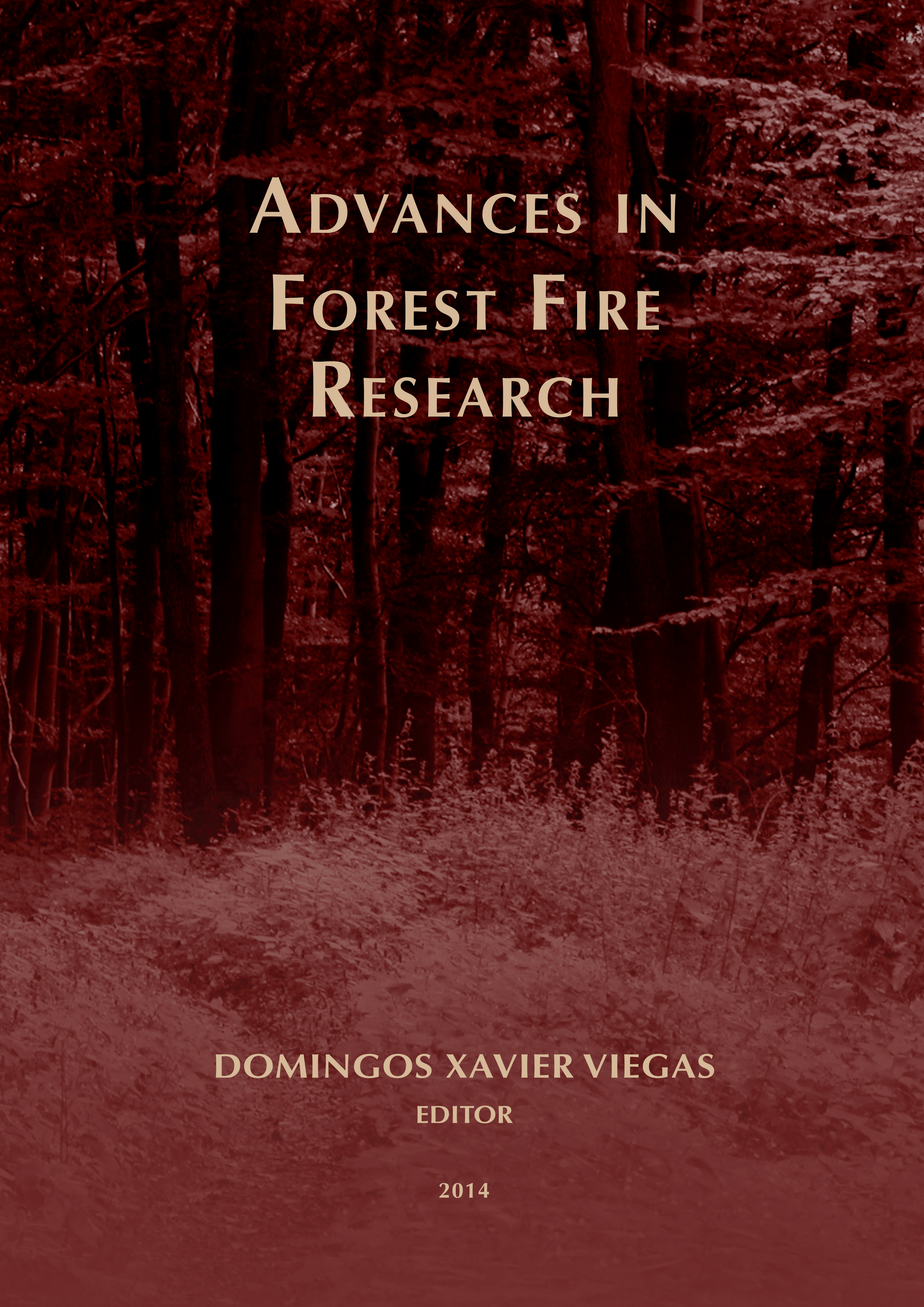

Advances in Forest Fire Research

Domingos Xavier Viegas

Editor

2014

A hi-resolution 40-year gridded fire weather/danger climatology for Victoria, Australia

Timothy Brown[a], Graham Mills[b], Sarah Harris[c], Domagoj Podnar[a], Hauss Reinbold[a]

[a] *Desert Research Institute, Reno Nevada USA, tim.brown@dri.edu*
[b] *Monash University, Clayton Victoria Australia, gam4582@gmail.com*
[c] *Monash University, Clayton Victoria Australia, sarah.harris@monash.edu*

Abstract
A homogeneous 40-year (1972-2013) hourly 4-km gridded climate dataset for Victoria, Australia is being generated using a combination of mesoscale modeling, global reanalysis data, surface observations, and historic observed rainfall analyses. The primary purposes of this dataset are optimizing planned burning and land management strategies, and scenario planning for major fire events. Outputs include fire weather and fire danger variables. The output data are created using the Weather Research and Forecast (WRF) model. Error correction techniques are applied to minimize any model biases. Outputs provide an almost limitless opportunity for hitherto unavailable analyses – fields of percentiles of forest fire danger index (FDDI) values, analysis of periods exceeding thresholds at any location, inter-annual and regional variations of fire season characteristics, analysis of prescribed burning windows, of atmospheric dispersion climates, and various atmospheric stability measures that might affect fire behaviour, and to assess climatologies of more esoteric mesoscale weather events, such as mountain waves, that may affect fire behaviour. This presentation describes the generation of the dataset, shows examples of output, and highlights use and relevance for fire management.

Keywords: *Fire weather, fire danger, climatology, dynamical downscaling*

1. Introduction

There is a need for a detailed understanding of the climatology of fire weather across the Australian landscape if strategic decisions to ameliorate the sometimes-extreme impacts of bushfires on the socio-economic wellbeing of the community are to be based on sound scientific evidence, and if variability and trends in this climatology are to be correctly interpreted. This paper describes the methodology by which a 1972-present high temporal- and spatial-resolution climatology of Victoria's fire weather is being developed. The climatology is intended to combine hourly values of meteorological variables on a regular, high spatial resolution, grid over Victoria, Australia with drought factors based on the Australian Water Availability Project (AWAP) rainfall and temperature analyses (Jones *et al*. 2009) to generate hourly gridded fields of Forest Fire Danger Index (FFDI).
The dataset will provide baseline climatology information for risk management assessments and climate change adaptation planning. The benefits of the dataset to the Victoria Department of Environment and Primary Industries and others include:

- Provides a high-resolution temporally and spatially complete record of temperature, humidity, wind, precipitation, drought and fire danger.
- Allows for analyses at local through regional through state scales.
- Shows interannual and decadal variability for the elements produced, as well as climate trend.
- Quantitatively links climate variability and trend to impacts from fire, heat waves, drought, etc.

- Provides a historical baseline that can be used in comparison studies with downscaled regional or place-based future climate data.
- Serves as input data for decision-support tools to obtain historic baselines.
- Provides quantitative climate values to help test agency strategies and predict ecological outcomes.
- Helps determine if assumptions that go into policy and operations are supported by what is known about the climate record.
- Helps determine the extent that fire management responses have been “driven” by climate versus other forcing factors (e.g., political, economic, public perceptions).

Specific fire management relevance and uses include, but are not limited to:

- Estimating climate related bushfire risk
- Estimating number of days suitable for planned burning
- Input into the allocation of fire management resources - including planned burning
- Bushfire case study analysis, refinement and improvement of burning prescriptions
- Development of climate envelopes for vegetation communities
- Development of weather predictions for "fire use" decision making, and future bushfire climate predictions for strategic planning
- Providing hourly high-resolution weather input for fire spread models

In situ observation networks more typically than not have inhomogeneities in time and space. Thus, there are some considerable barriers to basing a climatology on long-term meteorological observations, as shown by the relatively low number of reliable, long-term observation records available for such analyses (see Lucas *et al*. 2007). This has significant implications for fire weather applications. The bulk of the observations are based near population centres, and so do not necessarily reflect the conditions in the forests where the bulk of major bushfires occur, and which are concentrated in the slopes and valleys of the ranges through central and eastern Victoria. To fulfill bushfire management agency needs, an ideal climatology would be based on a homogeneous high-resolution temporal (i.e., hourly) and spatially gridded fire weather and fire danger dataset. This paper briefly describes the model configuration, running strategy, and quality control/assessment procedures we are using in developing such a dataset for Victoria.

2. Methods

The mesoscale model used is the Weather Research and Forecasting (WRF) model described by Skamarock *et al*. (2008). It is a well-supported and widely used non-hydrostatic model that includes a wide range of choices of physical parameterization schemes. Three integration domains are used in our configuration (Figure 1) with grid spacings of 36 km (outer mesh), 12 km (middle mesh), and 4 km (inner mesh). Each nest has 33 vertical model levels. Initial state and lateral boundary conditions for the outer mesh are provided by 6- hourly interval global reanalyses. Choices of physical parameterization packages selected are listed in Table 1.

We utilize two global reanalyses for initial state and lateral boundary conditions to start each WRF integration and nudge fields through the 15-day process. The National Centers for Environmental Prediction (NCEP) FNL (Final) Operational Global Analysis (NCEP 2000) data are on 1-degree by 1-degree grids prepared operationally every six hours, and was used for the 2000-2013 period. The ERA-Interim (Dee *et al*. 2011) reanalysis dataset is being used prior to 1999.

There are logistical and data set quality benefits in performing longer (multi-day) rather than shorter (1-2 day) integrations as it is desirable not to have too many discontinuities at the commencement of each new integration due to the need for the inner mesh to "spin up" from the smooth global reanalysis fields. One would intuitively expect that the model solution would drift somewhat from reality with time, although the use of analysis lateral boundary conditions rather than the forecast conditions used in operational forecast models should reduce this effect somewhat. After considerable testing, we chose to generate the data using 15-day integrations, but with the first day of each integration treated as a spin-up period and thus discarded. Therefore days 2-15 of each integration become Days 1-14 of each two-week data set period.

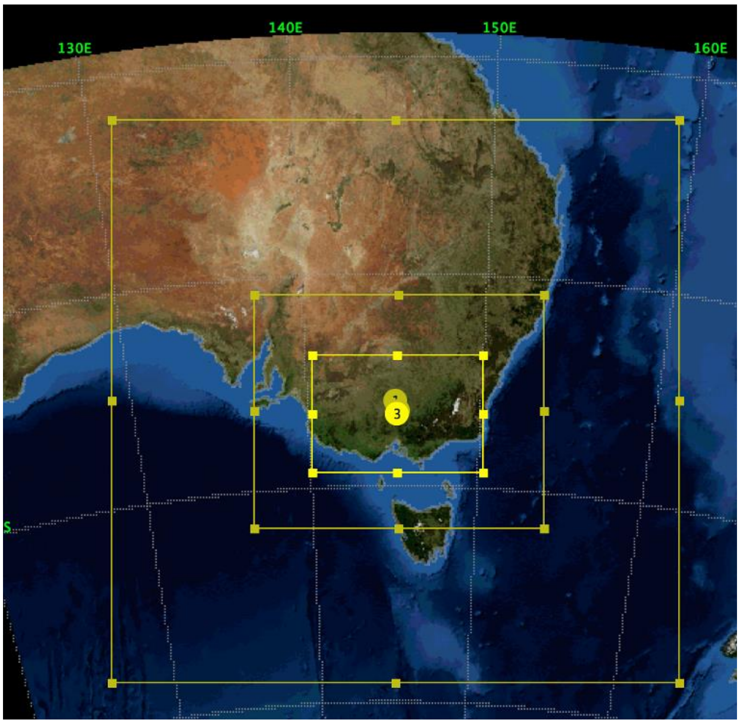

Figure 1. Map showing the three integration grids used in our configuration of the WRF model. Outer grid spacing 36-km, middle 12-km and inner mesh 4-km.

Table 1. List of physical parameterisations used in this WRF configuration.

Microphysics: Thompson *et al*. scheme: A new scheme with ice, snow and graupel processes suitable for high-resolution simulations (8).

Longwave Radiation: RRTM scheme: Rapid Radiative Transfer Model. An accurate scheme using look-up tables for efficiency; it accounts for multiple bands, trace gases, and microphysics species.

Shortwave Radiation: Goddard shortwave: Two-stream multi-band scheme with ozone from climatology and cloud effects.

Land Surface: Noah Land Surface Model: Unified NCEP/NCAR/AFWA scheme with soil temperature and moisture in four layers, fractional snow cover and frozen soil physics.

Planetary Boundary layer: Yonsei University scheme: Non-local-K scheme with explicit entrainment layer and parabolic K profile in unstable mixed layer.

Cumulus Parameterization: Kain-Fritsch scheme: Deep and shallow convection sub-grid scheme using a mass flux approach with downdrafts and CAPE removal time scale.

Diffusion Option: Simple diffusion: Gradients are simply taken along coordinate surfaces.

K Option: 2d Deformation: K for horizontal diffusion is diagnosed from just horizontal deformation. The vertical diffusion is done by the PBL scheme.

The 15-day integrations and model field nudging has produced remarkably small biases. Figure 3 shows cumulative distribution functions (CDFs) for a combined 30 observation dataset and corresponding model grid point for each station for the 10-year period 2004-2013. This includes all hours and days during this period. Further analyses are being undertaken to assess diurnal, seasonal and elevation biases.

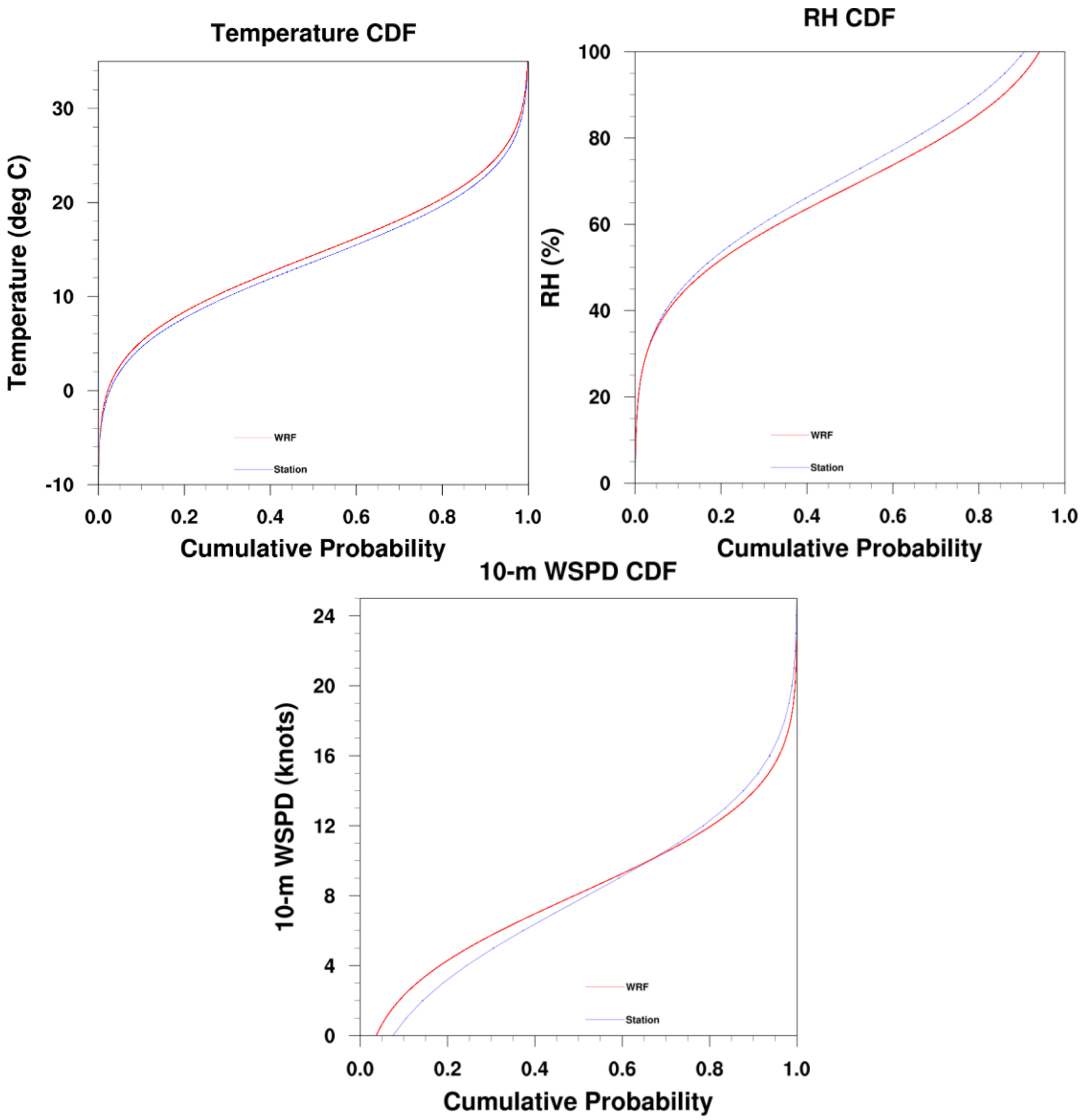

Figure 3. Cumulative distribution functions for 30 stations and corresponding model grid points for all hours and days 2004-2013 for temperature, relative humidity and wind speed.

3. Results

The surface data from WRF of primary interest include hourly temperature, relative humidity, wind speed, wind direction, Forest Fire Danger Index (FFDI) and precipitation. Daily data of interest include precipitation, Keetch-Byram Drought Index and the Drought Factor. Not surprisingly, a dataset of this size allows for the production of extensive statistics, graphics and analyses. Here we provide a few examples.

Figure 4 shows example maps of 2-m temperature, 2-m relative humidity and 10-m wind speed for 0500 UTC on 22-Jan-2006, a day of extreme fire danger over Victoria. At 0500 UTC a dry cold front has moved onshore in Victoria's west.

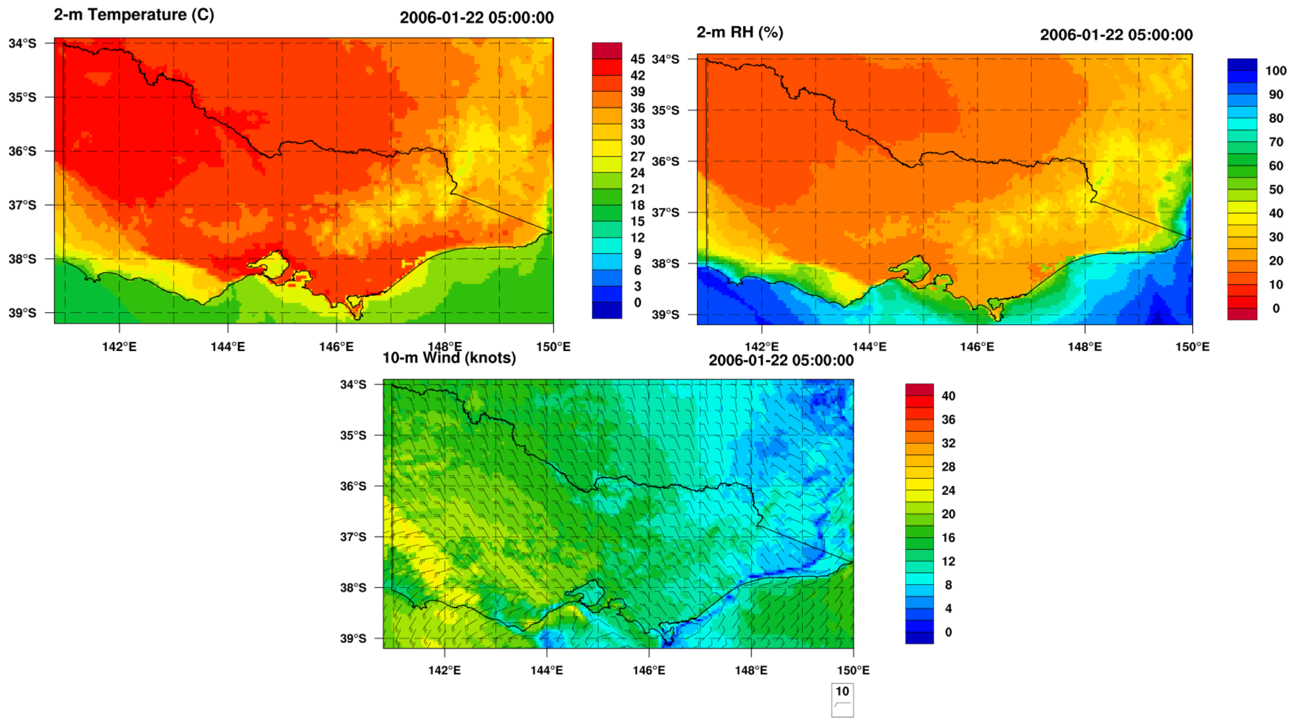

Figure 4. Example maps of 2-m temperature, 2-m relative humidity and 10-m wind speed for 22-Jan-2006.

Figure 5 shows an example of the diurnal cycle of January mean relative humidity by comparing 0500 and 1700 UTC.

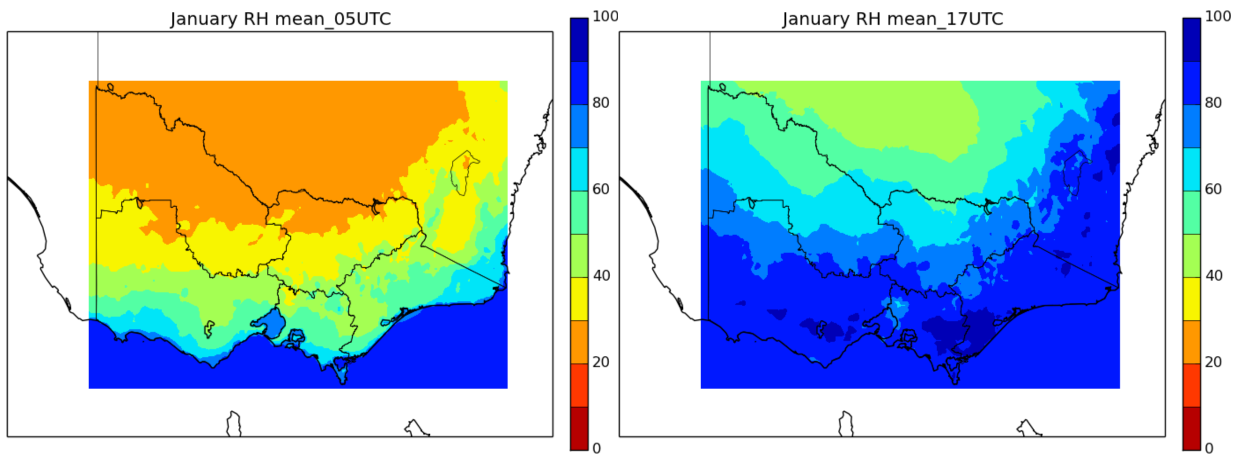

Figure 5. Example maps of January mean relative humidity highlighting the diurnal cycle by contrasting 0500 and 1700 UTC, respectively.

Figure 6 shows the maximum value of the FFDI for the December-February climatological season. The coastal and topographic effects are obvious, and the area of FFDI greater than 125 south of the ranges and west of Melbourne is notable.

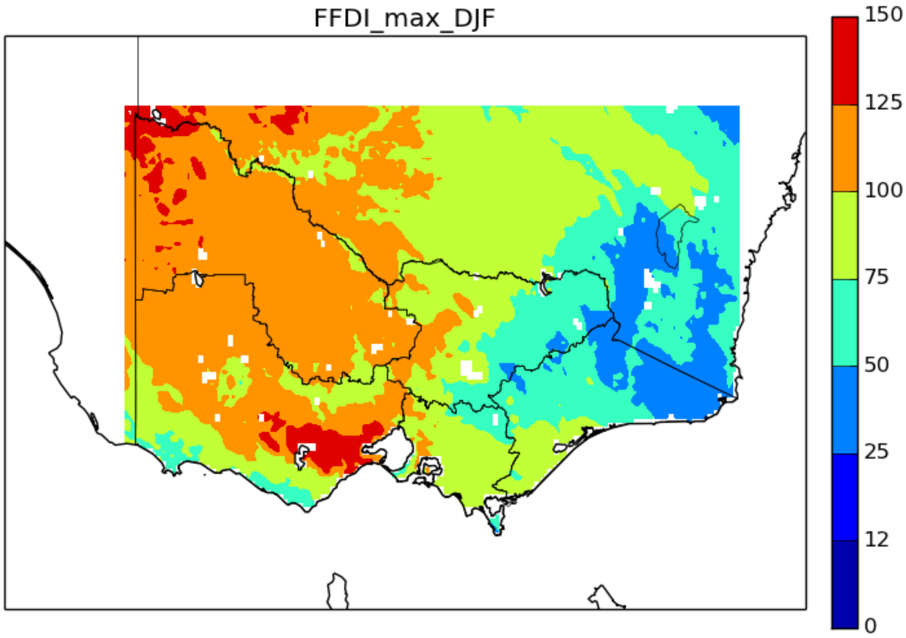

Figure 6. Example map of the climatological maximum FFDI value for the December-February season.

4. Summary

As of this writing, a 22-year climatology (1992-2013) has been completed. The full dataset is anticipated for completion by the end of 2014. While hourly 4-km surface variables are the primary priority of this project, the fact that the WRF model outputs hourly 3-dimensional fields of all atmospheric variables means that there is the opportunity to assess the climatology of above-surface weather on fire activity that has never been possible at this scale over Victoria before. These studies include the effect of atmospheric stability on fire behavior using indices such as those described by Mills and McCaw (2010), and the potential to perform climatological assessments of foehn/mountain wave events such as those described by Sharples *et al*. (2010) and Badlan *et al*. (2012), or other mesoscale systems that are difficult to analyse climatologically from the observational record.

5. References

Badlan, R.L., Lane, T.P., Mills, G.A., and Caine, S., 2012. Mesoscale modeling of two "drying events": governing processes and implications for fire danger. *Aust. Meteor. Oceanog. J.*, **62**, 143-156.

Dee, D. P., and 35 co-authors, 2011: The ERA-Interim reanalysis: Configuration and performance of the data assimilation system. *Quart. J. R. Meteorol. Soc.*, **137**, 553-597.

Lucas, C., 2010. On developing a historical fire weather data-set for Australia. *Aust. Meteor. Oceanog. J.*, **60**, 1-14.

Mills, G.A., and L.McCaw 2010. Atmospheric Stability Environments and Fire Weather in Australia – extending the Haines Index. CAWCR Technical Report No20, 158pp.

National Centers for Environmental Prediction/National Weather Service/NOAA/U.S. Department of Commerce, 2000: *NCEP FNL Operational Model Global Tropospheric Analyses, continuing from July 1999*. Research Data Archive at the National Center for Atmospheric Research, Computational and Information Systems Laboratory, Boulder, CO. [Available online at http://dx.doi.org/10.5065/D6M043C6.]

Sharples, J.J., McRae, R.H.D., Mills, G.A., and Weber, R.O., 2010. Foehn-like winds and elevated fire danger conditions in southeastern Australia. *J. Appl. Met. and Climat.*, **9**, 1067-1095.

Skamarock, W., Klemp, J., Dudhia, J., Gill, D., Barker, D., Duda, M., Wang, W. & Powers, J., 2008. ‘A Description of the Advanced Research WRF Version 3’, NCAR Technical Note NCAR/TN-475+STR.