CSIRO PyroPage
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www.csiro.au
Number 16 | **January 2018**

Spatially-variable thresholds for fire danger ratings

Current systems for determining fire danger nationally have been found to be inadequate and are presently being revised. Recent advances in spatial statistical analysis, in particular extreme event modelling using 'max-stable' processes, may provide an avenue for refining fire danger rating determination. This study used the spatial behaviour of extreme values of a common fire danger index to investigate the utility of employing spatially-varying thresholds for defining fire danger ratings.

Nationally applicable fire danger ratings

Fire danger rating systems used in Australia need to be nationally applicable. That is, the system employed in one location in the country needs to produce results commensurate with those produced in another part of the country. However, the climatic breadth of the continent means that some parts will experience a significantly different range of conditions than those in others. Similarly, the range of fire behaviour will be different.

For example, Tasmania has generally milder climate and thus currently lower calculated fire danger than the rest of the continent. The McArthur Forest Fire Danger Meter for Tasmania rarely exceeds a Forest Fire Danger Index (FFDI) of 75 (Fox-Hughes 2008), yet the state can still experience devastating bushfires.

While a consistent method for calculation of fire danger, particularly at regional scales, is necessary, interpretation of the calculated index into fire danger rating (FDR) could be carried out at more discerning local scales. Current fire danger systems apply the same thresholds when determining FDR from fire danger index. To explore the potential for spatially-variable FDR thresholds, recent advances in extreme event modelling using max-stable processes were applied to 53 years of historical weather data for the continent.

Max-stable extreme-event modelling

Extreme value analysis is a branch of statistics that deals with extreme deviations from the median of a probability distribution. It aims to determine the probability of an observation that is more extreme than anything previously recorded. However, fire danger, like its underlying weather components (e.g. air temperature, relative humidity, wind speed, recent rainfall, etc.), is spatially correlated over a given area. The theory of max-stable processes provides a generalisation of extreme value analysis for the specification of the behaviour of extreme events over continuous space.

This study applied the Bayesian max-stable hierarchical model of Reich and Shaby (2012) with amendments to enable it to be applied to data from a large number of sites. FFDI was calculated from interpolated daily weather data from more than 17,000 sites across the continent for the period September to April for the years 1958 to 2012.

Results

Figure 1 shows a long-term quantile map calculated using a grid resolution of 0.2° × 0.2° for FFDI values that would be exceeded in any given fire season with a 10% probability (i.e. a 10-year return level).

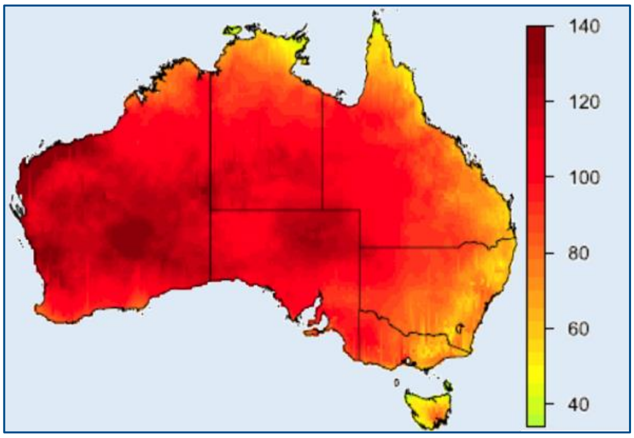

Figure 1. A map of 10-year return intervals for the FFDI calculated using max-stable extreme event analysis for the period September to April for years 1958-2012.

This figure shows that for the bulk of the continent the long-term 10-year return value is well above 80 but for most populated regions on the east coast and Tasmania, the value is much less, even though the fire risk in these regions can be quite significant. Conversely, where the 10-year return value is high there is often no or very little vegetation to carry fire. The spatial variability in FFDI can be used, in conjunction with knowledge of extreme values and fire behaviour, as a basis for identifying thresholds of fire danger rating that vary spatially across the continent.

If we assume that the probability of occurrence of Extreme fire danger (i.e. maximum FFDI between 75 and 100) at least once each season is 10%, then the results of Figure 1 can be used to illustrate the corresponding FFDI threshold values for that rating. Figure 2 shows the results based on local government boundaries for New South Wales and Victoria as an example.

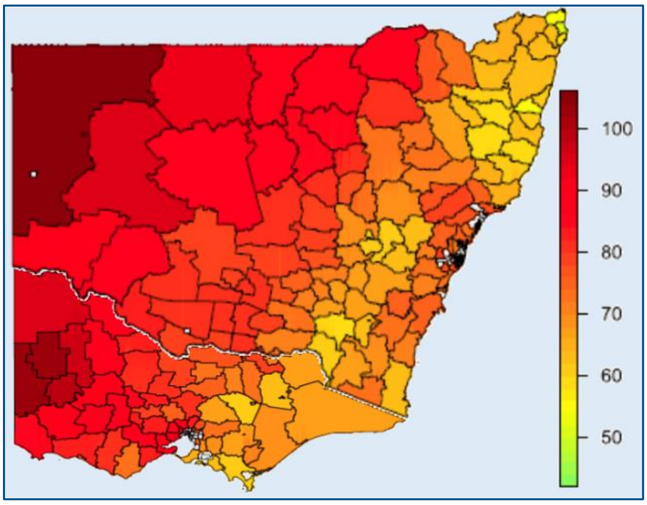

Figure 2. Calculated spatially-varying threshold values for Extreme fire danger for Victoria and New South Wales (an example only, based on local government boundaries).

This suggests that regions in the west and north of these states, where fuels are less predominant and fire weather is more consistently elevated could have higher FFDI threshold values than regions that have less frequent elevated fire weather and greater risk. Regions such as south-east Queensland, Tasmania and south-west Western Australia could have different thresholds than other parts of the continent to better reflect local fire danger but determined in a nationally consistent way.

Implications

These results indicate that there is practically significant spatial variation in the largest values of FFDI across Australia. This analysis could be carried out for return levels for any period, allowing different thresholds for different fire danger ratings to be investigated. It could also be applied to any fire danger rating system, including systems for vegetation such as grasslands. Furthermore, regions based on fire management or fire weather districts could be used for local interpretation of fire danger rating.

By accounting for maximum possible values, not just the highest recorded, the method properly accounts for the spatial structure of extreme events and can be applied in cases where there a large number of observation sites. It can also be used to study temporal changes in fire danger.

Figure 3 shows maps of the differences between the 10-year return levels for each decade during the period 1960-2010. This shows that there was significant interdecadal variation in FFDI and that this variation was highly spatially variable; for example, the FFDI in south-east Australia during the 2000s was significantly higher than that experienced during the previous decade.

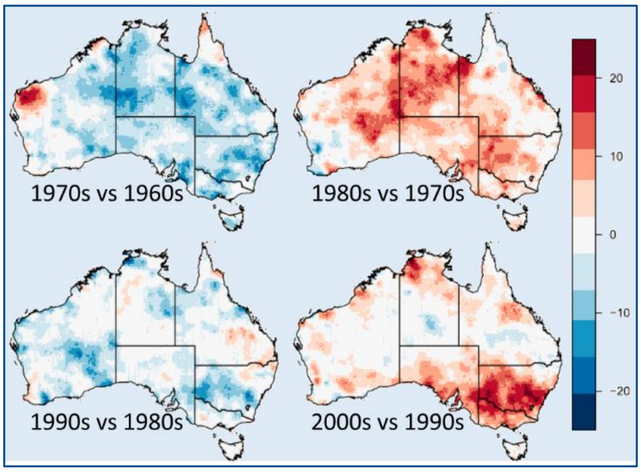

Figure 3. Quantile maps of decadal difference of 10-year return level estimates of FFDI for the period 1960-2010.

Further reading

Stephenson AG, Shaby BA, Reich BJ, Sullivan AL (2015) Estimating spatially varying severity thresholds of the forest fire danger rating system using max-stable extreme event modelling. *Journal of Applied Meteorology and Climatology* 54, 395–407.

References

Fox-Hughes P (2008) A fire danger climatology for Tasmania. *Australian Meteorological Magazine* 57, 109–120.

McArthur AG (1967) Fire Behaviour in Eucalypt Forests. Forestry and Timber Bureau Leaflet 107, Commonwealth Department of National Development, Canberra ACT.

Reich BJ and Shaby BJ (2012) A hierarchical max-stable spatial model for extreme precipitation. *Annals of Applied Statistics* 6, 1430–1451.

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