Trend and regional analysis of fatal off-piste and backcountry avalanche accidents in Austria within the years 1968 and 2011

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Abstract: In this article we analyze trend and regional patterns of fatal avalanche accidents caused by alpine skiers and snowboarders.

Keywords: Fatal snow avalanche events, time series, regional distribution.

1 Introduction and Data

In the Alps, backcountry skiing has become very popular in the last 50 years. Unfortunately, there are a lot of fatal accidents due to snow avalanches caused by skiers and snowboarders. In Austria, about 25 fatalities caused by snow avalanches every year are expected. Furthermore it is reported that the number of fatalities is more or less constant over the time (see for example Brugger et al., 2001).

In this paper our focus is on accidents caused by backcountry skiers keeping in mind that accidents due to backcountry skiing is by far the most common way to be involved in avalanche accidents. Until now there has not been an investigation for this special group of avalanche incidents in Austria. For our study we built a data base of fatal avalanche accidents recording the

- date
- municipal area where the accident took place
- federal state of the municipality
- number of persons involved
- number of fatalities
- type of activity (on/off-piste, backcountry skiing etc.)

of fatal accident events in Austria within the years 1980-2011 which is available from the annual reports of the Kuratorium fr alpine Sicherheit (1973–2011) and the annual reports of the information services of the federal states (see Amt der Tiroler Landesregierung, 1994–2010). For years before that time (back to 1968) we used aggregated information published in the annual reports of the Kuratorium fr alpine Sicherheit.

2 Methods

We propose the following model for capturing the:

$$\log(y_t) = f(t) + x_t$$

where y_t denotes the number of annual avalanche fatalities over time t. The logarithms of these count data are modeled as the sum of potentially nonlinear trend function $f(t)$ and a stationary remainder x_t. To account for potential serial correlation and periodic variation in the remainder, we consider autoregressive moving-average (ARMA) effects. In order to estimate the nonlinear function $f(t)$ we use the `R` package `mgcv` (see R Development Core Team, 2012; Wood, 2006).
Further on, for looking at the regional distribution of avalanche fatalities we build small area maps based on Austrian municipalities using the `GIS`-software `ArcMap`. We use Markov random field smoothing which helps us to identify regional hot spots of avalanche fatalities.

3 Results

In Figure 1, we give the plot of the nonlinear trend function of avalanche fatalities in Austria
If we look at the estimated function we take notice of an increasing trend (1970: approx 12 fatalities, 2010 approx 22 fatalities). Further on we point out that there is a lot of variation of the observed counts around the estimated function. Additionally, we notice a peak in the 1980s (1982-1988). We did not find any substantial serial correlation (contrary to the results of Pfeifer, Zeileis (2012)) or any sort of periodicity in the remainder x_t (see Höller, 2009; Tschirky et al., 2000).
Figure 2 gives the spatial distribution of avalanche fatalities within the years 1981 and 2011 based on Austrian municipalities. The coloring, however, is based on smoothed Markov random field estimates of avalanche fatalities (the number corresponding with each spatial unit in the plot is equal to the original count) .

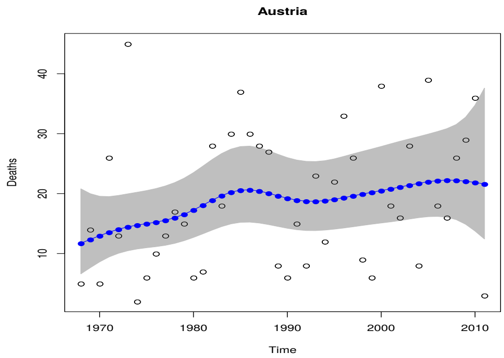

FIGURE 1. Observed and estimated annual avalanche fatalities in Austria within 1968–2011 including the 90% confidence band.

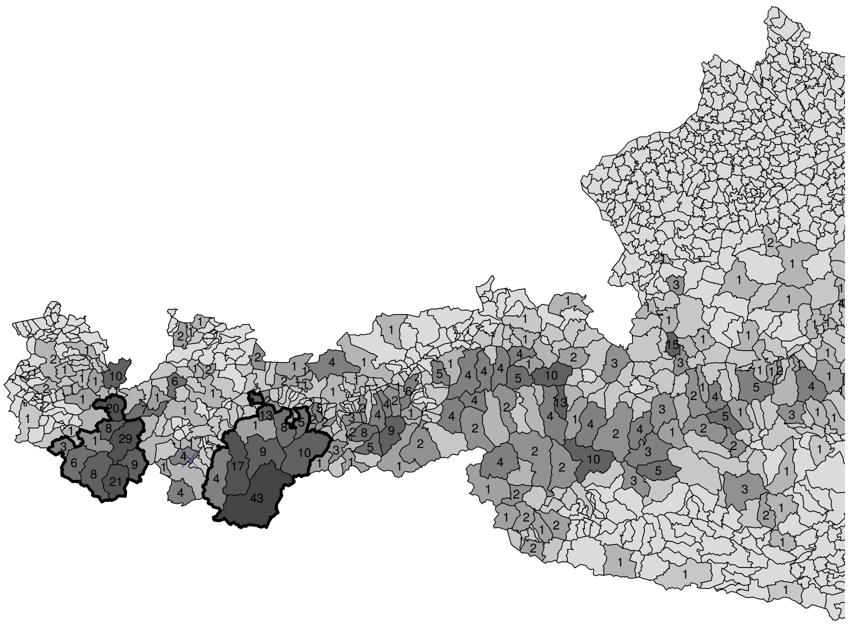

FIGURE 2. Regional distribution of avalanche fatalities in Austria within 1981–2010 including the observed numbers of fatalities within each spatial unit.

4 Conclusion

As the result of the trend analysis we notice an increasing trend of avalanche fatalities within the years 1968 and 2011. Additionally we take notice of a peak in the 1980s (an unusual period of increased snowfall/covering of snow in the 80's is discussed as a reason for the higher avalanche frequency).
As the result of the regional analysis we notice two hot spots of avalanche fatalities in Figure 2: 'St. Anton a. Arlberg (29)' (Arlberg-Silvretta) and 'Slden (43)' (southern part of tztal, Stubai-Khtai).
Because of the increasing trend and the rather 'narrow' regional distribution of the fatalities consequences on prevention of avalanche accidents are discussed.

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