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Changes in the diurnal cycle of fire danger with elevation in Tasmania: the old and the new

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Introduction

Understanding the timing of peak fire danger during the day is important for planning for fire suppression as well as for activities including fuel reduction burning. There is some evidence from observations that time of maximum fire danger varies with elevation. Studies in Tasmania and in the southeast mainland of Australia (Fox-Hughes 2008, Sharples et al. 2012) demonstrate that peak McArthur forest fire danger index (FFDI) frequently occurs during early-mid morning on the isolated elevated sites examined, but at much lower elevations it is recognised that the most common time of peak fire danger is mid-late afternoon. Similarly, case studies in California (Bagley 2017) have reported dangerous fire weather conditions overnight and in the early morning, which have overwhelmed fire fighting resources. Alpine fires are not uncommon in southeastern Australia, and recent examples include the Victorian fires of 2002-03, 2006-07 and 2009, Blue Mountains fires in October 2013 in NSW and regions of the Tasmanian fires in 2016 and 2019. In addition, some of the Queensland fires of late 2018 burnt at high elevation. It is important, then, to understand the characteristics of the fire weather that drive such events.
A prototype Australian Fire Danger Rating System (AFDRS) has recently been developed and trialled over the 2017-18 southern Australian fire season (see other presentations in this conference). The system was extended to operate over 2018-19, ahead of the implementation of an operational trial in the following three years. The AFDRS employs eight broad fuel types, directly linked to models of fire spread, and numerous sub-types to generate separate indices from which a common six level fire danger rating is derived. Ratings of 4 – 6 are scaled to represent conditions in which fire activity is difficult to control or dangerous. It is also valuable to assess the extent to which there are changes in the diurnal cycle of the AFDRS with elevation, as it begins to transition into operational use. There are some indications of diurnal variation in the AFDRS, with some initial results again presented at this conference. Here, we further investigate changes in the diurnal cycle with elevation in both the AFDRS and the currently operational McArthur FFDI.

Data and Methods

We employ the Bureau of Meteorology Atmospheric high-resolution Regional Reanalysis for Australia (BARRA, Jakob et al. 2017; Su et al. 2018), in particular, BARRA-TA, the downscaled version of the Australian regional reanalysis BARRA-R, over Tasmania, a domain characterised by substantial topographic variation (Figure 1). BARRA is derived from the ACCESS numerical weather prediction model used operationally in Australia. BARRA-TA has a horizontal resolution of 1.5 km, 70 vertical levels through the atmosphere and hourly (and for some parameters, every ten minutes) timesteps through each level. At the time of preparation of this abstract, BARRA-TA data was available for 2007-2016. We note that BARRA data has identified biases including under-representation of wind at higher windspeeds, in common with other reanalyses (Su et al. 2018). Relative humidity is derived from lowest model level grids (rather than using screen dewpoint temperature and relative humidity), due to a known problem with those fields.

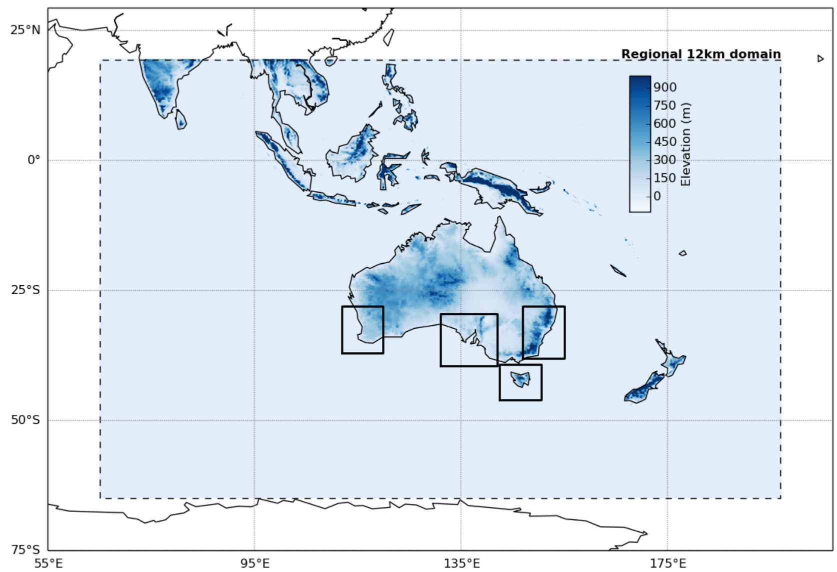

Figure 1 BARRA domain, including Tasmanian and other subdomains

Tasmanian elevation is calculated using the digital elevation model employed in BARRA-TA, again at 1.5 km resolution. Figure 2 shows the Tasmanian topography, stratified by 500, 700 and 1000 metre contours. We calculate McArthur FFDI values (McArthur, 1967) for each hourly timestep for all land points in the BARRA-TA domain, using Drought Factor updated daily, irrespective of actual fuel type at each grid cell. We also calculate AFDRS FDR values for each land point, informed by the vegetation type assigned to cells. For both McArthur FFDI and AFDRS, we filter out rating values below 3 as being of little interest for this analysis. In the case of the McArthur FDRS, this corresponds to FFDI values of less than 12. We aggregate BARRA-TA grid cells within the layers 0-500, 500-700, 700-1000 and above 1000 m in elevation, and identify time of peak McArthur FFDI and AFDRS rating for each day.

Results

Figure 3 a-d displays the impact of elevation on timing of peak daily McArthur FFDI in Tasmania, plotting the proportion of days on which fire danger peaks during each hour (in local time). Locations were grouped by elevation ranges across the nominal fire season, October –

March, for all available fire seasons (2007-16, including Jan-Mar 2007 and Oct – Dec 2016). Lower elevations (0-500 m, Figure 3a) generally experience peak fire danger during the mid-afternoon, as is typically anticipated, although with an approximately normal distribution around that time and long tails that include all other times during the day. Only small changes are observable between Figures 3a and 3b, the latter displaying proportional peak fire danger time for elevations between 500 and 700 m, but within the 700 – 1000 m elevation range (Figure 3c), the mid-afternoon fire danger peak is less prominent, and the proportion of mid – late morning occurrences of peak fire has increased. In the highest elevation range, above 1000 m (Figure 3d), the most common time of peak fire danger has shifted earlier in the day to 1100 local time, with a broader distribution of peak times than is the case at low levels (0 – 500 m).

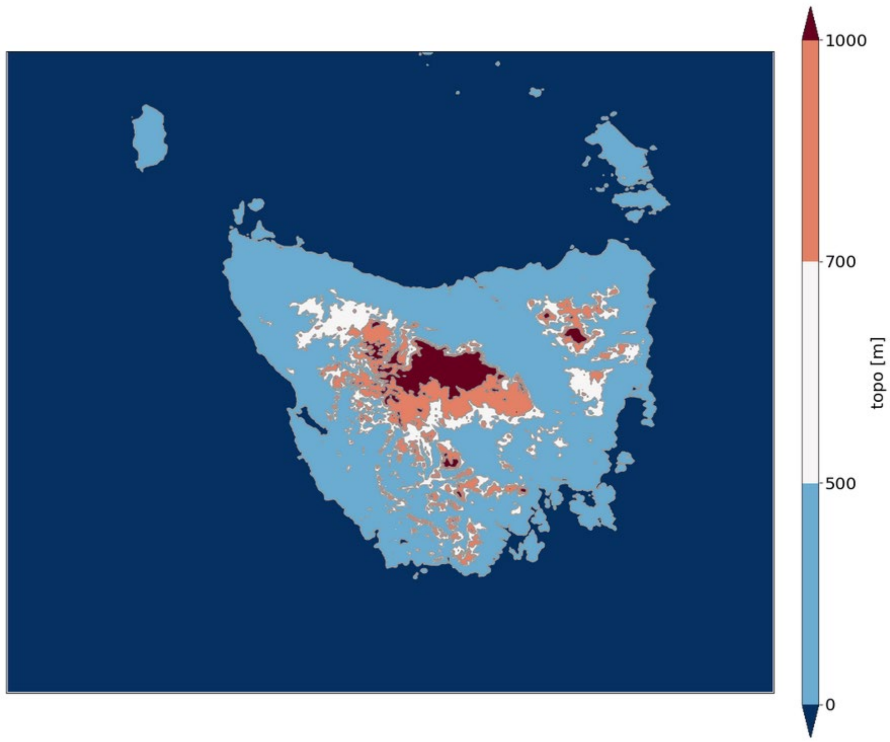

Figure 2 Tasmanian topography, stratified by elevations used in this analysis.

The prototype AFDRS presents a more complex and nuanced picture of changing peak fire danger time in comparison with the McArthur fire danger rating system. This is to be expected, as the different fuel types respond differently to each of the relevant weather parameters, which in turn vary, of course, with elevation. In addition, different vegetation types are more or less prevalent at different elevation ranges. For example, savannah, as open woodland, does not extend above 700 m elevation, and pine, representing pine plantation areas, does not extend above 1000 m. Further, some vegetation types do not occur in Tasmania, including mallee-heath and spinifex. Nonetheless, it is clear that there is an overall similar pattern of decreasing time of peak fire danger with increasing elevation. Figure 4 displays the proportion, by hour, of times during which fire danger peaks for the prototype AFDRS. As per Figure 3, these are aggregated across available fire seasons and by elevation range. Individual vegetation types are displayed separately, permitting a visual assessment of the differences in the response to elevation of each vegetation fire behaviour model. Note that the y-axis scale differs between the subplots of Figure 4.

There is a broad peak of times evident in Figure 4a, centred on the early afternoon at low (0-500 m) elevation, with 1500 hours again the dominant time. Pine and savannah vegetation types, in particular, have sharp fire danger peaks at this time. Interestingly, however, forest, grass and buttongrass, while exhibiting a primary peak at 1500, have a secondary peak already evident at around 1200, and heathlands have a broader peak at 1100-1200 hours, and only a minor secondary peak at 1500 hours. Across all vegetation types ("full" in Figure 4), a 1500 hours peak is visible, with a broad secondary peak at 1200 hours. Between 500-700 m elevation (Figure 4b), a similar distribution prevails, with the exception that savannah experiences a broader peak, extending earlier in the afternoon than is the case below 500 m.

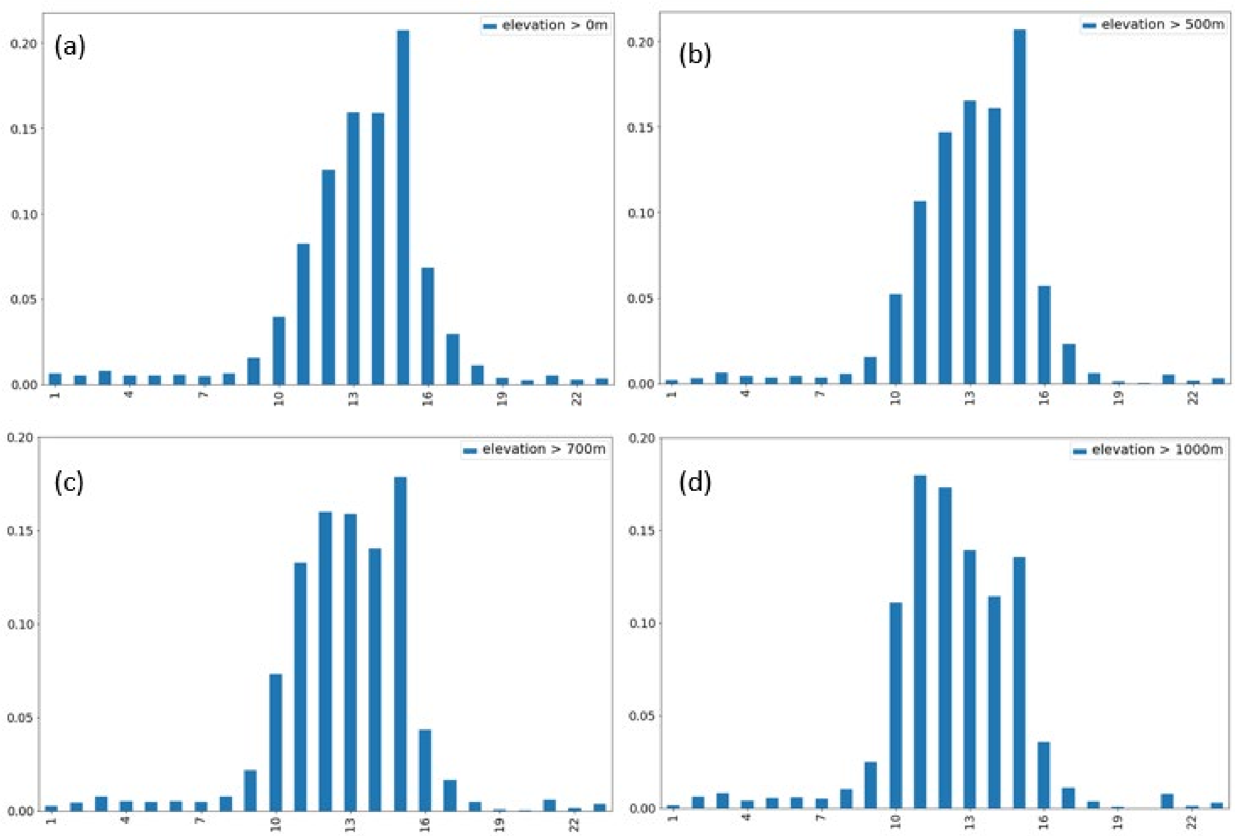

Figure 3 Proportion of days that McArthur fire danger peaks at each hour (local time), aggregated by elevation (a) 0-500 m (b) 500-700 m (c) 700-1000m (d) above 1000 m.

For the 700 – 1000 m range of elevations (Figure 4c), the diurnal peak fire danger has shifted earlier to 1200 hours for grassland, forest and "full" (including all vegetation types) and to 1100 hours for heathland. Interestingly, the peak for buttongrass and pine remain at 1500 hours. Above 1000 m, only buttongrass maintains a 1500 hours fire danger peak (noting that there is no pine in this elevation range). Forest and "full" have shifted back to 1100 hours, and heathland to 1000 hours, with the grassland peak remaining at 1200 hours.

Discussion and Summary

The fine grid and hourly temporal resolution of BARRA-TA permits detailed analysis of change in the diurnal cycle of fire danger in the McArthur and prototype Australian Fire Danger Rating

Systems. Both systems exhibit a shift to earlier in the day of the diurnal peak in fire danger with increasing elevation. In the case of the prototype AFDRS, this response is more complex than that of the McArthur FFDRS on account of the differing response to weather parameters of the various vegetation types within the system.

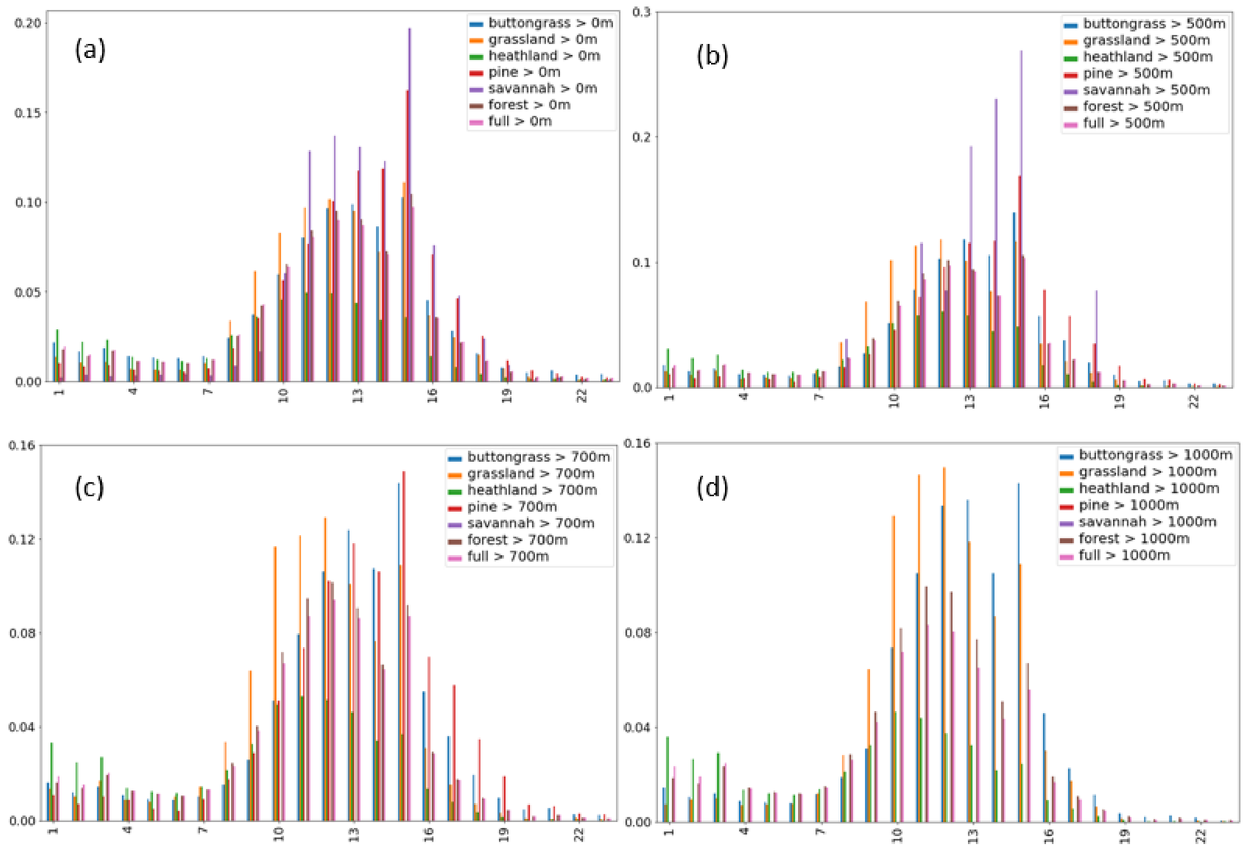

Figure 4 As Figure 3, but for the prototype AFDRS, displaying responses of individual vegetation types.

It is likely that the climatological occurrence of remnant subsidence inversions ahead of approaching cold fronts accounts for this phenomenon. Typically during the southern Australian fire season, a high pressure system retreats eastward as a cold front approaches. While the subsidence inversion is intact, low elevations generally experience relatively moist overnight-early morning conditions with light winds. Above the inversion, however, air has descended through the high pressure system and consequently warmed and dried. In addition, the airmass above the inversion will start to experience winds associated with a tightening pressure gradient ahead of the approaching front. As such, the inversion, usually at a height of between 500 – 1000 m above sea level, delineates a higher fire danger region aloft from a lower fire dangers closer to sea level. As the lower atmosphere warms during the day, the inversion is eroded, and eventually drier, higher momentum air from above the inversion mixes to lower elevations and the fire danger increases in the lowlands and stabilises, or decreases, aloft.

As noted above, differences in behaviour between vegetation types follow from their varying responses to weather parameters. For example, buttongrass is very sensitive to windspeed, but relatively insensitive to relative humidity, so diurnal changes in relative humidity resulting from the erosion of subsidence inversions will not affect buttongrass fire danger very strongly, and its time of peak fire danger might not be expected to vary as markedly as some other vegetation types. In addition, as noted above, some vegetation types (and associated fire behaviour models) are limited in their elevation range, which may affect these results.

This work confirms that the isolated observations made at high elevations of a different pattern of diurnal fire danger behaviour to that observed at the more common lowland observation sites are generally applicable in Tasmania, and quite likely throughout elevated areas of southeastern Australia. It is important, then, for fire managers to be aware that any operations at elevated sites are likely, in general, to experience peak fire danger earlier than the generally expected time of mid-afternoon.

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