A new quantitative smoke forecasting system for Victoria

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Monica Long[1], Alan Wain[1], Martin Cope[2], Beth Ebert[1], Maree Carroll[1], Kevin Parkyn[1], Natalie Tostovrsnik[3]

[1] Bureau of Meteorology
[2] CSIRO Oceans and Atmosphere
[3] Department of Environment, Land, Water and Planning, Victoria

Corresponding author: monica.long@bom.gov.au

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ABSTRACT

Smoke dispersion is a key concern for Government agencies. Government has a responsibility to protect community health in response to smoke events and to minimise the impact of smoke from planned burning. To inform community warnings and planned burn management, quality information is needed to support evidence-based decision making.

The Bureau of Meteorology has operated the HYSPLIT smoke dispersion system for use by fire and land management agencies for around 15 years. Recently DELWP funded research to improve smoke emission and transport modelling in Victoria. This project developed a new multi-tiered quantitative smoke prediction system which is a significant step forward compared with the old system. It applies recent observations of Victorian smoke emissions and atmospheric chemistry (as embodied in CSIRO's Chemical Transport Model) with the increased numerical capability in ensemble and high resolution weather modelling of the Bureau's ACCESS Numerical Weather Prediction suite.

The new smoke forecasting system has 3 tiers; Tier 1: 10-day ensemble forecasts of fire weather and fire danger indices to assist decisions on burn scheduling, Tier 2: 3-day forecasts of ambient air quality and smoke concentration from existing fires to provide background conditions for burns, and Tier 3: 1-day high resolution forecasts of smoke for planned prescribed burns to support go/no-go decisions.

In this presentation we will demonstrate the improved user interface for the smoke dispersion system and provide examples of output for each of the 3 forecast tiers. We will also describe the methodology for verifying the system output, including initial verification results. Finally areas of potential future work will be discussed, including how other jurisdictions can be involved so that this can become a national smoke dispersion system.

INTRODUCTION AND BACKGROUND

Government has a responsibility to protect community health in response to smoke events and to minimise the impact of smoke from planned burning. This involves monitoring smoke in the environment, particularly during fire events, and making evidence-based decisions about the effects of additional smoke from planned burning.

Smoke from vegetation fires is a mixture of different-sized particles, water vapour and gases. Microscopic particles such as PM2.5 and PM10 (defined as particles with diameters of less than 2.5 or 10 micrometres, respectively) and gases are small enough to be breathed deep into the lungs and can cause harmful health effects.

A new smoke forecasting system has been developed as a collaborative effort between the Bureau of Meteorology, CSIRO and DELWP to provide quantitative forecasts of the concentration of particles and other pollutants at ground level, along with other supporting information, to enable better decision making by planned burn managers. The system builds upon recent scientific research involving Melbourne, Monash, Wollongong and Macquarie Universities which addressed many of the knowledge gaps related to smoke emissions from burning fuels typically found in southeastern Australia. The results were incorporated into an integrated smoke forecasting system that explicitly models the temporal evolution of smoke emissions from fires during different stages of the burn cycle.

SYSTEM OVERVIEW

The smoke forecasting system was designed to support risk mitigation and resource allocation planning at different time scales as shown in Figure 1. Agency personnel can access the forecasts on their desktop computer or mobile device by logging into a registered user website hosted by the Bureau.

FIGURE 1. 3-TIERED SMOKE FORECASTING SYSTEM

TIER ONE: COMING WEEK

To indicate whether conditions are likely to be favourable for planned burning in the coming week, medium range forecast products are generated from ensemble numerical weather prediction (NWP), where multiple runs of the weather model simulate the range of possible conditions. Probability charts for Forest Fire Danger Index (FFDI), as shown in Figure 2, are generated from the relevant weather variables (temperature, relative humidity, wind speed) in each ensemble member and drought factor forecasts from the Australian Digital Forecast Database are used to compute the forecast FFDI. At each grid point the probability of FFDI exceeding a certain threshold (for example, 25, or "very high") is estimated as the fraction of individual ensemble members forecasts with a FFDI value greater than or equal to the threshold.

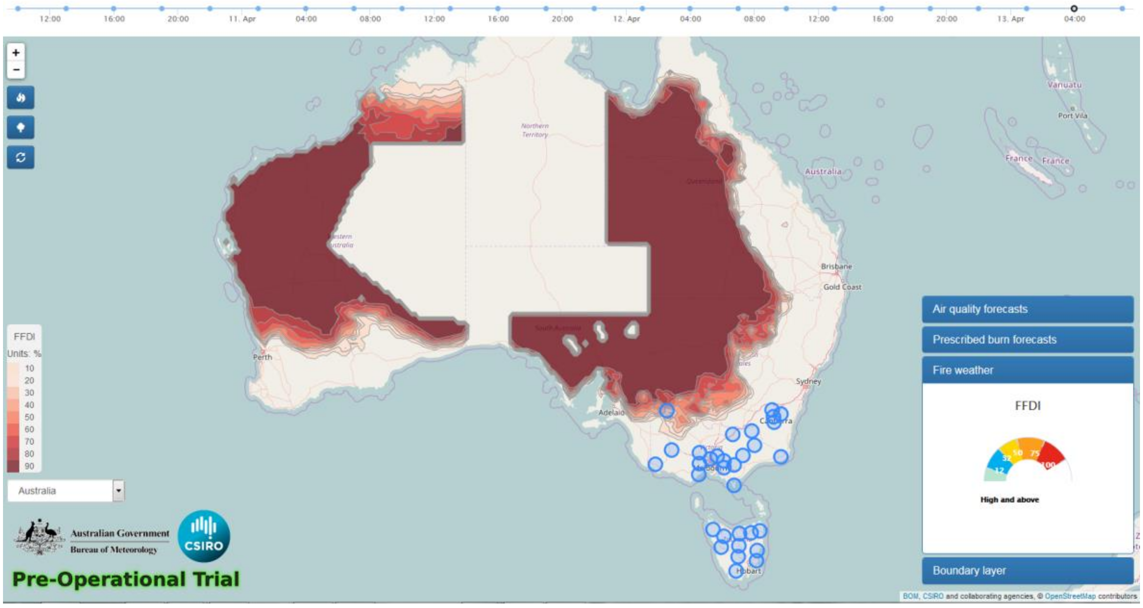

FIGURE 2. PROBABILITY CHART FOR FFDI > 12, VALID 4 AM LOCAL TIME 13 APRIL 2017. BLANK AREAS IN CENTRAL AUSTRALIA ARE DUE TO SOIL MOISURE DATA BEING UNAVAILABLE.

Ensemble meteograms are available for specific locations shown by blue circles on the map. These show the time evolution of wind speed, temperature, relative humidity, FFDI and GFDI. The median forecast is shown by the red line, while the box-whiskers show the distribution of possible values at each time. This is very useful for showing more extreme (but less likely) values that might be cause for concern.

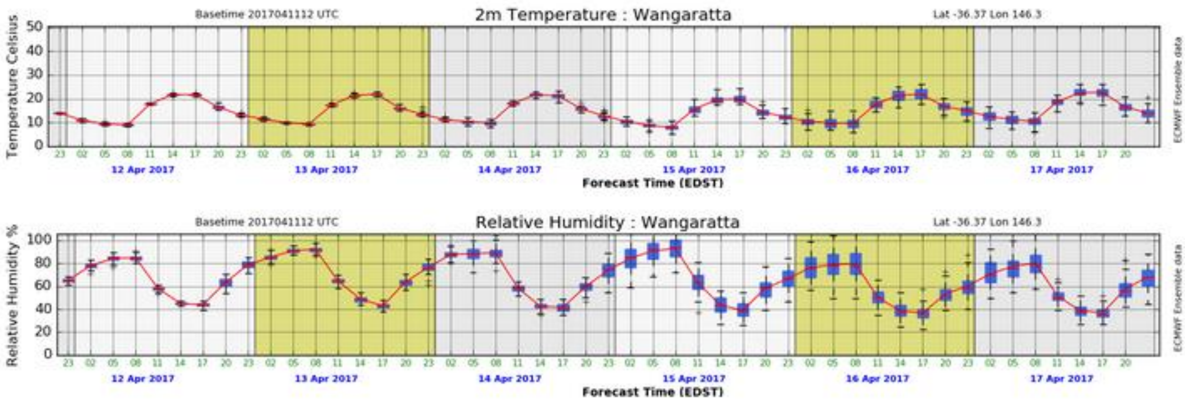

FIGURE 3. METEOGRAM SHOWING ECMWF ENSEMBLE INFORMATION OUT TO 6 DAYS (NOT ALL ELEMENTS DISPLAYED).

TIER TWO: NEXT FEW DAYS

To estimate the background air quality to which smoke from prescribed burning may be added, the regional air quality prediction system generates 3-day forecasts of fine particles and fine particle precursors for the Australian region. Meteorological forecasts from the ACCESS-R NWP model are used to drive CSIRO's Chemical Transport Model (C-CTM) in which aerosol and gaseous emissions are transported and can evolve, react with other compounds, and settle out. Sources of anthropogenic and natural emissions include

State EPA air emissions inventories, sea salt, dust and the biogenic emissions of volatile gases for the subsequent generation of secondary organic aerosol. In the case of fires, smoke emissions for the greater Australian region are generated from Sentinel hotspots. For Victoria, emissions are generated from DELWP active fire data with fire spread and intensity estimated using the Phoenix FireFlux modelling system (Walsh et al 2016).

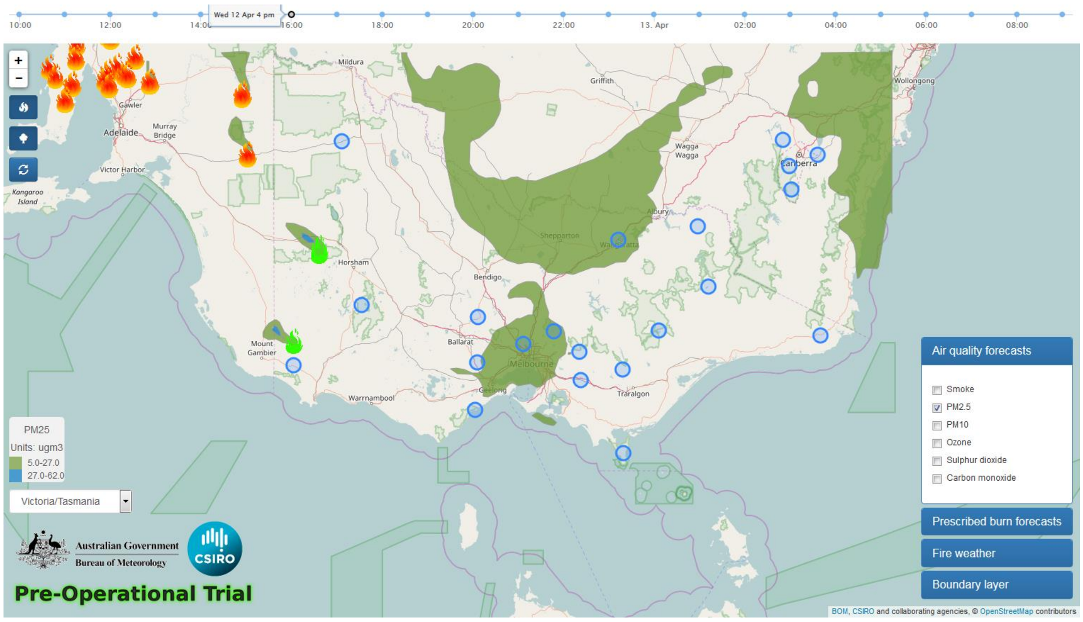

FIGURE 4. PM2.5 FORECAST VALID 4 PM LOCAL TIME 12 APRIL 2017, SHOWING INCREASED CONCENTRATIONS DUE TO GOING FIRES AND PRESCRIBED BURNS.

Additional meteorological forecast information to support prescribed burn planning includes spatial maps of ventilation index, atmospheric boundary layer height and transport wind and aerological (Skew T – log P) diagrams for specific locations.

TIER 3: TOMORROW

The prescribed burn forecast (see Figure 5) uses planned burn data from DELWP to create scenarios of the potential smoke effects from planned burns. Phoenix FireFlux is run based on burn information and weather data to generate a grid of cells burnt every 15 minutes. These grids are passed to an emissions module to estimate the emissions of PM2.5 and the plume rise of the smoke column. The emitted smoke is then dispersed by the coupled ACCESS-C weather model and C-CTM at 1km grid resolution. The ground-level footprint of each individual prescribed burn is then plotted in spatial maps at hourly time steps for use by DELWP. The model is run each afternoon so a final decision can be made on whether or not to go ahead on the following day, based on predicted PM2.5 concentrations. Smoke dispersion from up to 64 individual fires is tracked separately in the system, allowing them to be virtually "turned on" and "turned off" to assess their contributions to the overall particulate load and possible exceedances of the PM2.5 24-h average air quality standard (25 µg m-3). Tier 3 prescribed burn forecasts utilise a simplified atmospheric chemistry.

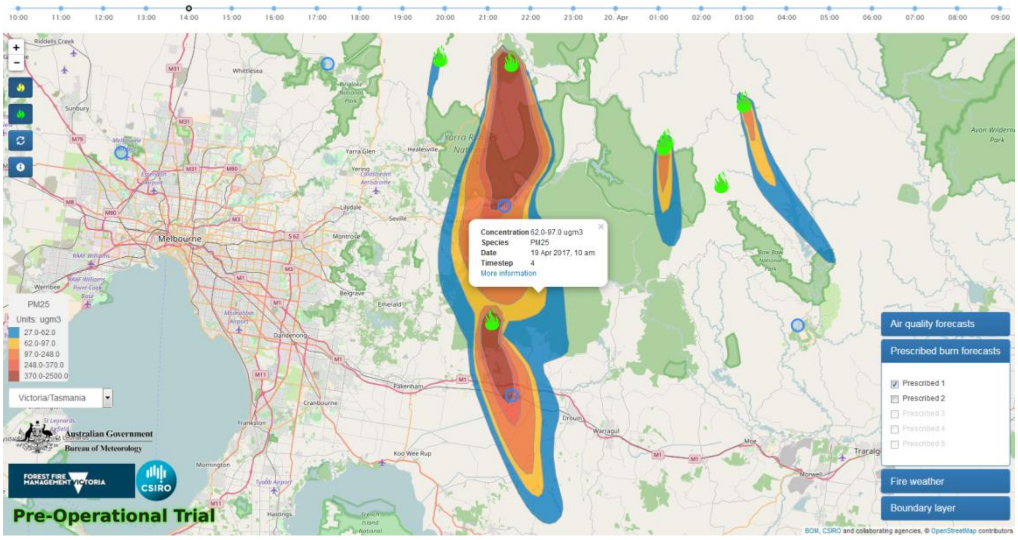

FIGURE 5. PRESCRIBED BURN FORECAST VALID 2 PM LOCAL TIME19 APRIL 2017, SHOWING THE PM2.5 OUTPUT FROM 5 SEPARATE PLANNED BURNS

SYSTEM VERIFICATION

Environment Protection Authority Victoria (EPA) monitors levels of PM2.5, PM10, ozone, sulphur dioxide and carbon monoxide at 17 sites across the state.

Verification software has been developed which allows the EPA data to be easily compared with the model values.

Some initial verification results are shown in Figure 6. This validation is guiding improvements in the modelling.

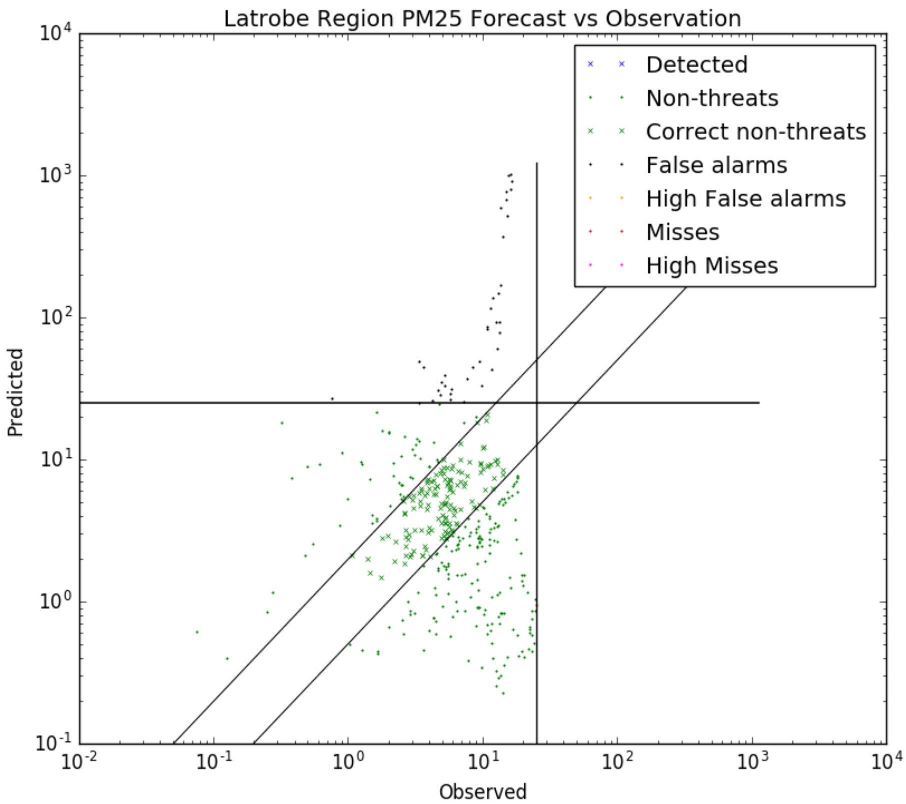

FIGURE 6. PREDICTED VERSUS OBSERVED PM2.5 FOR LATROBE VALLEY REGION, APRIL – MAY 2017. DIAGONAL LINES INDICATE WHERE THE FORECAST IS ACCURATE WITHIN A FACTOR OF TWO.

FUTURE WORK

Once the quantitative smoke forecasting system is operational, the Bureau will continue to provide an ongoing smoke forecasting service for fire agencies on a cost-recovery basis. The initial system is optimised for Victoria. With appropriate investment, the system could be expanded to provide all three tiers across the country. CSIRO are undertaking a new project to display real time smoke intelligence from satellite and radar remote sensing and social media reports of smoke. This will provide "ground truthing" for forecasts in real time, helping agencies to make better use of the products.

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