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Parametric analysis of regional trends in observed extreme rainfall in Denmark

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Introduction & Aim

Several studies have discussed a change in measured extreme rainfall in Denmark and other parts of Northern Europe, but the change has not been quantified by parametric models or compared to the changes predicted by climate models. The purpose of this study is therefore:

To identify and describe a development in the following extreme rainfall characteristics:

- The annual number of extreme events
- The intensity of the extreme events

While taking into account:

- Periods of rain gauge malfunction
- Correlation between neighbouring stations

Data material & Treatment

The extreme events from 70 high resolution tipping bucket rain gauges, that have been active from 1979 to 2009, were analysed. The rain gauge network is operated by the Danish Water Pollution Control Committee and the Danish Meteorological Institute.
Information regarding rain gauge malfunction and the geographical position of each station are available. When periods of malfunction have been taken into account the data represents 1428 years of observation.

A moving average procedure was applied to convert the measured 1 min intensities into rainfall with durations between 5 min and 24 hours. The extreme events was afterwards defined using the method of Partial Duration Series (PDS) with a fixed threshold level.
The PDS approach implies that the number of extreme events (*N*) follows a Poisson distribution.

Statistical methods & Results

N was modeled by two different approaches, where rain gauge malfunction was taken into account by including the number of active days (t_{active}).

Ordinary linear regression, Eq. 1:

$$\lambda_i = \frac{N_i}{t_{active,i}} = \alpha + \beta \cdot year_i + \gamma \cdot year_i^2 + \varepsilon_i$$

where *i* = 1...31 represents the 31 years of measurements and $\varepsilon_i = N(0,\sigma^2)$. The system is solved by the method of generalized least squares so correlation between neighbouring stations can be included.

The Poisson rate model, Eq. 2:

$$\eta_i = offset(t_{active,i}) + \alpha + \beta \cdot year_i + \varepsilon_i \quad , \quad \eta_i = \ln(N_i)$$

again *i* = 1...31 and $\varepsilon_i = N(0,\sigma^2)$. The model belongs to the family of Generalized Linear Models and is solved by the method of maximum likelihood, utilizing that the probability distribution of *N* is known and treating t_{active} as an offset.

The Poisson rate model gives the most adequate description of the observations, in terms of future predictions it can however be questioned if the exponential increase in the number of extreme events can be justified.
More explanatory variables can be included to reduce the unexplained explanation, both the North Atlantic Oscillation and the mean annual precipitation at each station was applied.

The mean intensity of the extreme events (μ) was modeled by ordinary linear regression on the log-transformed response, a significant increase in μ is found for some durations, but the underlying model assumptions are not entirely fulfilled. A non-parametric Mann-Kendell test showed in comparison only significance for a duration of 60 and 180 minutes.

Development in λ for a duration of 10 minutes

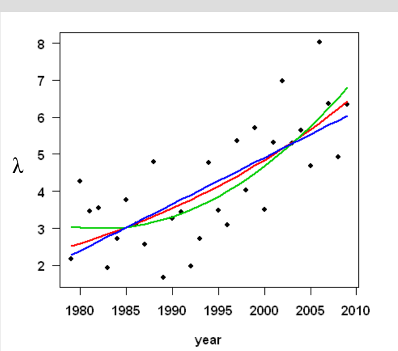

Figure 1:

Comparison between the observations and three different models.

Blue curve: Ordinary regression, see Eq. 1

Green curve: Ordinary regression with a quadratic relation to the year.

Red curve: The Poisson rate model, see Eq. 2

Conclusions & Outlook

- A significant increase in the number of extreme events was found for all durations, the average annual increase is estimated to about 2% by the Poisson model. The amount of explained variation is, however, in general very small.
- The mean intensities of the events is also increasing, but the natural variation of the process is high and thus better models are needed than what has been studied so far.
- The study has taken the initial step towards modelling of non-stationary trends in observed extreme rainfall. The work is on-going and the next steps include further refinement of the models and testing on other datasets, including output from regional climate change models. The objective is to develop a tool that can improve design of urban infrastructure with long design lifetime.