Camouflage, Bluff, or Real?

Statistical Uncertainty of Trends in Catastrophic Extremes.

Does global climate change affect the occurrence of catastrophic extreme events? Has the frequency of such events changed over the 20th century? Answering these questions is complicated by several sources of uncertainty. Among these, there is a statistical uncertainty, which is related to the rareness of catastrophic extremes. This uncertainty is fundamental and limits our knowledge of past trends and future predictions, regardless of ongoing improvements in data quality and prediction models.

Consider the situation where we attempt to determine, from an observed precipitation record, if there has been a systematic trend in the frequency of torrential rainfall events. 'Detecting' a trend implies assessing whether the observed sequence of torrential rain events is indicative of a gradual change in probability (i.e. the signal) or whether the sequence could be the result of purely random occurrence (i.e. the noise). The detection of the signal out of the noise becomes more difficult if there are only very few events. Even with observation records extending over many decades, it is possible that an existing trend is camouflaged by the noise in the record. The situation is comparable to that of a dice player aiming to find out, by repeated tosses whether his/her dice is skewed.

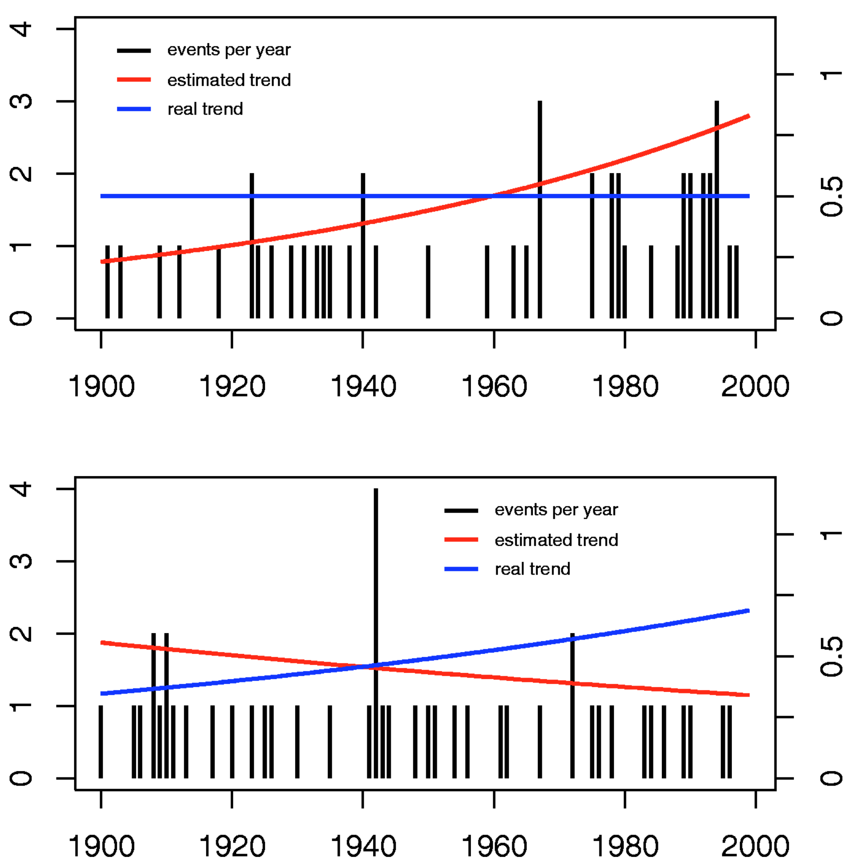

Figure 1: Statistically simulated random sequences of rare extreme events to illustrate possible misinterpretations in trend analysis. Annual counts of events in black bars (left-hand scale), real (blue) and estimated (red) trend of event probability (right-hand scale). The upper panel depicts the situation of a 'bluffed' trend, where random accumulation of events suggests an increase whilst the real probability is stationary. The bottom panel depicts the situation of a 'camouflaged' trend, where the real increase in event probability is not manifest in the event counts and therefore cannot be detected.

Coincidence can fool us

Figure 1 illustrates the possible errors that can be made in the interpretation of an observational record, due to the statistical uncertainty. The panels depict 100-year long sequences of annual counts of rare events, which have been artificially generated using a random number generator. For the sequence in the top panel, a constant event probability of one event per two years was assumed (blue line). It is pure chance that the simulated sequence has a higher number of events at the end of the period. Estimation of the trend for this sequence (red line) suggests an increase in event probability by more than a factor of two. Evidently, this trend is a 'bluff'; we know that the real probability has not changed. Scientists use statistical tests to prevent such misinterpretations. Application of a test for the present sequence indicates that 'bluff' is not a very unlikely possibility for the apparent trend.

The bottom panel (Fig. 1) displays another random sequence. During its construction, it was assumed that the probability of events increases by a factor of two over 100 years (blue line), but still, the century mean occurrence is one event per two years. Nevertheless, fewer events were simulated, by chance, towards the end of the period. The trend estimated for this sequence is decreasing (red line). The real (increasing) trend is camouflaged in the noise of the sequence and could not be detected.

Generally, it is possible that quite substantial real trends do not show up prominently in an observation record, such that a statistical test would fail to exclude randomness (bluff) as a cause.

Implications

The two examples illustrate that random clustering of events can fool us about the real variations in event probability. This is particularly serious for very rare events. There are several implications that should be considered:

- The apparent accumulation of catastrophic storms and flooding in Europe, over the last ten years could be either the sign of a real trend or of pure randomness. The statistical uncertainty precludes more precise statements about these very rare events.

- Catastrophic extremes are an inappropriate indicator for the detection of global climate change. A relationship between European catastrophic extremes and global climate change can, at present, neither be proved nor excluded. The emphasis on such a relationship in the public media brings the danger that the climate change problem is unjustifiably dramatized during periods of frequent catastrophes, and unjustifiably played down during periods of infrequent catastrophes.

- In their analysis of past variations and prediction of future changes, scientists primarily focus on *intense*, not necessarily catastrophic (damage-causing) events. The higher frequency of such events narrows down the statistical uncertainty and allows clearer statements. This is why the STARDEX project studies trends in indices characteristic of intense events. It has identified a gradual increase of intense winter precipitation and the frequency of hot summer days over large parts of Europe in the second half of the 20th century. It is unlikely that this is a 'bluffed' trend, although its relationship to global climate change is currently unclear.

- Finally, to make progress in our understanding of extreme events and their link to global climate change, purely statistical examination of long-period observation records and climate model simulation results is not sufficient. Scientists must aim at developing a more profound physical understanding of extreme events and the process chain from global climate change through to regional effects. The STARDEX project is an important part of these efforts.

Figure 2: Torrential rainfall in October 2000 caused serious damage in the Swiss Alps and Northern Italy. The rareness of such events makes it difficult to unequivocally detect gradual changes in their occurrence, but long-term changes can neither be excluded. (Foto: J.-P. Jordan, Swiss Federal Office for Water and Geology.)

Further reading:

Frei, C. and C. Schär, 2001: Detection probability of trends in rare events: Theory and application to heavy precipitation in the Alpine region. *J. Climate,* **14,** 1564-1584.

Wunsch, C., 1999: The interpretation of short climate records, with comments on the North Atlantic and Southern Oscillations. *Bull. Amer. Meteorol. Soc.,* **80,** 245-255.

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http://www.cru.uea.ac.uk/projects/stardex/

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