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Distribution of extreme wet and dry days in Estonia in last 50 years

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Abstract. Estimation of extreme wet and dry weather conditions on the basis of moving average of daily precipitation allows to determine the most drastic periods and trends of the precipitation regime in Estonia in last 50 years. The wet and dry days have been selected from the calculation results of the precipitation moving average. A day is considered as extreme wet when the moving average of the daily precipitation is at least 10 mm on 10 successive days till this day. A day is considered as extreme dry when there was no precipitation during 20 successive days till the observed day. Inter-annual variability of the average number of wet and dry days in Estonia has remarkably grown in 1957–2006; the years with a large number of wet or dry days can be easily distinguished. The increase of the annual total number of extreme (wet and dry) days is obvious.

Key words: climate extremes, daily precipitation, flooding, drought, moving average, Estonia.

1. INTRODUCTION

The Intergovernmental Panel of Climate Change defines an extreme weather event ‘as an event that is rare within its statistical reference distribution at a particular place’ [1]. In Europe reported extreme events are heat or cold waves, floods, windstorms, droughts, fires, snowstorms etc. Numerical estimation of risks of these events is required in disaster plans, engineering works, hydrology, irrigation projects and in many other fields of human activities. A lot of scientific debate is concerned with whether the current warming trend will be also leading to increased frequency, intensity, duration and severity of extreme weather events [1,2].

The amount of extremely high or low precipitation, leading to flood or drought, is also a substantial weather risk, about which meteorological service should give the best information to the public. A long period without precipitation causes a drought. There are four different ways to define the draught: meteorological, agricultural, hydrological and socioeconomical [3,4]. Meteorological drought is a measure of the departure of the precipitation from normal. Due to climatic differences, what is considered a drought in one location may not be a drought in another one. Agricultural drought refers to a situation when the amount of moisture in the soil no longer meets the needs of a particular crop. Hydrological drought occurs when surface and subsurface water supplies are below normal. Socioeconomical drought refers to the situation when physical water shortage begins to affect people. The lack of precipitation is mostly connected with the anticyclonal weather, which dominates in Estonia more often in spring or early summer [5,6], but lately also in August–September.

Due to heavy or long-lasted rainfall the ground water level and water level in rivers and lakes rises, causing flood. European experience distinguishes three types of floods: flash and river floods and storm surges. Floods can cause yield losses and disruption of roads, rail lines, electricity supply systems, water supplies etc. High values of precipitation in Estonia are mainly of two different kinds. Firstly, heavy convective rainfall, lasting for a few hours and extending typically over a few hundred square kilometres, which occurs predominantly in warm season. If this rainfall is heavy enough, it causes large 10-day or even monthly precipitation totals in the sites of rainfall. Secondly, multi-day wet spells, which are connected with the cyclons, going over Estonia in most cases from the South (from the Mediterranean and the Black Sea) and bringing heavy precipitation. The area of precipitation is then larger and the monthly or 10-day totals of precipitation are often substantial in many areas of the country [6].

In the last years, extreme dry as well as extreme wet periods have occurred in Estonia. In July 2006, the precipitation was only about 22% of the average level, which caused big harm to agriculture; the heavy precipitation in summer 2004 caused flooding in the fields of many districts all over Estonia [7].

The task of this research is to estimate the extreme wet and dry weather conditions on the basis of the moving average of daily precipitations. It allows to find the most drastic periods and trends of extremes in the precipitation regime of Estonia in the last 50 years.

2. METHODS AND MATERIAL

Traditional analysis of the precipitation regime is carried out on the basis of the precipitation sums in a day, a 10-day period, a month and a year, and also on the number of dry and wet days in a month and a year, on the maximum number of consecutive dry and wet days, extremes with fixed thresholds, precipitation percentiles, etc. [6,8,9]. The method of moving average allows to find more severe dry or wet spells, which can last also for several months. The preliminary task, when looking at dry or wet spells, is to define a dry and a wet day. Usually the definition of a dry day is zero rainfall. A wet day is the day with precipitation over the threshold, depending on the climate conditions in the observed area. It is also important, how much the data are rounded.

Here are some examples of the indicators of the extreme precipitation regime (R is total precipation in a day):

- maximum number of consecutive wet days $(R \geq 10\ \text{mm})$ [8];
- maximum number of consecutive dry days $(R < 0.1\ \text{mm})$ [8];
- number of dry and wet days in a month or in a year with chosen threshold [8];
- the number of subsequent dry and wet days [10];
- mean dry and wet spell length [10].

In this research we specify very wet and very dry conditions for a day by counting the moving average (or running total) of daily precipitation data till that day. It means that the wet or dry day is a day, reflecting a period with too much or too little precipitation preceding the observed day. These indicators should be calculated for a determined number of days n and thresholds t to show the meteorological, agrometeorological, hydrological or socio-economical drought or flood for the area. The values of n and thresholds t define the day as a dry day or a wet day depending also on the goal of the research. For example, by the agrometeorological research these limits depend on the species of plants, on the state of vegetation, soil conditions, the air temperature and humidity, etc.

The moving average of precipitation is calculated through all observed days, without distinguishing months or years (for 50 years in this study).

Mathematically for a sequence $\{a_i, 1 \leq i \leq N\}$, where N is the total number of days, an n-moving average is a new sequence $\{s_i^{(n)}, 1 \leq i \leq N - n + 1\}$, obtained by taking the average of subsequent n terms:

$$s_i^{(n)} = \frac{1}{n} \sum_{j=i}^{i+n-1} a_j . \tag{1}$$

To specify a day with extreme precipitation, we have first used the same criteria that our agro-meteorologists have been using to estimate the field conditions of Estonia [11]. The occurrence of extreme wet conditions is counted when the moving average of the mean total of daily precipitation is at least 10 mm $(t = 10)$ on 10 consecutive days $(n = 10)$. So the last (i+9)th day of the 10-day period has been counted as a wet day.

The occurrence of extreme dry conditions is counted in case where there is no precipitation $(t = 0)$ during 20 consecutive days $(n = 20)$: if $s_i = 0$, the last $[(i + 19)\text{th}]$ day of this 20-day period has been counted as an extreme dry day.

Often the extreme wet (dry) days come one after another and their number shows the intensity of a wet or a dry spell. In some years several wet or dry spells may occur.

First, the calculation of the amount of wet and dry days was carried out for long time series at 7 meteorological stations in Estonia (Fig. 1) [12]. In this study, the comparison of the annual amount of wet days with the maximal number of consecutive wet days $(R \geq 10\ \text{mm})$ and with the 5-day precipitation total RX5 [8] was made for the time series at Kunda. Also the number of dry days without

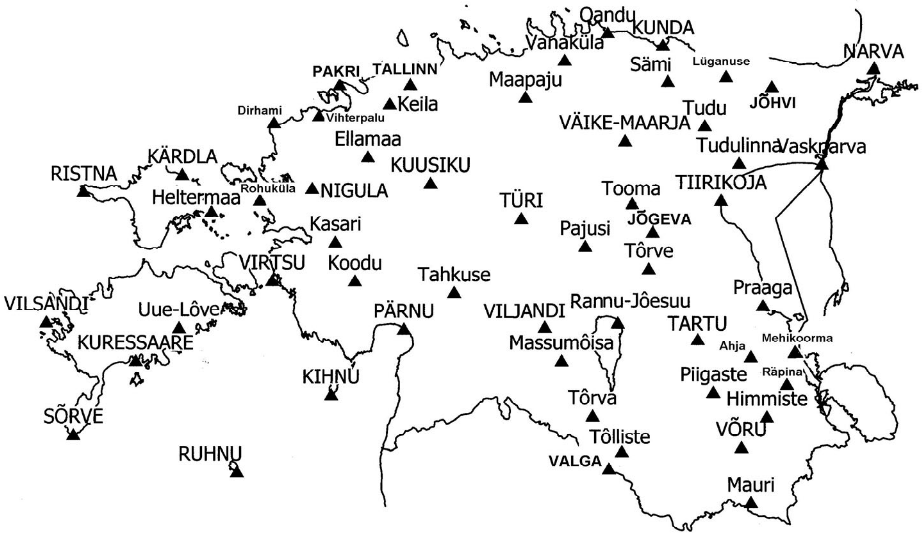

Fig. 1. Location of the meteorological stations (capital letters) and small precipitation stations (small letters), used for counting of wet and dry days.

precipitation was compared with the maximum number of consecutive dry days [[10]]. We are of the opinion that the wet and dry days in our study more clearly indicate the most extreme days of precipitation regime at a site.

To analyse the Estonian mean amount of wet and dry days and their annual distribution in the last 50 years, we have counted the 10- and 20-day moving average of precipitation through the precipitation data in 1957–2006 of 56 Estonian meteorological and precipitation stations (Fig. 1). Precipitation measurements are carried out with the aid of the Tretjakov gauge with standard methods, described in [[13,14]]. When the data were missing, the data of a neighbouring station have been used. The most relevant neighbouring station has been chosen on the basis of correlation analysis.

3. RESULTS AND DISCUSSION

The wet days with an average 10-day precipitation 10 mm and more occur in Estonia only in summer and autumn from June to November and more frequently in July and August (Fig. 2). The annual dynamics of the traditional characteristics of precipitation – the monthly mean number of days with precipitation 10 mm and more – is similar to the dynamics of the mean number of wet days (mean of stations in 1957–2006).

Dry days with no precipitation in a 20-day period may occur in every month. The biggest number of these days is in August, in early summer and in late summer–autumn period (Fig. 3).

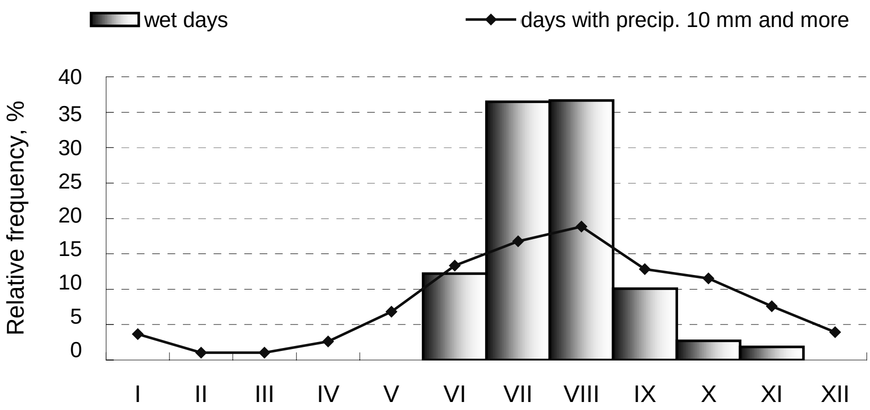

Fig. 2. Monthly distribution of wet days and days with precipitation 10 mm and more; mean of the 56 stations (1957–2006).

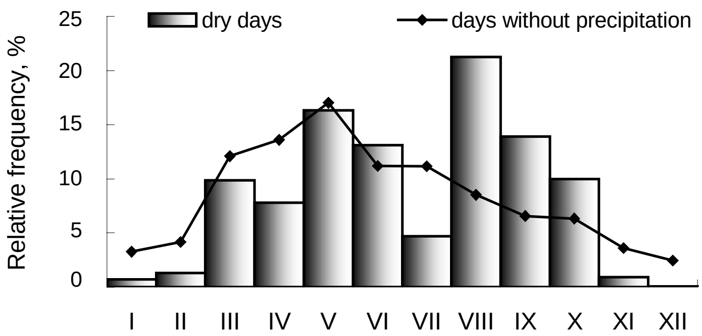

Fig. 3. Monthly distribution of dry days and days without precipitation; mean of the 56 stations (1957–2006).

A traditional characteristic – the mean number of days without precipitation – is maximum in May and decreases steadily until the end of the year, while the danger of dry days is highest in August.

Extreme wet or dry days with the chosen parameters are mostly successive and in the majority of cases the number of wet or dry days in a year has been counted from one rain or drought spell. Inter-annual variability of the average number of wet and dry days apparently shows a growing tendency in the last 50-year period (Fig. 4). It is essential to point out, that the number of wet and dry days depends on the chosen criteria.

For the used criteria, in 1957–1977 dominated dry days and in 1978–1989 wet days. Based on the average of 56 stations, there was no more than 1 wet day a year in 1951–1977. Since 1978, the mean number of wet days per year has

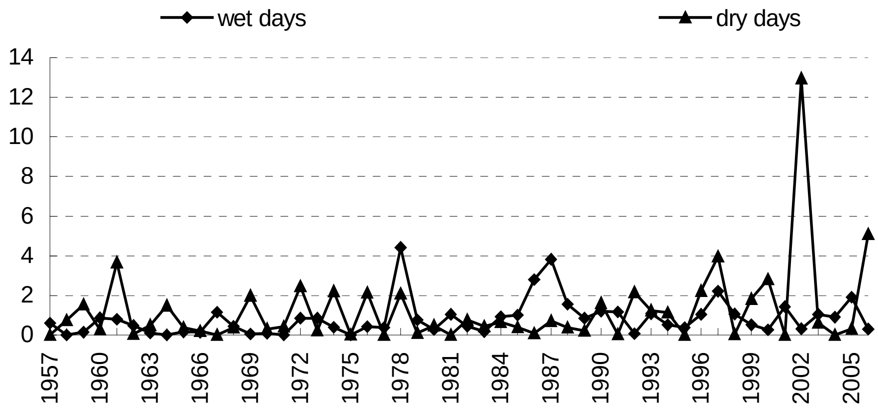

Fig. 4. Number of wet and dry days in 1957–2006; mean of 56 stations.

essentially risen – the mean number of wet days is close to zero only in four years after 1978. The wettest years were 1978 and 1987 with 4 wet days. The number of dry days seems to have essentially risen at the end of the 20th century.

The severest drought in 2002 with the mean number of 13 dry days was observed in August–September. The mean number of dry days in that year was more than twice bigger than in 2006, which was the second driest year over all the period. The period without precipitation lasted in Valga for 41 and in Mauri for 49 days in August–September (the number of dry days was respectively 21 and 29). In 2006, in many districts there were two dry spells – the first one in May and the second one in July.

The current warming trend, about 1–1.7 °C in Estonia for the recent 50 years [15] is expected to lead to increased frequency, intensity, duration and severity of extreme weather events [1]. Therefore, the annual number of extreme (wet and dry) days together has been presented as the average of 56 stations. It confirms the statistically significant rising trend of extreme precipitation events in Estonia in 1957–2006 (Fig. 5).

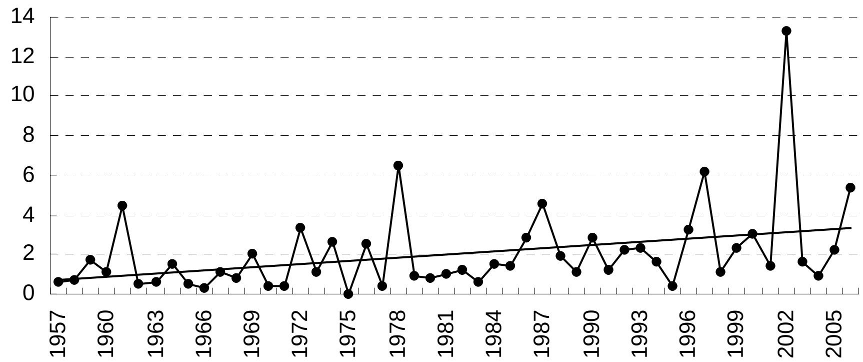

Fig. 5. Number of extreme (wet and dry) days, mean of 56 stations.

4. CONCLUSIONS

The estimation of extreme wet and dry weather conditions on the basis of moving average of daily precipitation allows to determine the most drastic periods and trends of the precipitation regime in Estonia in the last 50 years. We specify very wet and very dry conditions for a day through the moving average of daily precipitation data till this day. When the mean daily precipitation is at least 10 mm on 10 consecutive days then extreme wet is the last day of this 10-day period. If there is no precipitation during consecutive 20 days then the extreme dry is the last day of this 20-day period.

The number of calculated wet and dry days allowed us to find severe wet and dry spells in the last 50 year period in Estonia and to study the annual distribution of extreme (wet and dry) days. The inter-annual variability of the number of extreme wet, extreme dry and total extreme days shows an apparent increasing trend in Estonia. The increase of the annual number of extreme wet and dry days together indicates to the rising trend of the extreme precipitation events in Estonia in 1957–2006.

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Ekstreemselt kuivade ja sajuste päevade jaotus Eestis viimase 50 aasta jooksul

Tiina Tammets

Ekstreemselt väikeste ja suurte sademetega perioodide leidmine ööpäeva sademete hulga libiseva keskmise alusel võimaldab määrata viimase 50 aasta sademetevaesemad ja -rikkamad aastad ning kuud. Liigniiskeks päevaks on 10 mm ja suurema sademete hulgaga 10-päevase perioodi viimane päev, ekstreemseks sademeteta (ehk põuaseks) päevaks 20-päevase sademeteta perioodi viimane päev. Tulemused on esitatud 56 Eesti meteoroloogiajaama ja sademete mõõtejaama keskmise alusel. Liigniisked päevad esinevad Eestis ainult juunist novembrini, põuased päevad aga kogu aasta jooksul. Kõige rohkem on liigniiskeid päevi juulis-augustis, põuaseid päevi aga augustis ja mais. Ekstreemsete päevade aastase kogusumma varieeruvus on 50 aasta jooksul suurenenud ning selliste ekstreemsete päevade üldarv on kasvanud. Kõige rohkem paistab silma 2004. aasta, mil sademeteta päevi oli mõnedes mõõtejaamades rohkem kui 30 ja ekstreemselt kuivade päevade keskmine arv ulatus 13-ni.