RURAL FIRE RESEARCH Update

SCION

JANUARY 2018 | ISSUE 11 | ISSN 1178-7775

Photo: John Foley, Fire and Emergency New Zealand

2015 Waikakaho fire.

Smoke forecasting: Learning from the 2015 Marlborough wildfires

Smoke modelling forecasts for use during wildfires, and prior to planned burns, can minimise impacts on communities from wildfire smoke. Three recent (2015) major Marlborough forest fires were used to test the predictive capability of the BlueSky Smoke Modelling Framework (BlueSky Framework) for New Zealand. The modelling can be used to predict the location and concentration of smoke. Such predictions can be used for air traffic control, health warnings, or selection of the right conditions for planned burns so as to avoid smoke nuisance. Predictions of smoke footprints and ground concentrations are increasingly important because the current climatic trends are increasing both the likelihood and size of wildfires.

We found:

- Onamalutu fire: the smoke plume from satellite images matched the modelled smoke plume.
- Wairau Valley fire: the modelled and satellite smoke plumes matched.
- Waikakaho fire: the modelled and satellite smoke plumes did not match.

Further testing and refinement of the Bluesky Framework for the New Zealand environment is underway as part of Scion's MBIE-funded 'Extreme Fire' research programme.

Introduction

The BlueSky Smoke Modelling Framework (BlueSky Framework) was designed by the US Forest Service to predict and track smoke plume footprints (the location, length and breadth of the smoke plume) and concentrations. In New Zealand, we are working towards implementing the BlueSky Framework. New Zealand has a unique combination of complex topography, fast changing meteorology, and mixed fuel types resulting in complex fire behaviour and smoke production. Three recent fires in Marlborough were used to test the BlueSky Framework performance in New Zealand, and to assess the type of data required for a successful New Zealand smoke prediction system.

The goal of this research is to predict smoke trajectories and concentrations from wildfires, helping to provide tools that can be used to minimise smoke impacts on communities, such as:

- Health effects from fine particular matter ($PM_{2.5}$)[1], ozone, and other pollutants in the smoke.
- Quality of life effects from the smell and negative aesthetics of smoke.
- Economic effects from aircraft having to detour or cancel flights, drivers having to detour or delay trips, tourists changing holiday locations and/or getting trapped at a location.

Predicting smoke concentration can allow:

- Health authorities to issue appropriate warnings to populations, including directions to change behaviour and to predict medical staffing needs for treating people with respiratory issues.
- Air traffic control to maximise safety and minimise cost in directing air traffic.
- Councils to make decisions on road closures.
- Civil Defence authorities to make best decisions about evacuations.
- Schools or other organisations (e.g. sport events) to make decisions about closures or change of venue.

Smoke predictions used as a tool during burn planning can inform on the plume's direction and the timing of when it will dilute or conversely, remain concentrated. This helps to reduce downwind smoke impacts.

Methods

We modelled smoke concentrations and visually compared them to satellite images to evaluate the BlueSky Framework's ability to predict the footprint (or trajectory) of smoke plumes from the Marlborough wildfires. This enabled us to show the smoke plume in terms of general shape, direction and the comparison of higher and lower concentrations based on the density/opaqueness of the plume in the satellite image.

Smoke plume footprints and concentrations were modelled for the Onamalutu (4-10 February 2015), Wairau Valley (10-12 December 2015) and Waikakaho (25-30 November 2015) fires. We chose these large fires from the same region because they produced a large quantity of smoke, making finding satellite imagery of the smoke for modelled to-imaged comparisons more likely.

Comparisons of modelled smoke concentrations with actual surface plume concentrations were not possible, because there were no clear smoke signals recorded at the single air quality monitoring station in the region (in Blenheim).

To produce smoke predictions the BlueSky Framework:

- **Gridded weather data in time and space.** We used two data sets of different resolutions: coarser scale data from the Global Forecasting System (GSF) from the US-based National Center for Environmental Prediction (NCEP); the finer scale data from the Weather Research and Forecasting Model, as implemented by the University of Canterbury for the Onamalutu and Waikakaho fires. We could only access the NCEP data for the Wairau Valley fire.
- **Fire location and size.** We used location and size as determined post-fire by the Rural Fire Authority.

Photo: John Foley, Fire and Emergency New Zealand

2015 Onamalutu fire.

Results

The results varied for the three fires.

Onamalutu fire

- There was a good agreement between the modelled and satellite smoke plumes, in terms of footprint, direction and areas of high concentration. Both showed a smoke plume of decreasing concentration from west to east.
- The modelled smoke plume was similar for both weather input data sets (GSF (coarse grid) and NCEP (fine grid)), i.e. weather data resolution had little impact.

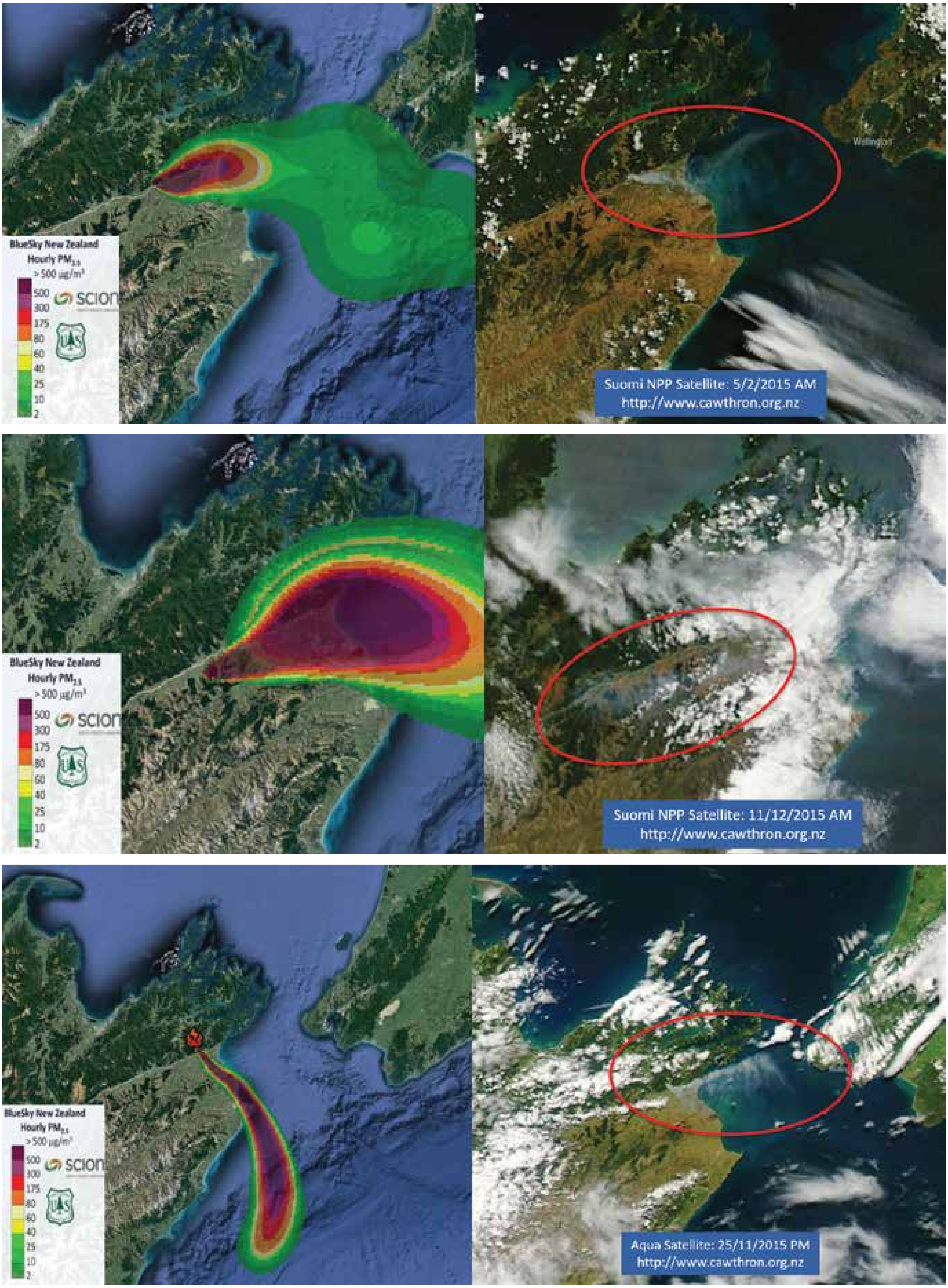
Wairau Valley fire

- There was good agreement between the modelled and satellite plume direction.
- It was hard to draw conclusions about the correlation of concentrations since the available satellite data is obscured with clouds towards the north-east.

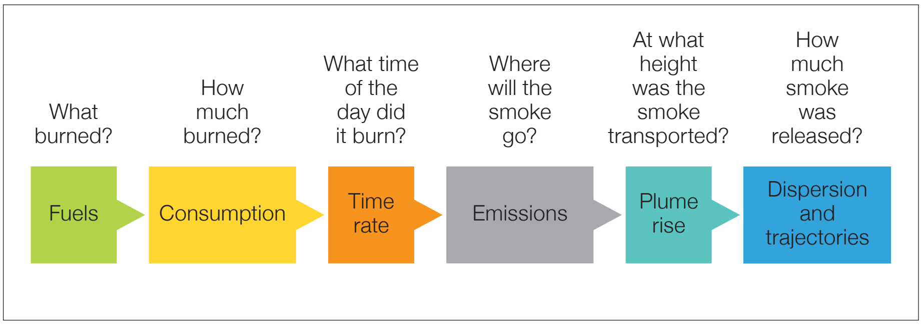
Waikakaho fire

- There was a pronounced difference in the modelled and actual smoke plume direction.
- There is evidence of the outer edges of the satellite plume, away from terrain, being pushed to the south-south-east by the governing wind as the model suggests.
- For this case, we speculate that the smoke was caught in a terrain-induced eddy or down-valley flow which caused the plume to spread towards the north-east.
- Neither the coarser nor the finer resolution weather data captured the observed plume behaviour.

[1] $PM_{2.5}$ is particulate matter with a diameter of 2.5 micrometers or smaller. These very fine particles are present in smoke and are of concern because they penetrate deep into the lung, causing health problems including respiratory issues, heart conditions and cancer.



Modelled fire plumes (left) and actual plume from satellite (right) for the: Onamalutu wildfire (top), Wairau Valley wildfire (middle) and Waikakaho wildfire (bottom). The modelled concentrations shown are on the high side, as we used an assumption of 'heavy fuels' in the simulation to generate a 'worse case' scenario.



The BlueSky Framework incorporates a range of interlinked datasets and models which answer the above questions.

Challenges encountered

It has proven difficult to obtain sufficient, reliable, high-resolution gridded weather data to run the BlueSky Framework.

Satellite images of plumes from wildfires are rare, and the images available are often of low quality or obscured by clouds (as seen with the satellite image of the Wairau Valley fire plume).

We would like to compare modelled smoke concentrations to actual data. Unfortunately, the current scarcity of air quality monitoring stations in rural areas of New Zealand means that comparative data will be rare.

Conclusion and future activities

We have learned. Availability and accuracy of input data and comparative data is essential for testing the models. There is a need for more, reliable weather data, which we are now trying to access.

Note: Scion has two E-Sampler measurement monitors, for rapid deployment in smoke plumes to obtain $PM_{2.5}$ concentrations from smoke for future testing of the BlueSky Framework.

The model performed well for two case studies but not the third. Further testing and refinement of the Bluesky Framework for the New Zealand environment is required. This is currently underway as part of Scion's MBIE-funded 'Extreme Fire' research programme.

Future work. Further analyses are required, including investigating:

- The best meteorological data grid resolution for input into the BlueSky Framework.
- Plume height predictions relative to smoke plume motion for the Waikakaho fire to capture the down valley flow.
- We are undertaking a detailed smoke plume modelling study for the 2017 Port Hills fires.

Real time fire and smoke modelling. We are in the process of developing a fully-linked, real-time fire and smoke modelling system for New Zealand with collaborators from the US Forest Service's AirFire Team, Alberta Sustainable Resources & Development, Heartland Software and CSIRO's Atmospheric Sciences group.

The linking of the Prometheus Fire Growth Model to the BlueSky Framework, and development of small and fast fire-smoke modelling is a world first. This will be a game changer in addressing smoke issues in New Zealand and world-wide.

A beta version of a real-time smoke forecasting tool is available for the 2017-2018 fire season.

Photo: John Foley, Fire and Emergency New Zealand

2015 Parsons Road, Wairau Valley Fire.

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Funding for Scion Rural Fire Research is provided by the Ministry of Business, Innovation and Employment (MBIE) along with direct funding and significant in-kind support from NZ Rural Fire Sector organisations (Fire and Emergency New Zealand, Forest Growers Levy Trust Inc, Department of Conservation, members of Local Government NZ, NZ Defence Force and Federated Farmers of NZ Inc).

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