Methods of comparing fire danger indices*

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Introduction

Over the past decade several methods have been proposed to compare the performance of fire danger indices, in an effort to find the best indices for particular regions or circumstances. Various authors have proposed comparators and demonstrated different responses of indices to their tests, but rarely has much effort been put into demonstrating the validity of the comparators themselves. Indices have been developed with different input parameters and different mathematical formulations. This can result in indices that show different frequency distributions of occurrence over time. We contend that these difference mean that if the performances of indices in a particular region are to be compared, the comparison method must be based on non-parametric principles. Some previously published comparison studies use methods that may introduce spurious differences between indices.

Methods

Consider a hypothetical fire index (index 'A'), that is based simply on a sinusoidal function of the calendar day of a year. Two further indices are constructed as transformations of the first, with index 'B' = ln(A) and index 'C' = $e^{A/10}$. Finally, index 'D' is independent and discontinuous. A direct comparison of index values (*Ix*) requires that the indices be normalised onto a common scale. Viegas et al. (1999) do this linearly, with: $I'x = 100(Ix - Imin)/(Imax - Imin)$. **Figure 1** shows our normalised hypothetical index values through the course of a year, along with ten arbitrarily selected 'fire occurrence' days. After plotting the frequency distributions of their normalised indices (**Figure 2**), Viegas et al. (1999) test the discriminatory power of each index (its ability to seperate 'fire days' from ‚non-fire days' using the Mahalanobis Distance (Md). A larger Mahalanobis Distance is presumed to represent greater differentiation of fire/nonfire-days. Andrews et al. (2003) used firstly a 'percentile analysis'; comparing index values at 3 quantiles from the entire set of daily index values with the values at the same quantiles from the set of 'fire-day' index values. They followed this with a logistic regression technique to test the predictive ability of each index, in terms of the range of values produced by the logistic model and a pseudo R^2 for model fit. Verbesselt et al. (2006) used Akaike's Information Criteria to test their logistic models, and also rated indices based on the 'c-index' (the area under a receiver operating curve). Padilla and Vega-Garcia (2011) also used ROC-based methods.

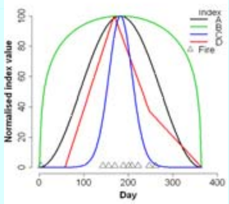

Figure 1, Normalised hypothetical index values over one year.

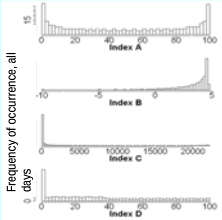

Figure 2, Frequency distribution of hypothetical indices.

New comparator method

We present here a further non-parametric method of judging index skill. Each daily index value is converted to a percentile value from the full set of all days. Selecting the days where fire occurred, those 'all-day' percentile values are arranged in order of rank, and plotted with rank on the 'x' ayis and percentile value on the 'y' axis. Indices A, B and C are identical, while Index D is not. (**Figure 3**). A robust regression of the curve rates the indices, expressable as 'y=ax+b'. A theoretically perfect index would show percentile values on fire days all at the upper extreme, with a slope (a) approaching zero and a 'y' intercept (b) approaching 100. An index of zero skill would have a slope approaching 100/(number of fires) and a 'y' intercept approaching zero. This 'ranked percentile' method also allows graphical interpretation of the indices.

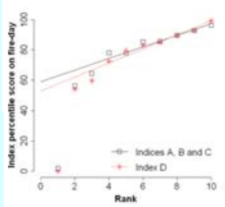

Figure 3, Non-parametric rank-percentile analysis of hypothetical indices

Comparator performance

The results of the various comparators (**Table 1**) demonstrate that only the non-parametric methods (c-index and our ranked percentile method) correctly detect that indices A, B and C are effectively identical. All others give different rankings (r).

Table 1. Four hypothetical fire danger indices rated with various comparators

	Md		percentiles		logistic regression						c-index		Rank-Percentile	
Index		r	Sum delta	r	model range	r	RL²	r	AIC	r		r	(a,b)	r
A	0.740	2	75.25	2	0.004 - 0.074	3	0.026	1	6.02	1	0.737	2	3.836, 58.90	2
B	0.116	4	67.85	4	0.002 - 0.037	4	0.008	4	-0.55	4	0.737	2	3.836, 58.90	2
C	0.855	1	83.3	1	0.015 - 0.109	1	0.016	3	4.32	3	0.737	2	3.836, 58.90	2
D	0.740	4	73.05	3	0.008 - 0.099	2	0.02	2	4.82	2	0.730	4	4.658, 52.60	4

Practical application

Several indices are currently being considered for use in Austria. As an example of index comparison using real data, we apply the comparators discussed here to assess the FMI, Angström, M68 and Nesterov indices (Arpaci et al. 2010) in one region of Austria, over a five year period. The frequency distributions of the FMI and Angström indices are broadly similar, but the others are considerably different (**Figure 4**). The effect of this can be seen in the results (**Table 2**). All comparators agree that the Angström index is superior to the FMI, but differ in their assessment of the others. Only the two non-parametric methods (the c-index and ranked percentile method) are in full agreement in both tables. The graphical comparison using the ranked percentile method (**Figure 5**) clearly shows the greater skill of the Angström index in this example.

Table 2. Four real fire danger indices rated with various comparators

	Md		percentiles		logistic regression						c-index		Rank-Percentile	
Index		r	Sum delta	r	model range	r	RL²	r	AIC	r		r	(a,b)	r
FMI	1.012	4	91.84	2	0.0009 - 0.1931	4	0.043	3	35.17	2	0.778	3	1.670, 51.30	3
Angström	1.285	3	94.91	1	0.0004 - 0.2288	3	0.060	1	45.75	1	0.805	1	1.396, 61.08	1
M68	2.259	1	78.48	3	0.0112 - 0.5286	1	0.014	4	32.42	4	0.798	2	1.649, 54.66	2
Nesterov	2.173	2	51.59	4	0.0079 - 0.4164	2	0.052	2	33.77	3	0.701	4	3.089, 14.45	4

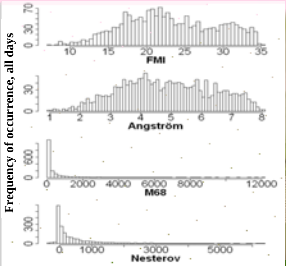

Figure 4, Frequency distribution of real indices.

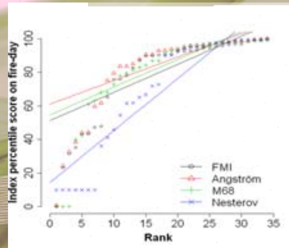

Figure 5, Non-parametric rank-percentile analysis of four indices

Conclusions

When comparing fire indices that may have different frequency distributions, the use of parametric methods can create spurious results. The proposed ranked percentile comparison method is distribution-robust.

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