this information to benefit both forecasters and the emergency services.



▲ Above: RESEARCH IS IMPROVING SATELLITE-BASED MAPPING OF BUSHFIRES AND PRESCRIBED BURNS. PHOTO: KARIN REINKE.

quantification of fuel loads in fire landscapes (pre- and post-fire). In consultation with end-users, the landscapes identified as a priority are peri-urban areas, desert/mallee and closed (multiple canopy) forests. These techniques seek to add quantitative rigour to existing fuel hazard estimation practices.

RESEARCH OUTCOMES

TET-1 has been evaluated using fire simulations. The results indicate that TET-1 can detect fires that range in size from 1 m² through to 100,000 m² depending on fire temperature. Simulations show that TET-1 may detect small, hot fires or larger, low temperature fires under ideal conditions, as well as being able to detect spotfires ahead of the main fire body. The ability of TET-1 to detect large areas at low temperatures suggests it may be useful in mapping recently burnt areas.

Using a new algorithm and computer scripting, Himawari-8 has been used to track three fires in Western Australia. Results showed

that the fires were able to be continuously tracked during the day, at a resolution of 500m. While the spatial resolution is lower than available from TET-1, the ability to process imagery every 10 minutes may enable almost real-time fire detection, a capability that cannot be achieved from other satellites.

To help land managers quickly and more accurately assess fuel loads before and after prescribed burns, a beta smartphone application, Fuels3D, is being developed. Using a computer vision technique, called Structure from Motion (SFM), the phone's camera takes a series of photos which are then analysed to create a point cloud. A point cloud represents the external surface of an object. SFM allows for the extraction of information about the structure, which results in a 3D model of the fuels. A number of different technologies were reviewed by the team to assess which could underpin a low-cost, high quality service. Trials with end-users are ongoing.

MAPPING BUSHFIRE HAZARD AND IMPACTS

BACKGROUND

This project uses cutting edge technology and imagery to produce spatial information on fire hazard and impacts needed by planners, land managers and emergency services to effectively manage fire at landscape scales.

RESEARCH ACTIVITY

The project is focused on two related activities:

1. Fire hazard mapping and monitoring – this focuses on spatial information of fuel load, structure and moisture properties that can assist fire preparedness through better fire danger ratings and fire behaviour predictions. The information supports logistics and resources planning by emergency services, and can also improve fire management by helping guide activities such as scheduling and implementing prescribed burning. Discussions between researchers and end-users indicate that the greatest and most urgent information gap is spatial information on forest fuel load, structure and moisture.
2. Fire impacts on landscape values – land managers need spatial information on the expected fire impacts on landscape values, such as water resources, carbon storage, habitat and remaining fuel load. Relevant issues include the impact



▲ **Above:** RESEARCHER DR MARTA YEBRA MEASURING THE SPECTRAL RESPONSE OF GRASSLANDS AT AN EXPERIMENTAL BURN SITE. PHOTO: CAROLINA LUIZ.

of unplanned or prescribed fires and subsequent recovery on catchment water yield and the carbon lost due to fire and then subsequently taken up during regeneration. Current prediction methods are crude and make bold assumptions (for example, about the similarity of the water use patterns between (well-studied) recovering mountain ash forests and (unstudied) other forest types.

RESEARCH OUTCOMES

The team has developed the Bushfire Information System, the first Australia-wide system with potential for operational estimation of live fuel moisture content (one of the primary variables affecting bushfire ignition) and flammability using satellite data. Evaluation is ongoing and improvements expected, but current outputs

are already useful for fire managers to monitor spatial and temporal dynamics in fuel moisture, providing insights into risk of unplanned fire and optimal scheduling of prescribed burning.

The team has also developed, tested and published software to classify a dense point cloud derived from a mobile laser scanner into different vegetation components: ground returns, near-surface vegetation, elevated understory vegetation (shrubs), tree trunks and tree canopy. The resulting classified point cloud is used to automatically derive information on the different fuel components that are important for fire hazard assessment such as total biomass, fractional cover and height. These results open a pathway of automatically deriving detailed vegetation structure information from ground-based LiDAR.

MITIGATING THE EFFECTS OF SEVERE FIRES, FLOODS AND HEATWAVES THROUGH IMPROVEMENTS TO LAND DRYNESS MEASURES AND FORECASTS

BACKGROUND

Accurate soil moisture information is critical for the management and warning of fires, floods and other natural hazards. Fire ignition, intensity and spread rate are strongly influenced by soil moisture content – the occurrence of large destructive fires corresponds to very large soil moisture deficit values. Many studies suggest that soil moisture significantly influences rainfall as well as temperatures and heatwave development.

RESEARCH ACTIVITY

This project is developing a high resolution, state of the art soil moisture analysis system that makes use of surface and remotely sensed observations, land surface modelling and data assimilation. The Joint UK Land Environment Simulator-based Australian Soil Moisture Information (JASMIN) system is a more accurate alternative to the Keetch-Byram Drought Index (KBDI) and Mount's Soil Dryness Index (MSDI) that are currently used for operational fire danger prediction.

This new system uses the Joint UK Land Environment Simulator land surface model, which is used by the Bureau of Meteorology numerical weather prediction systems and also used at many other international weather prediction centres. The JASMIN outputs are calibrated to have the same dynamic range and statistical properties as KBDI and MSDI. This retains the accuracy, temporal and spatial resolution of JASMIN products and will allow much easier incorporation of calibrated JASMIN products into operational fire danger

prediction systems. Downscaling methods will be implemented to provide soil moisture information at about 1 km resolution.

RESEARCH OUTCOMES

The study has produced a 40-year historical dataset at 5 km resolution of KBDI and MSDI using observation-based analyses of rainfall and maximum temperature. This new gridded dataset of KBDI and MSDI can be compared with the much used, lower 25 km resolution, Finkele-Mills dataset, and will be a valuable resource for researchers working on fire climatologies, ecological and flooding studies across Australia.

KBDI, MSDI and JASMIN outputs have been verified against soil moisture observations from around Australia. The soil moisture observations are located in many different land types including forests, savanna, croplands and grasslands. Verification shows that JASMIN soil moisture analyses are significantly more accurate than KBDI and MSDI, and that KBDI has a significant wet bias. A case study has been undertaken using the 2013 Blue Mountains State Mine fire, with results showing that JASMIN would have provided more accurate guidance than KBDI.

END USER STATEMENT

Managing our response to natural hazards demands we understand the current situation and are able to predict its likely development. Projects in this cluster are tackling some of the biggest situational awareness challenges for fire and flood response: understanding the arrangement, amount, and moisture content of fuels, along with monitoring of soil dryness and fire detection. The modelling work in the cluster is developing cutting edge methods which will help to improve predictions of severe storms, floods and bushfires. Utilisation of research outcomes from the cluster will make a difference to how we prepare for and respond to natural hazards in the future.

– **Dr Stuart Matthews, Senior Fire Behaviour Analyst, NSW Rural Fire Service**



▲ **Above:** THE CLARENCE RIVER HAS FLOODED AREAS AROUND GRAFTON, NSW, FOUR TIMES SINCE 2009, SIGNIFICANTLY AFFECTING MANY RURAL PROPERTIES SUCH AS THIS ONE IN FEBRUARY 2013. PHOTO: NSW STATE EMERGENCY SERVICE, CLARENCE NAMBUCCA REGION.

IMPROVING FLOOD FORECAST SKILL USING REMOTE SENSING

BACKGROUND

Flood forecasting systems aim at predicting the arrival time, water depth and velocity of a flood and are relied upon heavily by water and emergency managers. These systems consist of a hydrologic and a hydraulic model, using observed and predicted rainfall as primary inputs. The hydrologic model calculates the amount of water that is flowing through the river network, while the hydraulic model converts this flow volume into river water levels/ velocities and floodplain extents. The accuracy and reliability of these flood forecasting systems has significantly improved, but due to errors and/or uncertainties in the models and model parameters, it is still difficult to provide accurate flood warnings. This study is using remote sensing to improve modelled flood forecasts.

RESEARCH ACTIVITY

The project has two test sites – the Clarence River in northern New South Wales, and the Condamine River in southern Queensland. Field work has been conducted in both locations to gather missing data, which is expected to improve the existing models.

RESEARCH OUTCOMES

Improving the hydraulic model at both test sites is underway, based on a combination of field data, in-situ collected data, and remote sensing data. The comparison of the model results with remote sensing-derived observations of flood extent and levels will allow the validation of the model protocol, which will lead to calibration of the numerical model.

A joint calibration experiment using both streamflow and remote sensing soil moisture data has also been conducted in the Clarence River. Four scenarios were tested, with results indicating that remote sensing soil moisture has the potential to improve streamflow estimation, with improvements likely to be better where river gauges do not exist. It was also found that the impact remote sensing soil moisture data decreases when the density of calibration sites increases. The same calibration strategies are being implemented in the Condamine River, and a comparative study of the two locations will be conducted.

The Bushfire and Natural Hazards CRC is a national research centre funded by the Australian Government Cooperative Research Centre Program. It was formed in 2013 for an eight-year program to undertake end-user focused research for Australia and New Zealand.

Hazard Notes are prepared from available research at the time of publication to encourage discussion and debate. The contents of *Hazard Notes* do not necessarily represent the views, policies, practices or positions of any of the individual agencies or organisations who are stakeholders of the Bushfire and Natural Hazards CRC.

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