

REGIONAL AND SEASONAL ANALYSIS OF 15-MIN PRECIPITATION IN SWEDEN

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1. Introduction

Short-term rainfall observations are important for various reasons. Climate change is the one of the most critical global problems nowadays. The time resolution of the climate models used to describe climate phenomena are shorter and shorter. Observed short-term rainfall are required for checking whether climate model can describe sub-daily rainfall variability (Walther, 2010).

In addition, short-term rainfall is needed for flood control management. The water retention capacity of the land has declined because of the increased amount of impervious surface areas. As a result, the flood concentration time is significantly shortened and the flood peak discharge is drastically increased.

In Sweden 15-minute precipitation data has been observed in 117 gauges from around 1995. This is the first time in Sweden to observe short-term rainfall with a national gauge network (Hernebring, 2006). That means characteristics of the short-term rainfall intensity in Sweden still remain poorly understood. So far, there has been no study about spatio-temporal characteristics of short-term rainfall over entire Sweden.

In this study the data was initially corrected by removing abnormal values and considering them as missing data. After that, the basic characteristics of Swedish precipitation were investigated. The hourly accumulated amount of precipitation and frequency of rainfall intensity was calculated on both regional and seasonal basis by dividing Sweden into four regions and the year into four seasons.

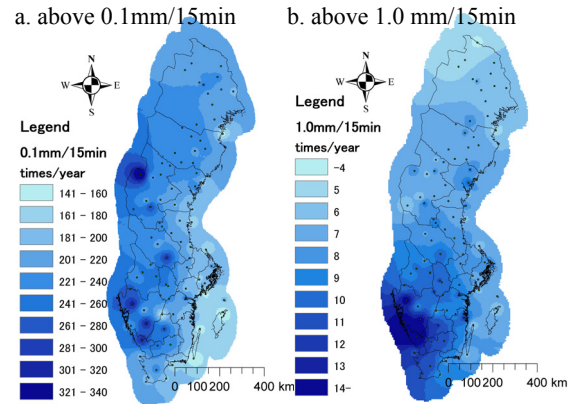


Figure 2 Spatial distribution of precipitation frequency

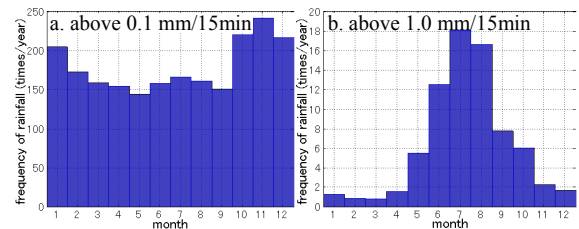


Figure 3 Annual distribution of precipitation frequency

Table 1 Outline of the dataset

number of gauges		117
period	start	1995 or 1996
	end	1995 or 1996
average distance		61.8km
Volume resolution of rainfall		0.1mm
accumulation intervals		15-min, 1-hour, 6/12-hour, 1-day

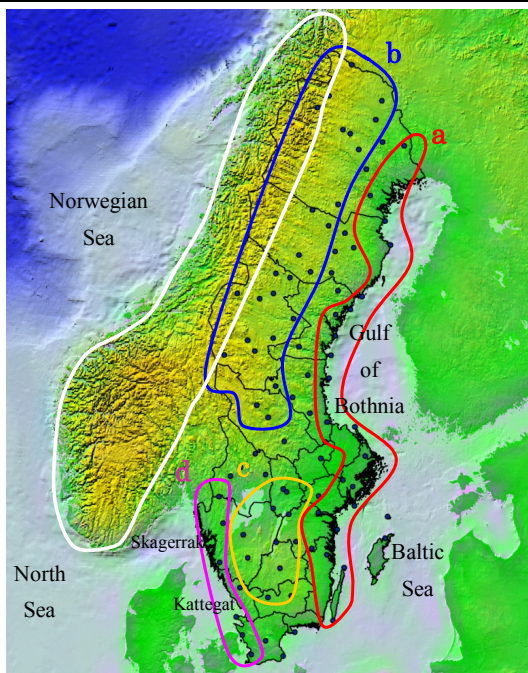


Figure 1 Gauge network and study regions

2. Gauge Network and Data

Table 1 is the outline of the dataset, and Figure 1 is the map of the locations of gauges. The data was observed by automatic all weather precipitation gauges. In Figure 1, Sweden is divided into four regions according to climate zone: a) East Coast (EC), b) Northern Mountains (NM), c) Southern Highlands (SH), and d) West Coast (WC) (e.g. Walther, 2010).

The data quality was checked and the data was corrected and compiled. The data used in this analysis are from gauges having more than 12 years data, and less than 10 percent missing values. After this screening 90 gauges were left from 117 gauges.

3. Spatio-Temporal Characteristics

3.1 General Features

The average accumulated amount of precipitation in whole Sweden is 581 mm/year. The southern part of Sweden has higher amount precipitation than the northern part. Annual precipitation in most of the southern part is more than 600 mm/year, and that in most of the northern part is less than 500 mm/year.

Figure 2 shows the spatial distribution of the frequency of precipitation intensity a) above 0.1 mm/15min, and b) above 1.0 mm/15min. As the unit of precipitation of the data is 0.1 mm, the 0.1 mm/15min precipitation frequency represents the total amount of 15-minute precipitation. As Figure 2-a indicates, the total precipitation frequency decreases from the western part to the eastern part. It would be considered that the moist air from Norwegian Sea is becoming dry going to east. Figure 2-b shows, the frequency in the southern part is higher than in the northern part. The cause of the difference between south and north would be considered to be the difference of topography. Figure 1 shows that there is a mountain chain in western Norway: white area. Rain shadow from these mountains would be the main cause of the less precipitation in the northern part. The wind usually comes from

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west to east. The mountains block the passage of moist air that can produce rain. Therefore west of these mountains it is apt to be rain and east of these mountains it is not apt to be rain (Johannessen, 1970). However Figure 2-a shows that the total precipitation frequency is almost same between North and South. That is considered to mean that the rain shadow of the east mountains mainly affects the precipitation with intensity above 1.0 mm/15min.

Figure 3 shows the annual distribution of precipitation frequency a) above 0.1 mm/15min and b) above 1.0 mm/15min. The months of high frequency of the total precipitation frequency are in winter, but above 1.0 mm/15min high frequency months are in summer. The accumulated amount of rainfall is high from June to August. The result means that in winter there are apt to be many time of low precipitation, and in summer there are apt to be heavy rainfall. The difference of temperature between sea surface and continent would cause this effect. In winter the temperature of sea surface is higher than that of continent. Hence air is apt to get moisture from sea. In addition difference of temperature between southern part and northern part is higher than that in summer. Then cyclone tends to be formed (Johannessen, 1970). They would cause high frequency of low precipitation. On the other hand in summer the convective rainfall cells tend to be formed, generating short but high intensity rainfall.

3.2 Diurnal Patterns

Figure 4 shows the accumulated amount of precipitation of each region described in Figure 1. In Figures 5 to 6 there are the frequencies of occurrence in each season of precipitation intensities above 0.1 mm/15min and 1.0 mm/15min, respectively. To compare each region and season with the same condition, the amounts and the frequencies were divided by the number of gauges in each region, the number of years in the data (12), and the number of months (3). The seasons are defined so that spring is from March to May, summer is from June to August, autumn is from September to November, winter is from December to February.

As Figure 4 indicates, the highest amount of rainfall occurs at around 16:00 in summer in WC, and the lowest at 21:00 in spring in EC. There are clearly high amounts from 12:00 to 20:00 in summer in the inland regions (NM and SH). It is considered that the formation of the convective clouds is the main cause of the afternoon peak in summer. The surface of the continent is apt to become heated by sunlight in the afternoon. A warm and moist air layer builds up, eventually rises and produces intense rainfall. However, the sea areas of Bothnia Gulf, east of EC, and Kattegat, west of WC, generally prevent the formation of convective clouds around EC and WC in afternoons. Sea breeze mixes the air and moreover translates the warm and moist air mass to the inland soon. That is why the afternoon peak is mainly found in the inland regions (NM and SH) rather than in the coastal regions (EC and WC). In other seasons there are not big changes of hourly amounts. Thus, sunlight heating and convective clouds formation is not a main cause of the precipitation.

Figure 5 shows that the frequencies of total precipitation, above 0.1 mm/15min, are almost same at all times of the day, and winter and autumn have a higher frequencies. On the other hand, Figure 6 shows the frequencies of rainfall above 1.0 mm/15min are higher in summer from 12:00 to 20:00, and the frequencies in summer are the highest of the entire. From the result it is clear that the afternoon peak of summer rainfall amounts comes from a high frequency of heavy rainfall above 1.0 mm/15min.

4. Conclusion

In this study the characteristics of Swedish 15-minute precipitation was analyzed and the results below were found.

First, the characteristics of Swedish precipitation depend on the rain shadow of the Norwegian mountains in the west. Second, in summer afternoon the frequency of rainfall intensity above 1.0 mm/15min is at its peak. It is likely that the main cause is convective clouds. This means that the summer afternoon peak of accumulated rainfall comes from high-intensity convective rainfall.

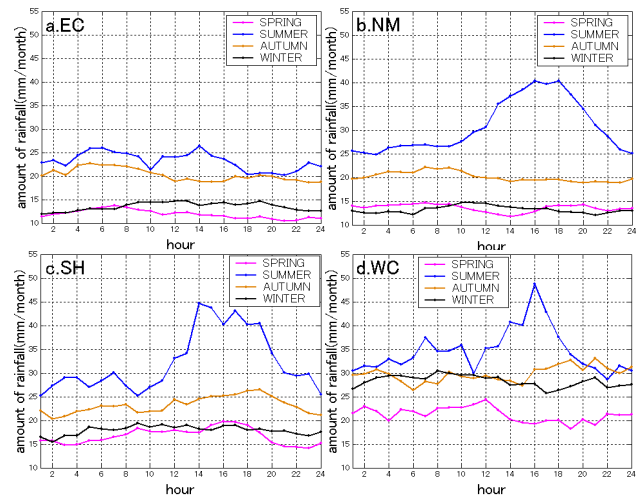


Figure 4 Hourly accumulated amount of precipitation

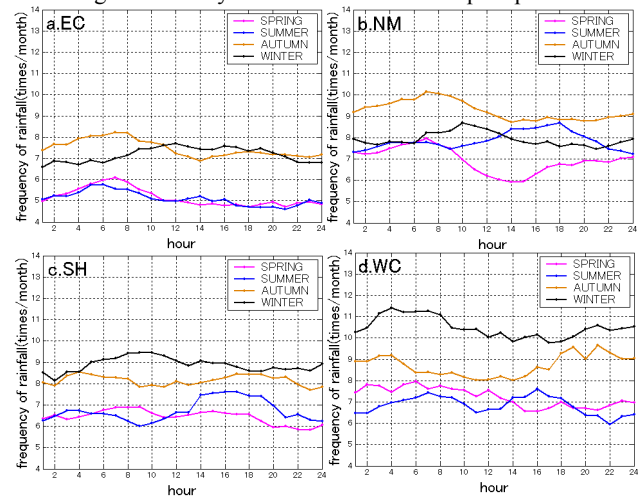


Figure 5 Frequency of precipitation > 0.1 mm/15min

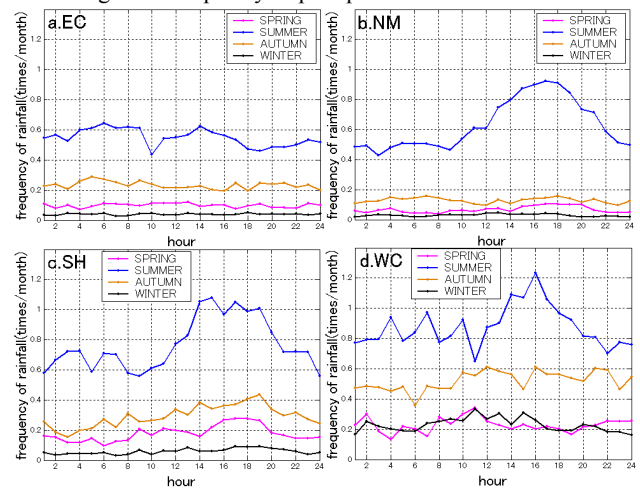


Figure 6 Frequency of precipitation > 1.0 mm/15min

However, in the coastal regions the afternoon peak is not clear. Third, the frequencies of total precipitation in winter is higher than that in summer. On the other hand, the frequency of precipitation intensity above 1.0 mm/15min in summer is higher than in winter.

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